Semantify Educational Resources using SKOS and Learning Object Ontologies

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***Abstract*—**It is well known through experience that learning material is annotated in so many diverse ways, as the sources that maintain and curate them. Semantification of metadata descriptions can often resolve interoperability issues and strengthen the knowledge value of resources. To this end, SKOS can be a solid linking point offering a standard vocabulary for thematic descriptions. Using contemporary ontology management tools, such as WebProtégé, we show how this process can be streamlined and how it can help knowledge intensive institutions, including libraries and universities, towards aligning incoming learning material or enhancing their own.

***Keywords*—**SKOS, Thesauri, Learning Objects, Ontologies, WebProtégé.

I. Introduction

A growing number of digital repositories systems, maintained by universities, libraries, archives and other educational institutions worldwide, are responsible for the preservation and management of educational resources. A kind of educational resource that is increasingly used by such institutions in recent years is the Learning Object (LO). In the IEEE Draft Standard for Learning Object Metadata [5], a LO is defined as "*any entity – digital or non-digital – that may be used for learning, education or training*". LOs are widely purposed and/or reused as a meaningful and effective way of creating content for e-learning [13], especially within learning- and course- management systems.

Therefore, through this work we proceed with the design and adoption of a LO metadata profile, originating from the widely known IEEE LOM standard. The resulting profile combines terminology with the Dublin Core metadata terms specification [1] and is intended for the efficient characterization of LOs, preserved and managed by educational institutions. Our goal is not to simply create another specialized LO metadata profile, but to contribute towards knowledge discovery across digital LOs repositories, ultimately helping institutions access, maintain and enhance learning material.

To this end, we follow a "semantification" process i.e., the transformation of the textual information captured by a metadata instance into a semantically enriched and thus machine-understandable format. Ontologies are a knowledge representation technique, offering all of the necessary constructs towards this process. They constitute the pillar of the Semantic Web, allowing knowledge reuse and sharing across applications. Ontologies have long been used for many applications in the field of education [2], so their utilization for describing educational resources can have many advantages, from facilitating the design of a LO-based course to improving the discovery of educational resources.

Going a step forward, in our LO profile's ontological representation, the subject of a LO is determined to be expressed not as a mere text keyword, but as a *concept* of a thematic thesaurus. The machine readable format of a thesaurus is achieved by the exploitation of the Simple Knowledge Organization System (SKOS) standard [10]. SKOS provides a standardized way to represent thesauri – and knowledge organization systems in general – using the Resource Description Framework (RDF) [8] and the Web Ontology Language (OWL) [11].

By combining our LO ontologies with SKOS thesauri, we can ensure a semantically enhanced characterization of LOs within the context of a digital repository, thus increasing discoverability of its resources. In addition, we set the basis for cross-repository semantic interoperability.

To manage and render accessible our LO metadata schema and ontologies, as well as any thesaurus generated explicitly to be used in combination with them, we make use of the WebProtégé ontology editor [15]. WebProtégé is a lightweight, web-based tool for ontology editing that comes with useful collaborative features and allows for the publishing of its maintained ontologies. To increase its user friendliness and aid LO ontology and thesauri maintenance and accessibility by other institutions, we have also extended WebProtégé with a couple of additional features.

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To give a more thorough understanding of our work, we start by describing our LO ontology schema (Section II). We then proceed by giving the main characteristics of the SKOS model and its importance in knowledge organization, presenting also two thematic thesauri expressed in this format (Section III). In Section IV we summarize the features of the WebProtégé editor and describe our modifications on top of it. An example of a LO ontology is given in subsequent Section V. Conclusions and future work follow in last Section VI.

II. A Learning Object Ontology Schema

Although several educational metadata schemata have been proposed over time, we are based upon the IEEE LOM standard in order to build our LO metadata profile. The reason we opted for the IEEE LOM is that this standard includes "*the minimal set of attributes needed to allow LOs to be managed, located, and evaluated*" [12] and has proven to be a widely adopted and internationally recognized open standard for the description of LOs. Our LO metadata profile adopts only a subset of the IEEE LOM element set. Our ultimate goal is the creation of a schema that would be broad enough to cover the most important educational and pedagogical aspects of an educational resource handled by a digital repository, but not exhaustively analytic, so as to become awkward in use.

The ontological binding of our LO metadata profile is expressed in the *LO Ontology Schema*. Apart from those entities representing elements originating from the IEEE LOM schema, we have also declared classes, capturing notions found in the DCMI recommendation for the Dublin Core (DC) metadata terms. This correlation helps control the values of fields for LOM properties and can increase interoperability with applications that are based on DC. In particular, LOM concepts *IntendedEndUserRole*, *InteractivityType* and *TypicalLearningTime* have been defined as refinements of the DC classes *AgentClass*, *MethodOfInstruction*, *SizeOrDuration*, respectively. For the LOM specific entities the official LOM namespace has been used (http://ltsc.ieee.org/xsd/LOM/, prefix lom:), whereas DC classes have been declared under the namespace http://purl.org/dc/terms/, prefix dcterms:.

The *lom:LearningObject* class is a top class used to capture the notion of an LO, or an educational resource in general. The various characteristics of an educational resource are represented as either classes or properties in this ontological schema. The datatype properties *lom:description*, *lom:identifier*, *lom:language*, *lom:rights*, *lom:size*, and *lom:title* are used to declare a short description, a unique identifier, the LO's content language, the copyright policies, and finally LO's physical size and title, respectively. We chose to express these elements of the LOM schema as datatype- and not as object- properties given that they simply assign values to some of the resources' basic characteristics and convey no correlations among them.

The *lom:LearningResourceType* class aims at specifying the different educational types that can be assigned to LOs and it is associated with a predefined list of terms (Exercise, Experiment, Figure, Lecture, etc.). Each such term is an instance of the *lom:LearningResourceType* class and works as filler to the object property *lom:learningResourceType*. In a similar way, concepts met in our LO metadata profile, like the groups of end-users to which a LO applies, the intended instructional context, LO's level of difficulty, average learning time, level of completeness (draft, revised or final) and type of interaction (active, expositive, etc.) are captured using the appropriate object properties *lom:intendedEndUserRole*, *lom:context*, *lom:difficulty*, *lom:typicalLearningTime*, *lom:status*, *lom:interactivityType* respectively. These properties correlate a LO with a predefined set of values, each of which is represented as an instance of the corresponding class.

Potential relationships among LOs can be captured via the object property *lom:relation*, which is used exactly to correlate instances of the *lom:LearningObject* class. In addition, we use the *dcterms:Agent* class to include any person or organization responsible for the creation (or other modifications) to an educational resource. The object property *lom:contributor* comes to implement this type of correlation.

Finally, it is important to note that the *lom:keyword* property, used in our LO profile in order to express the thematic subject of the LO's content, is represented as an object- rather than a datatype- property. Our intention is to directly correlate the subject keywords of a LO to SKOS concepts, thus increasing the value of our LO ontology when used in the context of knowledge discovery applications. A summary of the classes and properties declared in the *LO Ontology Schema*, are shown in Fig. 1.

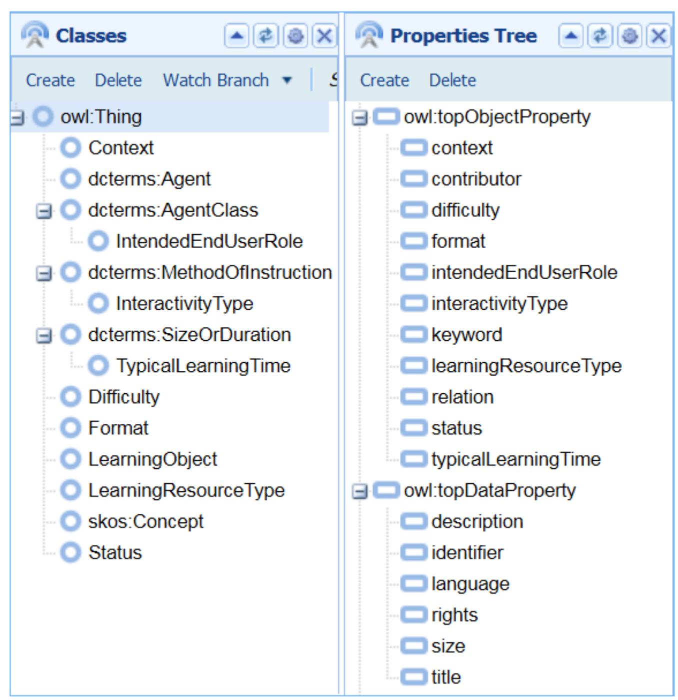

Fig. 1 Class and property hierarchies in the Learning Object Ontology Schema

Our *LO Ontology Schema* can form the basis for building more specific ontologies, targeting at the description of LOs that serve the educational purposes of various knowledge domains, university courses etc. Publishing these ontologies on the Web, using a tool such as WebProtégé can significantly increase LOs management and discoverability across digital repositories. What is more, with their unique and directly accessible identifier – assigned through the *lom:identifier* datatype property – LO exposure to other discovery mechanisms, digital repositories and the Web of Linked and Open Data (LOD) [3] becomes feasible.

III. Thematic Descriptions Using SKOS

SKOS is a model for expressing Knowledge Organization Systems (KOS) [4], including thesauri, in machine readable format. It provides a uniform representation of a set of terms and hence a common mechanism for the thematic indexing and retrieval of information. With the aid of SKOS, we can easily perform an integrated search against systems that are based upon controlled and structured vocabularies, such as institutional repositories and digital libraries. Additionally, as an RDF application, SKOS allows editing, publishing and interconnection of concepts on the Web, as well as their integration into other concept schemes. The terminology of SKOS has been formally expressed into RDF/OWL. An example of the SKOS structure is shown in Fig. 2.

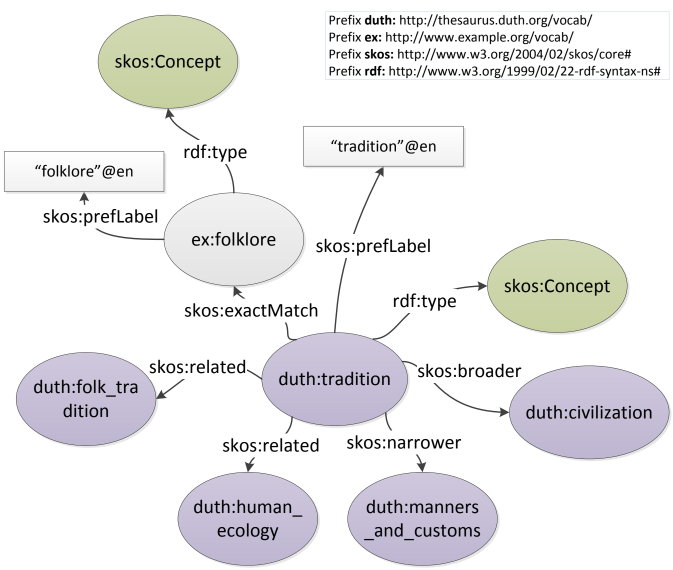

Fig. 2 Example of the structure of a SKOS concept

A. The SKOS Vocabulary

Given that SKOS is designed exactly to describe concept schemes, *concept* is its basic structural element. A SKOS concept can be viewed as a unit of knowledge, i.e., an idea or notion, an object or a class of objects and events that govern many knowledge organization systems. Therefore, *concepts* are abstract entities, which are independent of their names (i.e., the labels) used to characterize them. SKOS introduces the class *skos:Concept* to indicate that a particular term is a concept. The individuals of the *skos:Concept* class can belong to a specific concept scheme. A concept scheme is expressed through the *skos:ConceptScheme* class.

The concepts/terms of a thesaurus, when expressed in SKOS format, are identified by URI's and assigned string labels in one or more languages. In addition, they are documented with various types of notes and interconnected with semantic relations through informal hierarchies.

Table 1 The SKOS Core Vocabulary

SKOS Term	Description
skos:Concept	*An abstract idea or notion; a unit of thought*
Concept Schemes	
skos:ConceptScheme	*A concept scheme in which the concept is included*
skos:inScheme	*Relates a resource to a concept scheme in which it is included*
skos:hasTopConcept	*A top level concept in the concept scheme*
skos:topConceptOf	*Is top concept in scheme*
Lexical Labels	
skos:prefLabel	*The preferred lexical label for a resource, in a given language*
skos:hiddenLabel	*A lexical label for a resource that should be hidden when generating visual displays of the resource.*
skos:altLabel	*An alternative lexical label for a resource*
Semantic Relations	
skos:broader	*A concept that is more general in meaning*
skos:narrower	*A concept that is more specific in meaning*
skos:broaderTransitive	*Has broader transitive*
skos:narrowerTransitive	*Has narrower transitive*
skos:related	*A concept with which there is an associative semantic relationship*
skos:semanticRelation	*A concept related by meaning*
Mapping Properties *(to other concept schemes)*	
skos:exactMatch	*Has exact match*
skos:closeMatch	*Has close match*
skos:broadMatch	*Has broader match*
skos:narrowMatch	*Has narrower match*
skos:relatedMatch	*Has related match*
skos:mappingRelation	*Is in mapping relation with*
Notations	
skos:notation	*A string used to uniquely identify a concept within the scope of a given concept scheme*
Documentation Properties	
skos:changeNote	*A note about a modification to a concept*
skos:definition	*A statement or formal explanation of the meaning of a concept*
skos:editorialNote	*A note for an editor, translator or maintainer of the vocabulary*
skos:example	*An example of the use of a concept*
skos:historyNote	*A note about the past state/use/meaning of a concept*
skos:note	*A general note*
skos:scopeNote	*A note that helps to clarify the meaning and/or the use of a concept*
Concept Collections	
skos:Collection	*A meaningful collection of concepts*
skos:OrderedCollection	*An ordered collection of concepts, where both the grouping and the ordering are meaningful*
skos:member	*A member of a collection*
skos:memberList	*An RDF list containing the members of an ordered collection*

To express these characteristics, the SKOS model uses a set of properties, firstly in order to define a concept itself and secondly to relate it with other counterparts in a concept scheme. Table 1 summarizes available SKOS properties, organized into categories according to their purpose, and gives a brief description of their usage.

B. Two Thematic Terminological Thesauri

To take advantage of the potential of our LO Ontology schema, when building ontologies that capture and describe LOs, we needed a thematic thesaurus so as to directly map a LO's subject (via the *keyword* property) with SKOS concepts. These concepts would be best to originate from a standard, authoritative and controlled vocabulary rather than being arbitrary literals.

To this end, we proceeded with the creation of two thesauri – initially not in SKOS format – that cover two very common fields of knowledge: *Maths* and *Medicine*. These thesauri were actually extracted from the Thesaurus of Greek Terms, a bilingual (Greek, English) controlled vocabulary published by the National Documentation Center in Greece[1] (EKT). The latter covers a very broad field of knowledge and was created in order to facilitate libraries, museums, information centers and other institutions in Greece in characterizing and managing their digital material.

The *Maths Thesaurus* is comprised of 76 terms, making reference to 17 other related terms, whereas the *Medicine Thesaurus* contains 54 terms and makes reference to 71 additional terms. Although both of these thesauri cover specific fields of knowledge, they are generic enough and thus sufficient for the characterization of the most common subjects met in these thematic areas.

After extracting these two thesauri, our goal was to take care for their transformation into SKOS, so as to render them exploitable across different digital repositories and semantic applications. Besides, the migration of all type of knowledge organization systems into SKOS has long been recognized as a need, especially by those organizations that deal with controlled vocabularies. Some prominent examples are the Library of Congress Subject Headings (LCSH) [14] and the Food and Agriculture Organization Thesaurus[2] (AGROVOC).

In their initial format, both the *Maths* and the *Medicine Thesaurus* are expressed in XML syntax and follow the structure of any usual subject thesaurus, as defined by ISO 2788 [7]: they make use of hierarchical (<BT>, <NT>, <MT>), associative (<RT>) and equivalence (<UF>) relations. In addition, for each term in Greek, its English translation is provided (<ET>), as well as its correspondence to the Dewey Decimal Classification system (<dewey>).

To achieve the SKOS transformation, we implemented a mapping of the XML elements to SKOS notions, as shown in Table 2. As a result, we took the SKOS version of these two thesauri, which is in alignment with what SKOS specification defines.

[1] http://www.ekt.gr/en/

[2] http://aims.fao.org/vest-registry/vocabularies/agrovoc-multilingual-agricultural-thesaurus

Table 2 Mapping to SKOS elements

XML element	Function	SKOS notion
<TERM>	The described term	<skos:Concept>
<USER>	Thesaurus' owner	–
<CONTEXT>	Term's label	<skos:prefLabel lang="el">
<MT>	Microthesauri term	<skos:broaderTransitive>
<ET>	English translation	<skos:prefLabel lang="en">
<ET>	Alternative English translation	<skos:altLabel lang="en">
<BT>	Broader term	<skos:broader>
<NT>	Narrower term	<skos:narrower>
<RT>	Related term	<skos:related>
<UF>	Opposite of the Used Instead (USE) term	<skos:altLabel lang="el">
<SN>	A short description	<skos:definition>
<DEWEY>	A number indicating the correspondence to Dewey system	<skos:notation>

A snippet of a SKOS concept – belonging to the resulting SKOS version of the *Medicine Thesaurus* – can be seen in Fig. 3.

```
<skos:Concept rdf:about="http://ekt.example.org/vocab/pediatrics">
   <skos:prefLabel xml:lang="en">pediatrics</skos:prefLabel>
   <skos:prefLabel xml:lang="el">παιδιατρική</skos:prefLabel>
   <skos:inScheme rdf:resource="http://duth.example.org/vocab"/>
   <skos:broaderTransitive rdf:resource="http://ekt.example.org/vocab/
   medical_sciences"/>
   <skos:broader rdf:resource="http://ekt.example.org/vocab/medicine"/>
   <skos:related rdf:resource="http://ekt.example.org/vocab/child_psychiatry"/>
   <skos:related rdf:resource="http://ekt.example.org/vocab/children"/>
   <skos:notation rdf:datatype="http://dewey.info/schema-terms/Notation">
   618.92</skos:Notation>
</skos:Concept>
```

Fig. 3 SKOS representation of concept 'pediatrics'

IV. Deployment on WebProtege

WebProtégé is a free and opensource lightweight ontology editor and knowledge acquisition tool for the Web. WebProtégé allows users to create, upload, share and collaboratively edit ontologies expressed in OWL. In its current version, it is underpinned by the OWL API [6], it provides full support for OWL 2 ontologies, and comes with a simplified user interface, suitable for users with different levels of ontology expertise.

Two major features of WebProtégé that render it an appropriate tool for collaboratively deploying SKOS thesauri and ontologies and publishing them to the Web are the following:

Configurable user interface: The WebProtégé user interface is built as a portal, composed of *tabs* and *portlets* that provide independent pieces of functionality. Users can personalize UI layout, removing tabs or portlets that are not useful in their projects or adding other ones. Overall, the user interface can be configured to reflect users' OWL expertise and satisfy their projects' specific requirements.

Collaboration support: WebProtégé allows users to track changes and choose to watch entities or even whole hierarchies of entities (branches), with the possibility to receive e-mail notifications on them. They can also have contextualized threaded discussions and notes attached to selected entities in the ontology. In addition, through an extensible access policy mechanism, users can define who may view or edit an ontology. Finally, it is possible to generate statistics of the ontology-development process.

In addition to these features, we implemented some additional facilities for WebProtégé with the intention to further enhance user's interaction with this tool and make it more convenient for editing and publishing LO ontologies and SKOS thesauri. More specifically:

(1) An extra column, displaying the ontology's download link, has been added in the project view list of the WebProtégé home page. This link offers an explicit view of the ID that WebProtégé assigns to its projects. Additionally, it gives direct access to the corresponding WebProtégé project (ontology) and it is appropriate for use with OWL *imports* declarations.

(2) The possibility to change the default namespace for created projects has been added. In WebProtégé this namespace is by default set to *http://webprotege.standford.edu/*, a value that is not always desirable by project administrators. The new, implemented feature has been incorporated as an additional property option to the WebProtégé properties file and allows system administrators to customize a priori their projects' IRI prefix, based on their institutions' needs.

(3) Similarly, another property, specifying the desired IRI suffix for each newly created entity, has been added to the same file. By setting this property, administrators can bypass system's default configuration, which is determined to use a randomly produced Universally Unique Identifier (UUID) [9] for this purpose. Now, as an alternative, they can predefine to use the entity's label (name) instead.

Although WebProtégé bears features that significantly simplify its usage, it is a tool – and not a human expert – that can't vouch for the semantic and structural correctness of the ontologies under development. Although such kind of mistakes can be eliminated using WebProtégé collaborative features, the final result is always up to the ontology expert's familiarity with OWL.

In an attempt to address this concern, we provide WebProtégé users with 'empty' templates, meant to be used as the basis for the creation of thesauri and LO ontologies. In this way an ontology expert, instead of creating a project from scratch, is encouraged to start by uploading the appropriate template. In particular, we implement a *thesaurus* template that imports the SKOS vocabulary and is used for the deployment of thematic thesauri, and a *LO Ontology* template that imports the LO ontology schema and leads to the creation of LO ontologies. The advantage of this approach is that users start building their projects having already at their disposal all necessary SKOS- or LO-specific *classes* and *properties*. As a result, they can eliminate common mistakes when building semantic correlations among entities. In addition, the process of editing an ontology becomes easier, given that allowable fillers for each class are known a priori and become available through the autocomplete feature of WebProtégé. The suggested procedure workflows for deploying thesauri or LO specific projects in WebProtégé are depicted in Fig. 4.

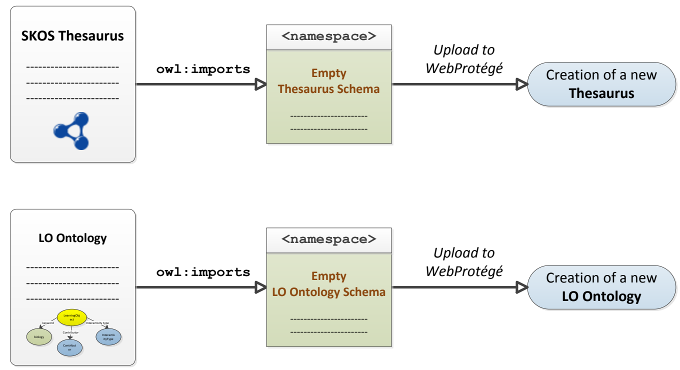

Fig. 4 Suggested procedure workflow for building a new thesaurus or a LO ontology in WebProtégé

V. An Example

In what follows we present an example of a LO instance, characterized using our LO metadata schema. This instance is part of a LO ontology that has been developed for semantically describing educational resources in the field of Medicine. The resulting ontology has been published through the WebProtégé editor.

The set of technical and educational characteristics of the selected LO, expressed through a set of object and datatype properties, can be seen in Fig. 5.

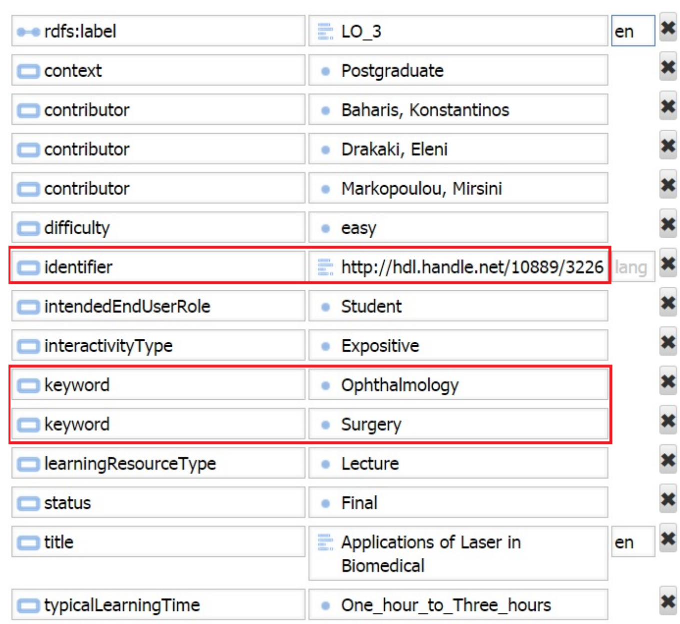

Fig. 5 A snippet of a LO instance in WebProtégé

It is important to note that the *keyword* field of every LO has been filled using SKOS concepts coming from our Medicine Thesaurus. Hence, for every LO instance captured in the ontology, the corresponding object property *keyword* has been assigned to an existing *skos:Concept* individual. This alternative for expressing a LO's subject – instead of using a mere text keyword – can lead to improved interoperability and advanced retrieval capabilities. For example, resources with content characterized by *related*, *narrower* or *broader* in meaning concepts (and captured through the corresponding SKOS properties) can also be retrieved.

Finally, through this example, it becomes evident how through its *identifier* property, the LO instance acquires a resolvable, unique identifier that provides direct access to the actual resource's location.

VI. Conclusions and Future Work

Semantification of LO metadata can help towards having machine understandable descriptions of learning objects as well as facilitating cross-platform semantic interoperability. Starting from a LOM-based metadata profile, we have shown how to create a LO Ontology Schema and how this can be populated in order to yield semantically-enhanced descriptions of learning resources for various domains.

This Ontology Schema is further enhanced by the fact that it is possible to integrate with other ontologies, namely ones providing organization of thematic terminologies or thesauri. To foster the potential of such an approach, thesauri are expressed in SKOS format. The transformation of thesauri into SKOS is adopted by many institutions worldwide, recognizing the need to increase LOs discoverability among heterogeneous educational repositories and dissemination of knowledge.

We have demonstrated the use of WebProtégé as an environment suitable for the whole ontology lifecycle, from design to publishing, maintenance, administration and reuse. Our implemented additions on top of the system only make it more useful and convenient for this purpose.

The systematic creation and development of learning object ontologies of variable granularity (e.g., thematic-, course-oriented or other) following the LO Ontology Schema and using WebProtégé can provide educational institutions with a simple yet powerful tool for exposing their LO collections publicly. Indeed, a university or library can for example utilize the infrastructure presented in this paper in order to establish its own Learning Object Repository (LOR). In addition, it can be used as an entry point into the Web of Linked and Open Data (LOD), given the integration capabilities of the schema with SKOS or other external ontologies and datasets, while at the same time maintaining the original context and provisioning information of learning material.

As future work, semantic aware applications can be developed, that consume ontologies available through this infrastructure in various ways. For example, the thesauri we developed and maintain can seed a query expansion mechanism that searches and harvests external LORs, based on semantic matching and/or reasoning. Results from these queries can be integrated back into the LO ontologies or served to a Learning Management System, such as e-Class, so as to widen the scope of extracurricular learning material available to students.

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