Handbook of Research on E–Learning Standards and Interoperability:
Frameworks and Issues

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Chapter 12
Enhancing Digital Repositories with Learning Object Metadata

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ABSTRACT

In this chapter the authors present the basic characteristics about some existing educational metadata schemata and application profiles. They focus on the widely adopted IEEE LOM standard and give a brief analysis of its structure. Having in mind the utilization of educational metadata schemata by digital repositories preserving educational and research resources, they concentrate on a considerably popular system for this reason, DSpace. The authors want to show how the IEEE LOM metadata set can be incorporated in the default DSpace's qualified Dublin Core metadata schema, introducing enhancements to the existing University of Patras live installation. For this reason, they document a potential LOM to Dublin Core metadata mapping and reveal possible gains from such an attempt. Further, they propose an ontological model for the repository's metadata that takes also into account the educational characteristics of resources. In this way, they show how a semantic level of interoperability between educational applications can be achieved.

INTRODUCTION

The rapid growth of the World Wide Web in the past few years has led to a considerable increase of educational material that is available in electronic form. The increased amount of digital information renders the efficient search and retrieval of educational resources a more complex and difficult process. For this reason, it is of crucial importance the proper description and characterization of electronically available learning objects, using

educational metadata. Such an effort would ensure the reusability and discoverability of learning objects whereas it would facilitate the interoperability of educational applications.

Having these in mind, our work is focused on one of the most popular existing metadata schemata, namely the IEEE LOM standard. LOM includes "the minimal set of attributes needed to allow learning objects to be managed, located, and evaluated" (Nair, & Jeevan, 2004) and has proved to be a widely adopted and internationally recognized open standard for the description of learning objects. But apart from IEEE LOM, other metadata schemata with similar characteristics have been deployed over time, aiming at fulfilling the same requisites in the race for the efficient management of educational resources. All of these standards, either directly related to LOM or not, make their own contribution to the characterization of learning objects and play an important role in the exchange of information in an interoperable way.

Nevertheless, the increasing number of applications that exploit educational metadata as well as the existence of many metadata specifications, sometimes poses the adoption of a sole metadata schema by an application a rather inefficient solution. As a better practice towards this direction, the use of application profiles is suggested. An application profile is defined as a combination of elements coming from different metadata schemata and is usually created in order to satisfy the needs of a particular application.

All these deployed metadata models are mainly utilized by digital repository systems that aim at preserving and managing educational material. A very popular system implemented for this reason is DSpace[1]. On top of DSpace many institutional repositories have been built worldwide. These systems exploit DSpace's inherent facilities and the fact that it uses the qualified Dublin Core element set as its base metadata schema. However, this schema is sometimes proven to be inadequate for the efficient characterization of

the great amount of the educational and research assets that we imported in institutional or other repositories of related purpose. That's why the deployment of an application profile, extended with learning object metadata and specific to the needs of an educational repository, is attempted through this work.

This article is further organized as follows: We start by presenting the basic structure of the IEEE LOM schema. We then give a brief overview about other widely known learning object metadata standards and see how these standards may be related to the IEEE LOM. Some profiles specific to educational applications are also mentioned. In the next section we describe how we managed to incorporate the LOM metadata schema in the University of Patras institutional repository, which is built upon the DSpace system. Furthermore, we analyze the implemented enhancements to this particular digital repository system and explain how they can improve the end-user experience and interaction with the overall system. We proceed by referring some issues regarding interoperability and semantics in digital repository systems that manage educational resources. Finally, we talk about possible future implementations regarding the best possible utilization of learning objects through similar kind of repositories.

LEARNING OBJECT METADATA STANDARDS

Learning objects (Wiley, 2002), have been defined as "any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning". In (Danziel, 2002) learning objects are defined as "an aggregation of one or more digital assets, incorporating meta-data, which represent an educationally meaningful stand-alone unit" and according to (IEEE LTSC, 2002), a learning object is "any entity -digital or non-digital- that may be used for learning, education or training". Examples of reusable digital

sources are images, video files, audio files or even a web page.

Learning Objects can be formally characterized by using metadata. Metadata can be defined as "data about data" or "information about information" (Berners-Lee, 1997). They are a set of attributes that try to best describe the content of a digital source. Hence, in a similar way, the content of a digital educational source can by described using the notion of educational metadata.

A widely adopted metadata element set, specifically applying to the field of education, is the IEEE LOM standard. IEEE LOM, which has been published by the Institute of Electrical and Electronics Engineers Standards Association, constitutes a standard designed for the description of learning objects. LOM has a wide range of elements for characterizing educational material that can be grouped into nine categories: *General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation* and *Classification*.

The LOM data model is a hierarchy of elements, as shown in Figure 1. There are nine categories in the first level and each of them has some sub-elements that can be single ones or aggregations of other elements. Some of this data model's elements can be repeated either as single or as group elements.

When the LOM schema is deployed, it is not necessary to use all of the data model's elements. The creation of an application profile allows someone to define which of them will be used together with their permitted values. Some of them can be dropped out and some other can be added from another metadata schema.

Apart from LOM, other metadata sets have been implemented in order to be utilized in the characterization of educational resources. It seems, though, that these sets are somehow related to LOM as they have many characteristics in common. The most popular among these metadata element sets, are summarized below:

Figure 1. The elements of IEEE LOM standard

a schematic representation of the hierarchy of elements in the LOM data model
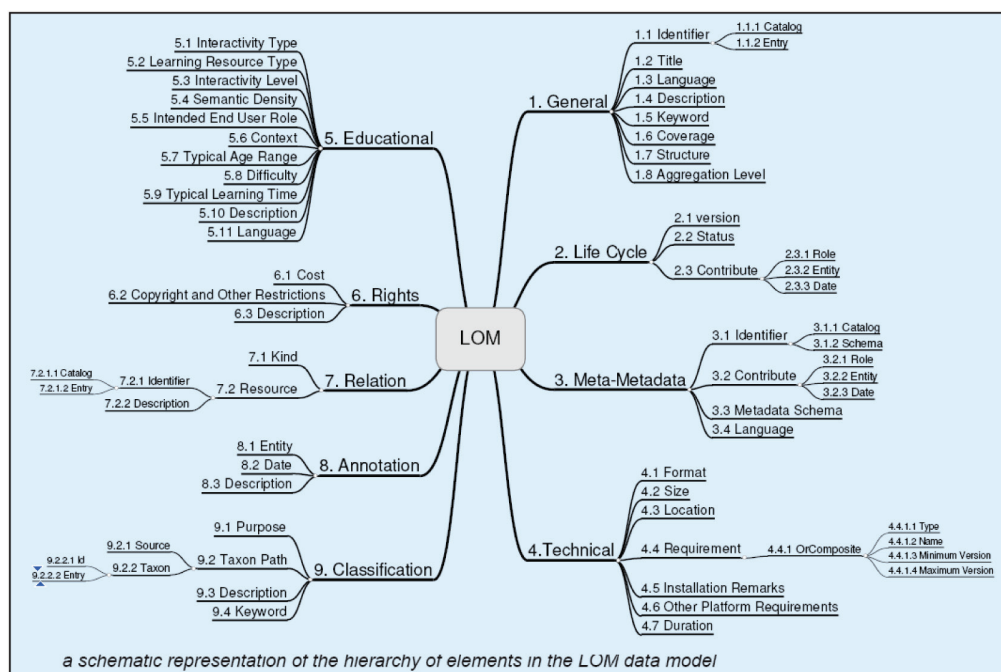
- The *Instructional Management Systems*[2] (IMS) Project started in 1997 as part of a non-profit organization in United Stated of America and constitutes an effort for the development of standards for online educational purposes. IMS is now a global organization and its main interests are the online access of educational objects. IMS develops and encourages open specifications that facilitate distributed online activities, like the locating and utilization of educational sources.

- The *ARIADNE* metadata standard[3] is the result of the work and the related experiments carried out till 1995 by various European and global organizations. The contents of this standard are described according to the XML schema. It is comprised of 47 elements, 27 of which can be directly mapped to the LOM elements. Similarly to LOM, the ARIADNE metadata schema can be organized into the following categories (Najjar, Duval, Ternier, & Neven, 2003) which are *General, Semantics, Pedagogical, Technical, Indexation* and *Annotations*.

- *Dublin Core* (DC) (DCMI, 2008) is a group of fifteen elements designed so as to provide a simple way to describe educational objects and to facilitate the latter's discovery and use. Optionally, additional attributes can be used. The DC metadata schema was one of the first that was adopted by plenty of metadata applications. Many organizations have adopted the DC schema, further augmenting them with more specific to their needs elements.

Application Profiles

A single metadata schema cannot always meet the needs of all kinds of applications. For this reason, the use of *Application Profiles* (Heery, & Patel, 2000) has been proposed. According to (Duval, Hodgins, Sutton, & Weibel, 2002), an application profile is an aggregation of metadata elements selected among one or more metadata schemata and combined in a new one. The latter's goal is to adequately fulfill the application's special needs and to retain interoperability with its base schema.

In particular, because the elements of the new profile usually come from more than one metadata schemata, this gives to the application the ability to cover its needs by exploiting the features of the existing schemata and to further augment them with new characteristics. As an example, one application can choose only a subset of the DC elements or create a totally new schema by combining the existing DC elements and by defining some new. Nevertheless, an application profile cannot be considered as being complete if it does not contain documentation that defines policies and practices about its proper usage.

In an application profile it is important to choose or define the correct vocabularies which will provide for the proper definition of the adopted elements. According to (Duval, & Hodgins, 2003), some techniques for producing complete definitions about application profiles are to give elements a mandatory status, to restrict the value space of data elements, to impose relationships between elements, not to include some elements and to identify taxonomies and classification.

Some known application profiles, aiming at providing a more effective description about learning objects, are the Canadian Core Learning Resource Metadata Application Profile[4] (CanCore), the SCORM[5] (Sharable Content Object Reference Model) model, the DC-Ed application profile, the UK Learning Object Metadata Core[6] and the GEM[7] (Gateway to Educational Materials) Metadata.

DIGITAL REPOSITORIES AND EDUCATIONAL METADATA

A digital repository is a mechanism responsible for storing, describing, preserving, managing and distributing any kind of digital material. Some

widely known mechanisms upon which a digital repository can be built are DSpace, Eprints[8] and Fedora[9]. Most of them exploit a simple and more general in meaning metadata schema, like DC, in order to characterize their content. Embedding educational metadata, though, seems to provide a faster and easier way to access the learning objects stored in these systems. More precisely, the exploitation of educational-specific metadata in digital repositories particularly intended for educational purposes has the following benefits:

- Allows the characterization and categorization of learning resources based on widely accepted standards and specifications, thus further boosting interoperability between systems and applications
- Facilitates integration in more complex systems, where queries are not handled only by one repository
- Helps in preserving and disseminating learning objects of higher "quality", making them easily discoverable and reusable
- Contributes to the efficient management of the vast and continually increasing number of resources, which demand for a more precise and refined way for their characterization
- Allows the exploitation of educational metadata by learning specific tools and applications that are able to consume them after harvesting them through an appropriate metadata harvesting facility

In the past years though, a lot of institutions and organizations, mainly acting on research and education fields, have realized the necessity to exploit educational metadata for the proper characterization of their digital assets. Some of these organizations, that have built digital libraries either by using the aforementioned digital repository mechanisms or by deploying their own ones from scratch are CAREO[10], MERLOT[11], JA-SIC[12]

and iLumina[13], included many others which are spread worldwide.

THE IEEE LOM STANDARD IN DIGITAL REPOSITORIES

One popular system particularly deployed for preserving and managing learning-specific resources is DSpace. DSpace is an open-source digital repository with one of the most rapidly growing user bases worldwide. It provides a way to manage research materials and scholarly publications in a professionally maintained repository, giving greater visibility and accessibility to its content over time. What is more, DSpace supports the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) (Lagoze, Van de Sompel, Nelson, & Warner, 2002) which offers a means to expose the repository's metadata. As a result, the repository's content is made available to service providers in an interoperable way.

On a default DSpace installation a qualified version of the Dublin Core schema is used which in turn based on the Dublin Core Libraries Working Group Application Profile (LAP) (DCMI Libraries Working Group, 2004). This schema can be extended with additional qualifications and elements. But apart from DC, other metadata schemata can also be imported in this system thus enhancing its capabilities and expanding its applicability to a more wide range of organizations and institutions.

Our work focuses on the University of Patras live DSpace installation[14], which has been developed as an institutional repository responsible for the preservation and dissemination of the University's research and educational material. Due to its intended role, we have extended the default metadata schema of this particular installation in order to incorporate the IEEE LOM data elements. The incorporation of this educational metadata standard finally enhances the reposi-

tory's provided services and facilities in several ways, as described in the following section.

Why IEEE LOM

Among the various available metadata that were studied, we chose to adopt the IEEE LOM so as to characterize the learning objects stored in the University of Patras institutional repository. The LOM schema is designed specifically to describe educational objects. As already mentioned, this standard focuses on the minimal set of attributes, needed to allow learning objects to be easily managed, located, and evaluated. It became popular mostly because of its simplicity in use. Therefore, due to its popularity, it is considered as a means to obtain interoperability among repositories and digital libraries that also support this schema. Besides, as stated in (Neven, & Duval, 2002), where a survey among ten learning objects repositories was performed, nine of them seem to use IEEE LOM as their base metadata schema. Additionally, according to (Al-Khalifa, & Davis, 2006), one of the IEEE LOM main features is that it can be easily extended so that new elements can be added and thus better fulfill the needs of a specific application. This capability gives a great motivation to people creating their own application profiles to use IEEE LOM as their base educational metadata schema.

Educational Metadata in DSpace

In order to import the IEEE LOM schema in the institutional repository of the University of Patras, a number of changes had to be made to the underlying DSpace system. As a first step, we had to import the LOM metadata schema in the system's metadata registry. This process was accomplished through the system's administration interface. Actually, we needed to manually create the LOM schema in the registry, starting by assigning a name and a namespace to it. Afterwards, we supplied the name of the content elements of this schema, as well as their refinements. For each

element, a small annotation indicating its usage was also possible. After the accomplishment of this step, we had to include the newly added fields in the submission process and to activate searching among those fields as well as their export through the OAI-PMH metadata harvesting facility.

In the University of Patras DSpace installation, though, not all elements of the LOM standard were incorporated. Some of them have a direct mapping to the DC metadata schema, as later explained in the section about interoperability issues and semantics. The rest are strictly provided for the characterization of educational resources and thus they have no correspondence to any of the existing terms of the provided DC metadata set. Therefore, we chose to adopt only a subset of LOM elements. This subset is comprised of elements that focus exclusively to the description of learning objects.

The import of the LOM metadata schema in the institutional repository had brought several enhancements in the system. These enhancements are reflected in the item submission and the advanced search process as well as in the item view and metadata harvesting facility, as described below and depicted in Figure 2.

Item Submission Process

When a new item is imported in the DSpace system, a standard submission process is followed which is normally comprised of three description steps followed by four general steps, necessary for completing the proper upload and storage of the item. During the description steps, users have to characterize the content they provide by filling its metadata values in the provided text fields. Each text field represents a specific DC element and the value assigned to it is the value supplied by the user in the corresponding textbox or list. For example, the content given by the user in the "Author" textbox becomes the value of the dc.contributor.author DC field whereas the "Title" corresponds to dc.title. Other kind of information

Figure 2.The incorporation of the LOM metadata schema in the DSpace system
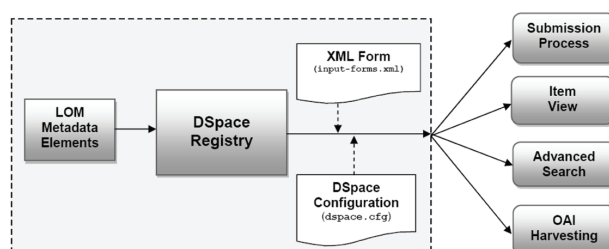
that users should supply about the submitted item concerns, for example, its type, its language and a set of subject keywords.

The metadata text fields are organized in pages and the process of filling a page's content fields is regarded as a distinct description step in the submission process. The structure of each page is defined in a fully parameterized XML file (input-forms.xml). Each page is represented by a form element in the XML file, where we have to declare the number of the page's fields and their correspondence to the DC elements.

In order for the proper utilization of the LOM metadata elements – apart from the initial process regarding their incorporation in the system's registry – we needed also to ensure their presence in the submission process. For this reason, we created a new form element inside the XML file that is responsible for the pages' structure. This form contains fields that correspond to the newly added LOM metadata fields and actually leads to the addition of a new page (description step) in the submission process, as shown in Figure 3. The new page is only activated and appears to users in case a "learning object" is submitted. The characterization of an object as being a "learning" one is provided in a preceding step, during the completion of the "Type" field. The LOM metadata fields that finally appear when submitting an item, together with their correspondent legal values, are presented in Table 1.

As shown in the Table 1, the incorporated LOM elements take values from a predefined value list.

This simplifies the way a learning object is described during the submission process. What is more, it offers a uniform way in describing learning objects.

As a result of these enhancements, a more complete characterization of the institutional repository's content is provided. In case that educational material is submitted in the DSpace system, users can utilize the incorporated educational metadata elements. Finally, the organization of this subset of elements in a separate submission page, allows for their dynamic appearance to the users, according to their previous selections.

Advanced Search

An advanced search facility, performing search in DSpace content's metadata, is by default provided by DSpace. Users can select from a list the metadata fields among which the supplied keywords will be sought. In this list we also added the "Educational Metadata" option. In fact, in order to enable search among the LOM elements, the configuration file of the DSpace system had to be altered (dspace.cfg). We had also to include the name of the LOM metadata schema among the already used search indices, otherwise DSpace wouldn't be able to perform search in these fields. The additional search index corresponds to all educational metadata.

As a result of this modification, users can now request to obtain learning objects, just by providing their keyword in a search field which

Figure 3. The submission process in DSpace. The dashed-line rectangle in the upper part of the figure represents the additional description page. This page (shown in the lower part of the figure) contains the newly added educational metadata fields
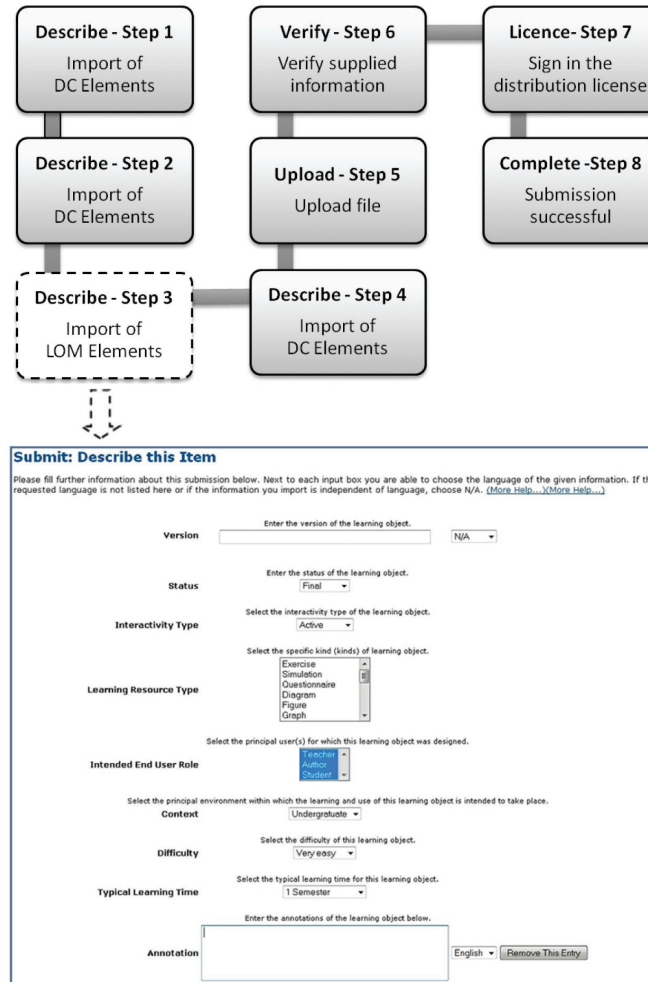
has the "Educational Metadata" option as a search type. Hence, the process of browsing educational resources becomes feasible though the standard – and familiar to the DSpace users – way.

Item View

After the successful submission of an item in a DSpace collection, the item can be retrieved through the simple or advanced search process. When the user selects to view a retrieved item, he is redirected to the "Item View" page. Here,

the user can see the metadata describing the requested item either in short or long format. The item view page is a common and familiar to DSpace users interface as this is where the basic information about an object is exposed. What is now different is that the object's LOM metadata also appear, provided that this object has already been characterized as a learning one. The same holds for the full item record, where all the metadata information concerning the object appears. In Figure 4 we can see an example of the short item record of a learning object.

Table 1. The incorporated LOM elements in the University of Patras institutional repository.

LOM Element	Description	Value
2.1 Version	The current version of the submitted learning object	*free text*
2.2 Status	The status of the learning object, regarding its completion level	Draft, Final, Revised
5.1 Interactivity Type	The sort of interaction between the user and the learning object	Active, Expositive, Mixed
5.2 Learning Resource Type	The type of the learning object	Exercise, Simulation, Questionnaire, Diagram, Figure, Graph, Index, Slide, Table, Narrative text, Exam, Experiment, Problem Statement, Self Assessment, Lecture
5.5 Intended End User Role	The kind of user groups to which the learning object applies	Teacher, Author, Student
5.6 Context	The educational level of the audience to which the learning object applies	Undergraduate, 1st Year, 2nd Year, 3rd Year, 4th year, 5th year, 6th year, Postgraduate, PhD
5.8 Difficulty	The difficulty level of the learning object	Very Easy, Easy, Medium, Difficult, Very Difficult
5.9 Typical Learning Time	The typical type that the intended users should devote in order to fully understand the learning object	Less than 1 hour, 1 hour to 3 hours, 3 hours to 5 hours, 1 Day, 1 Week, 1 Semester, 1 Year
8 Annotation	Any kind of additional information that concerns the learning object and has not be included in previous fields	*free text*

Metadata Harvesting

DSpace supports OAI-PMH which is an HTTP based protocol for interoperable metadata harvesting. This means that the institutional repository, which is a DSpace installation, is able to export its content through the supported OAI-PMH interface. This harvesting facility is configurable as to what elements are to be exported, supporting by default the simple DC, as well as its qualifica-

Figure 4. LOM metadata through the "Item View" page. The newly added metadata can be viewed in the dotted rectangle

Figure 5. A DSpace metadata record in its LOM format, as exposed through the OAI harvesting facility

```xml
- <lom:lom xsi:schemaLocation="http://ltsc.ieee.org/xsd/lomv1.0 http://ltsc.ieee.org/xsd/lomv1.0/lom.xsd">
  - <Contribute type="LifeCycle">
      <Role>author</Role>
      <Entity xml:lang="en">Solomou, Georgia</Entity>
    </Contribute>
    <Language type="General" iso="iso639-2">en</Language>
    <Keyword type="General" xml:lang="en">algorithms</Keyword>
    <Keyword type="General" xml:lang="en">complexity</Keyword>
    <Title type="General">Introduction to Algorithms</Title>
  - <TaxonPath type="Classification">
      <Source>dspace</Source>
      <Entry type="Taxon" xml:lang="en">Learning Object</Entry>
    </TaxonPath>
  - <TaxonPath type="Classification">
      <Source>dspace</Source>
      <Entry type="Taxon" xml:lang="el">Μαθησιακό Αντικείμενο</Entry>
    </TaxonPath>
    <Annotation xml:lang="en">Exercises for revising chapters 5 & 6</Annotation>
    <Context type="Educational" xml:lang="en">Undergratuate</Context>
    <Context type="Educational" xml:lang="el">Προπτυχιακό</Context>
    <Difficulty type="Educational" xml:lang="en">Medium</Difficulty>
    <Difficulty type="Educational" xml:lang="el">Μέτριο</Difficulty>
    <IntendedEndUserRole type="Educational" xml:lang="en">Student</IntendedEndUserRole>
    <IntendedEndUserRole type="Educational" xml:lang="el">Φοιτητής</IntendedEndUserRole>
    <InteractivityType type="Educational" xml:lang="en">Active</InteractivityType>
    <InteractivityType type="Educational" xml:lang="el">Διαδραστικός</InteractivityType>
    <LearningResourceType type="Educational" xml:lang="en">Slide</LearningResourceType>
    <LearningResourceType type="Educational" xml:lang="el">Παρουσίαση</LearningResourceType>
    <Status type="LifeCycle" xml:lang="en">Draft</Status>
    <Status type="LifeCycle" xml:lang="el">Πρόχειρο</Status>
    <TypicalLearningTime type="Educational" xml:lang="en">One semester</TypicalLearningTime>
    <TypicalLearningTime type="Educational" xml:lang="el">Ένα Εξάμηνο</TypicalLearningTime>
    <Version type="LifeCycle">2</Version>
  </lom:lom>
```

tions. What we did was to extend this OAI service so that it can expose the LOM metadata as well (Figure 5). This extension could be beneficial in the case of LOM-conformant applications that are able to consume LOM directly.

In order to ensure interoperability of our implementation to a maximum possible level, we also activated the OAI-PMH interface so as to export the institutional repository's metadata in the qualified DC format. As we will explain in subsequent section, we provide a mapping from the LOM schema to the qualified DC element. Thanks to this mapping and to our selected parameterization to export the qualified DC metadata through the OAI-PMH interface, the export of LOM metadata becomes possible as well. Thus, our institutional repository becomes able to render "mapped" elements available to the data providers, among which the newly added educational metadata are also included.

INTEROPERABILITY ISSUES AND SEMANTICS

In this section we will study some issues regarding the interoperability and the semantics of digital repositories enhanced with educational metadata. Firstly, we describe a mapping from the LOM schema to the DC metadata element set. This mapping has as a primary goal to achieve interoperability between the various digital repository systems. Interoperability can be further enhanced by exploiting Semantic Web techniques, like ontologies that are expressed in the Web Ontology Language (OWL) (Bechhofer, et al, 2004). As an example an ontological model for the repository's metadata is proposed which takes also into account the educational characteristics of resources.

Choosing the Right LOM Elements

As already mentioned, the University of Patras DSpace installation uses by default a qualified

version of the DC schema which can be further extended in order to enhance the system's capabilities. Our goal is to take advantage of the default DSpace schema's extension capability and enrich it with educational metadata. To achieve this we incorporate a subset of the LOM elements in the institutional repository. Among the LOM metadata elements that we chose to import in this system, there are some that appear to have a direct mapping to the inherent qualified DC metadata terms. So, we initially performed a mapping in order to investigate and find which exactly LOM elements correspond to the existing DC elements.

This mapping was considered necessary because it helped us to discover which of the LOM elements were already present in the repository's inherent schema through their DC correspondent. By this way we avoided repetition of elements in the repository's registry, namely we avoided the existence of multiple elements with the same semantic notions in our schema. The "missing" LOM elements were manually imported in the repository's metadata registry.

More specifically, the LOM metadata set comprises a hierarchy of elements, enumerating nine categories in the first level. Some of these elements have a direct mapping to DC terms, like for example *Title*, *Language* and *Contribute* which are mapped to dc.title, dc.language and dc.contributor respectively, as shown in Table 2. Consequently, the LOM elements with no explicit correspondence to DC that we finally chose to incorporate in DSpace were the following (nine in total): *Version*, *Status*, *Interactivity Type*, *Learning Resource Type*, *Intended End User Role*, *Context*, *Difficulty*, *Typical Learning Time* and *Annotation*.

Creation of a LOM Ontology

A process that took place right before the mapping of the newly added LOM elements to the DC terms was the creation of an ontology out of them. In particular, each LOM element that can accept values coming from a particular vocabulary

list (controlled vocabulary) was considered as a separate class. The members of this element's value space were then considered as instances of this particular class. We thus managed to group LOM vocabulary values into classes and when it was semantically consistent, we also related them to dcterms classes. The correlation with the dcterms classes helped us in rendering the semantic interpretation between a LOM value and a DC-Term notion even more clear and precise.

As an example of the LOM ontology creation, let's consider the LOM element *Interactivity Type* which can accept one of the following values: {*Active*, *Expositive*, *Mixed*}. For this element we created the class lom:interactivitytype and we made the declaration that the instances *Active*, *Expositive*, and *Mixed* are members of this class. We have also asserted that the lom:interactivitytype is a subclass of the dcterms:MethodOfInstruction,

Table 2. Mapping of some LOM elements to the DC elements.

LOM Element	DC Element
General	dc.description
Identifier	dc.identifier.uri
Catalog	dc.identifier dc.identifier.govdoc dc.identifier.isbn dc.identifier.issn dc.identifier.sici dc.identifier.ismn dc.identifier.other
Title	dc.title
Language	dc.language
Description	dc.description.abstract
Keyword	dc.subject
Life Cycle	dc.description.provenance
Contribute	dc.contributor
Role	dc.contributor.advisor dc.contributor.author dc.contributor.editor dc.contributor.illustrator dc.contributor.other
Entity	dc.publisher
Date	dc.date.accessioned

thus creating a direct correlation between this particular LOM and dcterms class. A similar correlation is possible to be asserted for the LOM notions lom:typicallearningtime and lom:intendedenduserrole. We actually considered them as being subclasses of the dcterms classes dcterms:SizeOrDuration and dcterms:MethodOfInstruction respectively. The complete LOM ontology hierarchy can be viewed in more details in Figure 6.

The reason why we opted for such a semantic-aware approach was that it helped in better defining the meaning of the LOM elements. For example, when we mapped the LOM element *Learning Resource Type* (lom.learningresourcetype) to the DC-term property dcterms:type (as there was no other closer in meaning term) the result appeared to be rather incomplete. This is because the dcterms:type has a more general use than the more concrete *Learning Resource Type* which is used in order to state the exact type of a learning object. Furthermore, we wanted to utilize this work in a later implemented upgrade of the DC schema – together with

the imported LOM metadata – to an OWL ontology (Koutsomitropoulos, Solomou, Alexopoulos, & Papatheodorou, 2009a).

Mapping LOM to DC

A remaining task was to map the nine LOM elements to the DC-Terms properties (DCMI Usage Board, 2008). We actually made an attempt to map these elements to those DC-Terms properties that seemed to better convey their meaning. The goal of such an attempt was to provide for semantic interoperability among repositories that serve educational purposes and that, like our institutional repository, utilize the qualified DC metadata. For this reason we took into consideration both the IEEE LOM specification (IEEE LTSC, 2002) and the work suggested in (IEEE LTSC, 2008) which proposes a potential LOM to DC Abstract Model (DCAM) (Powell, Nilsson, Naeve, Johnston, & Baker, 2007) mapping. According to that work a way to express LOM instances using the DCAM is proposed, arising from the necessity to have interoperable definitions of DC metadata terms

Figure 6. LOM ontology hierarchy
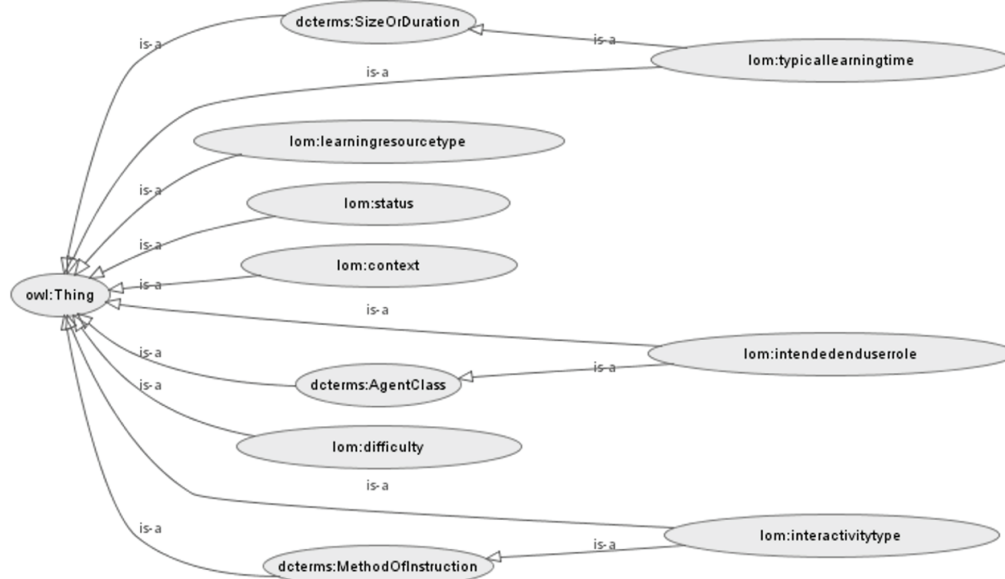
and learning object metadata elements that can co-operate. In addition, we studied some work regarding the provision of guidelines for the accommodation of additional metadata formats (like IMS-LOM) in DSpace, presented in (Prasad, 2006).

As a final step, we implemented the requested mapping from LOM to DC. We started by introducing and re-assigning namespaces. The dc: was replaced by dcterms: whereas LOM elements were prefixed with the lom: namespace. We then performed the requested mapping so that the LOM terms correspond to their closer in meaning DC-Terms. For example, we added in the DSpace metadata registry the elements lom.intendedEndUserRole and lom.interactivitytype which correspond to the LOM elements *Intended End User Role* and *Interactivity Type* respectively. We then mapped them to the most appropriate DC-Terms properties, namely the first one was mapped to dcterms:audience and the latter to dcterms:instructionalMethod. Finally, in order to better clarify these elements' actual value space, we have stated that dcterms:audience is of type lom:intendedenduserole and dcterms:instructionalMethod is of type lom:interactivitytype. Therefore, we explicitly define that whenever the DC-Terms properties dcterms:audience and dcterms:instructionalMethod are used, they are obliged to take values that come only from the lom:intendedenduserole and lom:interactivitytype classes respectively. For those LOM elements that no value space has to be defined, we just mapped them to the closest in meaning DC-Terms properties, without having to explicitly assign a value space (a type). The resulting mapping, concerning all the LOM elements, is presented in Table 3.

Exploiting a Learning Object Metadata Ontology

Because the use of ontologies leads to more interoperable applications and services, we exploit the upgraded DC metadata schema of the University of Patras institutional repository and we create an ontological model out of this schema. Having this ontology as a starting point, we further enhance the institutional repository with Semantic Web features. Besides, Semantic Web comes as a means to offer a new and challenging dimension in

Table 3. Mapping of LOM elements to the DC Terms properties

LOM Element		DC-Terms Property
2.1 Version	lom.version	dcterms:hasversion
2.2 Status	lom.status	dcterms:type type="lom:status"
5.1 Interactivity Type	lom.interactivitytype	dcterms:instructionalMethod type="lom:interactivitytype"
5.2 Learning Resource Type	lom.learningresourcetype	dcterms:type type="lom:learningresourcetype"
5.5 Intended End User Role	lom.intendedenduserrole	dcterms:audience type="lom:intendedenduserrole"
5.6 Context	lom.context	dcterms:educationLevel type="lom:context"
5.8 Difficulty	lom.difficulty	dcterms:type type="lom:difficulty"
5.9 Typical Learning Time	lom.typicallearningtime	dcterms:extent type="lom:typicallearningtime"
8 Annotation	lom.annotation	dcterms:description

the way information is managed and manipulated by traditional digital repositories.

In (Koutsomitropoulos, Solomou, Alexopoulos, & Papatheodorou, 2009a) we have proposed a method to create an ontological model for the institutional repository, by capturing the intended semantics of its DC metadata domain, taking into account the DC RDF(S) schema (Nilsson, Powell, Johnston, & Naeve, 2008). We actually created a semantic application profile of the qualified DC ontology, tailored for our repository's domain. We built upon the initial model and we didn't make any modifications in its original specification. In this process, we also took into account the LOM metadata, with which we have extended the original DSpace schema. Finally, we upgraded this ontology up to OWL and especially OWL 2 level (Hitzler, Krötzsch, Parsia, Patel-Schneider, & Rudolph, 2009), by incorporating new constructs and refinements, available only in these languages.

Therefore, through a series of syntax transformations, we have tried to better capture the semantic relations implied in these metadata as well as to construct the OWL specific instantiations, achieving a semantic level of compatibility with our ontology. The resulting ontology, including the new refinements, was afterwards populated in an automated way from metadata already existing within the live DSpace installation of our institutional repository, through its OAI-PMH interface.

The benefit of such an approach is that we are now able to utilize the original DC specification and to reuse it by providing a semantic application profile suitable for the particular domain's needs. We achieved this without interfering with the repository's internal data model and we have rather based upon the repository's inherent interoperability facilities, namely the OAI-PMH interface. As this approach is independent of the system architecture and relies mostly on interoperability interfaces, it can be likewise applied to enhance any modern digital repository system. Finally, looking back at the implemented mapping between DC-based information and LOM metadata, we see that the proposed improvements achieve semantic interoperability, even for the case that disparate schemata are used.

Moving a step forward, we have further extended our institutional repository by deploying some semantics-aware services on top of this ontology. These services provide for inference-based knowledge discovery, retrieval and navigation on top of the DSpace system, as we describe in (Koutsomitropoulos, Solomou, Alexopoulos, & Papatheodorou, 2009b). Because these services are possible to be implemented on top of other digital repository systems as well, a greater level of semantic interoperability can be gained.

FUTURE RESEARCH DIRECTIONS

As we saw in previous sections, the newly added LOM metadata can be exported through the OAI-PMH interface. This protocol enhances the interoperability of the system since it allows the metadata to be harvested in an automated machine-readable way. The OAI-PMH has been developed by the Open Archives Initiative which develops interoperability standards. A more recent protocol implemented by this organization is the Open Archives Initiative Object Reuse and Exchange (OAI-ORE) (Johnston, Nelson, Sanderson, & Warner, 2008). The OAI-ORE defines standards for the description and exchange of aggregations of Web resources. These aggregations are called compound digital objects, and may combine distributed digital resources with various types of objects like text, images, and video. An interesting aspect of the OAI-ORE protocol would be to be implemented for the DSpace system. Such an implementation could cause the supported compound digital objects to be created from resources stored in DSpace repository or even from resources stored in distributed DSpace repositories. Moreover, it would be interesting to see how educational metadata can smoothly cooperate with OAI-ORE so that we can create compound digital learning

objects. By this way, namely by exploiting the OAI-ORE features, repository systems that manage educational resources could benefit as well.

Furthermore, our work has been concentrated on implementing the LOM schema in a live DSpace installation, leading to the enhancement of this particular system with the ability to store more information about learning objects. Apart from DSpace, many other repositories are in use for educational purposes worldwide, like Eprints and Fedora. So, it would be worth to try to incorporate the LOM schema in these repository systems as well. It might also be interesting to create an abstract model that would facilitate the incorporation of the LOM schema in various digital repositories. These educational metadata could then be exported through the OAI-PMH interface – if the latter is supported. Moreover, it would be challenging to try to integrate OAI-ORE in other repository systems – apart from DSpace – thus enhancing them with the ability to create aggregations of digital objects, coming from distributed repositories and digital library systems.

In addition, a deeper look into the Simple Web-service Offering Repository Deposit (SWORD) (Allinson, François, & Lewis, 2008) protocol could be beneficial. SWORD defines a standard and common mechanism for depositing into repositories and other systems. This functionality adds many features to digital repositories since more services can be built on top of it, like the ability to submit a file to multiple repositories at once or to submit files using desktop applications or even standard office applications. This protocol has already been implemented for various digital library systems like DSpace, Eprints and Fedora. A significant point would be to see this interoperability features offered by SWORD in practice and to further enhance this common mechanism with educational metadata.

As a final task, we focus on the deployment of the ontological model for digital repositories which seems to offer a significant means for further enhancing semantic interoperability in these systems. Although the proposed ontology has been enriched with LOM metadata, it could be interesting to see how other educational metadata schemata could be utilized in such an ontology, as long as their corresponding mapping to the DC-Terms properties is provided. What is more, a possible application of the populated ontology to other digital repository systems, apart from DSpace, would possibly reveal significant benefits from such a closer to Semantic Web approach.

CONCLUSION

In this work we have shown how the IEEE LOM standard can be utilized by digital repositories that manage educational resources. We presented several metadata schemata and applications profiles that have been constructed for the efficient characterization of learning objects. According to their characteristics, the one that seems to be more promising and has gained significant ground over the others is the IEEE LOM. The latter is a very popular standard has been adopted by many institutions and it has been implemented by many educational specific applications.

In order to exploit this schema's features, we incorporated it in the DSpace digital repository system, upon which the University of Patras institutional repository has been built. Actually, we have shown how we extended the repository's inherent DC metadata schema and enriched it with educational metadata. Therefore, we made this repository capable of characterizing its content in a more efficient way, rendering it easily accessible and utilizable. What is more, the result of this implementation became obvious in several DSpace facilities, like the item submission process, as well as in the advanced search and item view facility. This means that the imported LOM schema is now used in practice and can be exploited by the repository's users for the efficient description of the submitted material. What is more interesting, though, is that these facilities can be easily

applied in other similar repository systems that use the DC element set for the characterization of their content.

In order for the LOM incorporation to be successfully accomplished, a mapping from the LOM to the qualified DC terms properties was preceded. Consequently, our repository is now consisted of educational and research material of higher "quality", where semantic relationships among items can also be implied. In addition, the system's metadata records can be fully exploited by the OAI harvesting service, through which a better level of interoperability can now be achieved. Besides, an extension to the OAI protocol so as to support LOM, along with the proposed mapping from LOM to DC, allowed us to easily expose these new metadata through the supported OAI-PMH interface (in their LOM or DC qualified format). This feature becomes true not only for the DSpace system, but also for any other OAI-compliant repository.

Finally, we implemented the LOM to DC mapping having in mind a later upgrade of this compound schema to an OWL ontology. We created LOM notions (classes), instead of mere LOM elements, whose members (instances) define the exact value space for the corresponding DC-Term. The creation of an ontological model out of these concepts and the use of Semantic Web features confirmed that new metadata concepts can be seamlessly integrated and further enhance the interoperability in this kind of applications.

REFERENCES

Al-Khalifa, H., & Davis, H. (2006). The evolution of metadata from standards to semantics in E-learning applications. In *17th ACM Conference on Hypertext and Hypermedia*.

Allinson, J., François, S., & Lewis, S. (2008). *SWORD: Simple Web-service Offering Repository Deposit*. Retrieved from http://www.ariadne. ac.uk/issue54/allinson-et-al/

Bechhofer, S., Harmelen, F., Hendler, J., Horrocks, I., McGuinness, D., Patel-Schneider, P., & Stein, L. A. (2004). *OWL Web Ontology Language Reference*. W3C Recommendation. Retrieved from http://www.w3.org/TR/owl-ref/

Berners-Lee, T. (1997). *Metadata Architecture*. Retrieved from http://www.w3.org/DesignIssues/ Metadata.html

Dalziel, J. (2002). *Reflections on the COLIS (Collaborative Online Learning and Information Systems) Demonstrator Project and the "Learning Object Lifecycle"*. Retrieved from www.colis. mq.edu.au/projects/dalziel.doc

DCMI. (2008). *Dublin Core Metadata Element Set, Version 1.1*. DCMI Recommendation. Retrieved from http://dublincore.org/documents/ dces/

DCMI Libraries Working Group. (2004). *Library Application Profile*. DCMI Working Draft. Retrieved from http://dublincore.org/documents/2004/09/10/library-application-profile/

DCMI Usage Board. (2008). *DCMI Metadata Terms. DCMI Recommendation*. Retrieved from http://dublincore.org/documents/dcmi-terms/

Duval, E., & Hodgins, W. (2003). *A LOM Research Agenda*. Retrieved from http://www2003. org/cdrom/papers/alternate/P659/p659-duval. html.html

Duval, E., Hodgins, W., Sutton, S., & Weibel, S. (2002). Metadata Principles and Practicalities. *D-Lib Magazine*, *8*(4). Retrieved from http:// www.dlib.org/dlib/april02/weibel/04weibel.html. doi:10.1045/april2002-weibel

Heery, R., & Patel, M. (2000). *Application Profiles: Mixing and Matching Metadata Schemas*. Retrieved from http://www.ariadne.ac.uk/issue25/ app-profiles/

Hitzler, P., Krötzsch, M., Parsia, B., Patel-Schneider, P., & Rudolph, S. (Eds.). (2009). *OWL 2 Web Ontology Language: Primer*. W3C Working Draft. Retrieved from http://www.w3.org/TR/owl2-primer/

IEEE LTSC. (2002). *Draft Standard for Learning Object Metadata (IEEE 1484.12.1-2002)*. Retrieved from http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

IEEE LTSC. (2008). *Draft Recommended Practice for Expressing IEEE Learning Object Metadata Instances Using the Dublin Core Abstract Model (IEEE P1484.12.4/D1)*. Retrieved from http://dublincore.org/educationwiki/DCMIIEEELTSCTaskforce?action=AttachFile&do=get&target=LOM-DCAM-newdraft.pdf

Johnston, P., Nelson, M., Sanderson, R., & Warner, S. (Eds.). (2008). *ORE Specification - Abstract Data Model*. Retrieved from http://www.openarchives.org/ore/1.0/datamodel

Koutsomitropoulos, D., Solomou, G., Alexopoulos, A., & Papatheodorou, T. (2009a). Semantic Metadata Interoperability and Inference-Based Querying in Digital Repositories. *Journal of Information Technology Research*, *2*(4), 37–53.

Koutsomitropoulos, D., Solomou, G., Alexopoulos, A., & Papatheodorou, T. (2009b). Knowledge Management and Acquisition in Digital Repositories: A Semantic Web Perspective. In *international Conference on Knowledge Management and Information Discovery*.

Lagoze, C., Van de Sompel, H., Nelson, M., & Warner, S. (2002). *The Open Archive Initiative Protocol for Metadata Harvesting*. Retrieved from http://www.openarchives.org/OAI/openarchivesprotocol.html

Nair, S., & Jeevan, V. (2004). A Brief Overview of Metadata Formats. *DESIDOC Bulletin of Information Technology*, *24*(4), 3–11.

Najjar, J., Duval, E., Ternier, S., & Neven, F. (2003). Towards Interoperable Learning Object Repositories: the ARIADNE Experience. In *IADIS WWW/Internet 2003 Conference*, (pp. 219-226).

Neven, F., & Duval, E. (2002). *Reusable learning objects: a survey of LOM-based repositories. In 10th ACM international conference on Multimedia* (pp. 291–294).

Nilsson, M., Powell, A., Johnston, P., & Naeve, A. (2008). *Expressing Dublin Core metadata using the Resource Description Framework (RDF)*. *DCMI Recommendation*. Retrieved from http://dublincore.org/documents/dc-rdf/

Powell, A., Nilsson, M., Naeve, A., Johnston, P., & Baker, T. (2007). *DCMI Abstract Model*. *DCMI Recommendation*. Retrieved from http://dublincore.org/documents/abstract-model/

Prasad, A. R. D. (2006). Implementing LOM Schema in DSpace. In *DRTC-ICT Conference on Digital Learning Environment*.

Wiley, D. (2002). *Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy*. Retrieved from http://reusability.org/read/chapters/wiley.doc

KEY TERMS AND DEFINITIONS

Digital Repositories: Mechanisms responsible for storing, describing, preserving, managing and distributing any kind of digital material.

Educational Metadata: Metadata about learning objects.

Application Profiles: Combinations of different metadata schemata.

IEEE LOM: A metadata standard about learning objects, published by the Institute of Electrical and Electronics Engineers Standards Association.

DSpace: A open source digital repository system that provides the tools for management of

digital assets. It is mainly used for the deployment of institutional repositories.

Interoperability: The ability of diverse systems and applications to co-operate (inter-operate).

Mapping: Correspondence between two different data models.

ENDNOTES

[1]   http://www.dspace.org/
[2]   http://www.imsproject.org/
[3]   http://www.ariadne-eu.org/
[4]   http://www.cancore.ca/
[5]   http://www.adlnet.org/
[6]   http://zope.cetis.ac.uk/profiles/uklomcore/
[7]   http://www.thegateway.org/
[8]   http://www.eprints.org/
[9]   http://www.fedora-commons.org/
[10]   http://www.careo.org/
[11]   http://www.merlot.org/
[12]   http://www.mis2.udel.edu/ja-sig/
[13]   http://www.ilumina-dlib.org/
[14]   http://repository.upatras.gr/dspace/