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Ontological modeling of educational resources: a proposed implementation for Greek schools

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Abstract In eLearning context searching for suitable educational material is still a challenging issue. During the last two decades, various digital repositories, such as Learning Object Repositories, institutional repositories and latterly Open Educational Resources, have been developed to accommodate collections of learning material that can be used for instructive and research purposes. In order to make this learning material publicly available through internet searching mechanisms, it has to be enriched with metadata. Nowadays, emerging Web 3.0 applications necessitate further enhancing learning resources with semantic knowledge to facilitate conceptually searching. Adding semantic value to educational resources could be achieved by modeling ontologically the metadata profile which describes them. The purpose of this work is to demonstrate the process of enhancing semantically learning resources by developing

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a new ontology and a prototype system to accommodate them. The designed ontology is originated from a metadata profile which is build according to the guidelines posed by Singapore Framework for Dublin Core Application Profiles. We focus on educational material for teaching courses on Informatics in primary and secondary education in Greece but the methodology and mechanism introduced could be easily adapted in any domain-specific setting.

Keywords Metadata · Application profile · Semantic web · Ontology · Educational resources · Education · Learning objects

1 Introduction

The adoption of appropriate learning material inside and outside the classroom has catalytic effects on the educational process and on new trends in emerging theories of learning. Nowadays, most of the learning material used in education is electronic. This means that it is published in a digital form, is manageable by computers and is accessed through the network; consequently, this material is daily qualitatively evolved by taking advantage of the capabilities of Information and Communication Technologies (ICT). An important and open research field of contemporary educational technology is the search and selection of appropriate learning material (Hsu 2012) as it is directly related to the quality of teaching and learning, affects instructional design and generally influences educational policies.

In eLearning context, the educational material is of major importance as such learning process broadly implies instructor's absence. In the past, various classifications have been presented that deal with the perception of digital learning material depending on its granularity, complexity, reusability, interoperability and undoubtedly on its educational value (Churchill 2007; McGreal 2004). The most rigorous term for learning material is "Learning Objects" (Wiley 2001) while the simplest one is "row" content. The notion of Learning Objects does not just imply a simple definition but a series of abilities that should characterize educational resources. Quite early, educational technologists had perceived the importance of content in eLearning settings (Downes 2001). In their effort for an efficient exploitation of digital educational material, they tried to give to Learning Objects some desirable attributes mainly for reusability and interoperability reasons (Boyle 2003; Polsani 2003). But satisfying all these desired attributes was proved a rather difficult task (Churchill 2007; Wiley 2007). Other known terms for learning material are: educational resources, educational object, course material, educational content etc. Nevertheless, the most common term during last fifteen years is Learning Object although recently the term "Educational Resource" is used more often.

Today's World Wide Web infrastructure affords adequate searching mechanisms for discovering suitable learning material among the huge number of online resources existing in the internet. For efficient web searching it is necessary to make use of befitting metadata which describe the resources themselves, beyond simple keyword tagging of the hosting pages, in a more structural and standardized form (NISO Press 2004). This implies specific management of the resources by exploiting their metadata descriptions in order to provide opportunities for locating resources in a more accurate way, by applying relevant criteria. In essence metadata is helping people organize, find, and retrieve resources effectively. Enriching with metadata educational resources supports increased potentialities for discovering the appropriate learning material that best fits specific educational requirements, according to common special purpose vocabularies not just generic keywords (Al-Khalifa and Davis 2006). Thus, in educational context, metadata modeling plays an important role, since it makes access to the online learning material faster, easier, and more effective. In the past, standardization bodies and initiatives have proposed various metadata models for educational material (IEEE 2002; DC-Ed n.d.; ISO/IEC 2010; Barker and Campbell 2014).

Emerging applications of Semantic Web (W3C 2015a) raise demands for semantic restructuring of metadata descriptions. Current search engines use keywords tagging for the description of webpages and metadata models for the characterization of the resources. Ontological enrichment of metadata models would provide added value to existing learning material by facilitating its conceptual searching and harvesting. The searching engines of Semantic Web are using advanced search mechanisms which process semantically users' queries (Berners-Lee et al. 2001). Ontologies stand beyond metadata tagging and vocabularies by describing furthermore concepts of a domain, relationships and logical reasoning (Papadakis et al. 2011). A lot of recent research on metadata structuring, include ontological approaches and propose new conceptual schemas to support enhanced eLearning applications (Hsu 2012; Dietze et al. 2013). Annotating learning material with metadata can be used for fast searching/retrieving, but discovering the essential material can be much more facilitated by a possible semantic modeling of it.

In educational context, a common international practice is the development of collections of educational material stored in digital repositories that are publicly available online. The term "digital repository" is used to describe web-based infrastructures for the preservation, management, discovery and delivery of digital content. Digital repositories feature mechanisms that utilize appropriate metadata models for the description and characterization of the hosting content (Koutsomitropoulos et al. 2010). During the last two decades various digital repositories with diverse appellations, such as Learning Object Repositories (LOR), digital libraries, institutional repositories and Open Educational Resources (OER), have been developed to accommodate collections of learning material that can be used for instructive and research purposes. Lately, the best known form of those digital repositories is that of Open Educational Resources. The term "Open Educational Resources" first appeared at UNESCO's 2002 Forum on Open Courseware as "teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" (UNESCO, OER Declaration 2012). Metadata and semantic web tools could further facilitate the exploitation of educational repositories by enforcing discoverability and interoperability.

This article aims to demonstrate the process of enhancing semantically learning material by exploiting existing Web 3.0 techniques. The methodology consists of two sequential stages which concern the processes of (a) designing the metadata model and (b) the implementation of the counterpart ontology within formal educational settings. Based on the resulting design, for validation reasons, we proceed further to a third stage that deals with the development of a prototype web-based system for controlling the ontology and accommodating educational resources. The mechanism created can be used for semantic searching of learning material through the emerging Web 3.0

infrastructures. In essence our work aims to demonstrate how to prepare educational material ready for the semantic web. We focus on learning material for teaching Information Technology (IT) courses in primary and secondary education in Greece, since there is not corresponding metadata model for the ample characterization of such educational resources. The methodology and mechanism introduced could be easily adapted in any domain-specific settings concerning Greek elementary and high schools.

The rest of the paper is structured as follows. In "Background" section we briefly present the main metadata standards for educational material and introduce the concepts of ontology and metadata application profile. "Methodology" section provides details about the proposed metadata application profile (GrED) for primary and secondary Greek education and describes the ontological restructuring of the metadata application profile. In "Implementation" section the software deployment for controlling the specific ontology in real conditions is presented. "Discussion-Perspectives" section refers on issues and potential applications of the implementation. In "Conclusions" section we discuss the usefulness of the implementation and future work.

2 Background

Metadata are structured information used to describe the attributes of a resource (digital or not), thus making easier the management, conceptual search and retrieval of it. The notion of metadata is old enough as the same concept exists for years in library cataloguing, where records contain structured information about books, papers, collection etc. (NISO Press 2004). According to the definition in (Berners-Lee 1997), metadata are "machine-readable information about electronic resources or other things". In our digital age, the great importance of metadata lies in the fact that the "meta"-information they convey is machine readable, therefore organizing, distributing and discovering of resources are achieved effectively by software interoperability tools (Nilsson et al. 2008a). For describing attributes of resources metadata specify *elements* each of which has its own meaning. By giving values to elements we can create metadata instances (records) of resources. A set of metadata elements combined so as to serve a specific purpose and according to a standardized concept, constitute a "*metadata schema*" (NISO Press 2004). Additionally a metadata schema could also include rules, relations and allowable values (controlled vocabularies). Encoding a metadata schema is called "*binding*" and it is achieved by using data modeling tools which are both human and machine recognizable. Most known such tools are XML (Extensible Markup Language), RDF (Resource Description Framework) and OWL (Web Ontology Language).

In the case of educational resources, metadata schemas that are used to describe the attributes should also be able to reflect the educational and pedagogical aspects of each resource (Hsu 2012). Therefore, in addition to various elements used to describe conventional attributes of a resource such as the creator, the title or the coverage – elements that are common in all metadata schemas - an educational metadata schema should also include elements regarding the resource's particular learning capabilities and educational soundness. Apart from the facilitation of selecting suitable resources, using recognized metadata schemas based on existing standards is also important mainly for interoperability reasons: metadata descriptions of learning resources (records) may be exchanged among different digital collections; search queries may be propagated among different (and interconnected) repositories; and generally the retrieval of educational material from different sources is facilitated.

Towards this direction, various standardization efforts around the world have focused on the study and implementation of metadata element sets for describing learning resources. The two most important standards that rule the design and creation of educational contexts are the ANSI/IEEE 1484.12.1– 2002 / Cor1–2011 Standard for Learning Object Metadata - LOM (IEEE 2002) and the Dublin Core (ANSI/NISO 2013). The IEEE LOM is an open standard that aims to describe educational content and particularly the learning objects. According to the IEEE development team, the learning object is "any entity, digital or non-digital, which can be used for learning, education or teaching" (IEEE 2002). The elements of LOM are grouped hierarchically in 9 categories. Each category contains sub-elements. Some of these sub-elements are simple elements while others may also contain sub-elements. The main objective of the IEEE LOM is to facilitate the processes relating to the use of learning objects. This may mean that a teacher or a student can have full access to a learning object so with great ease to reproduce, incorporate in her/his work, evaluate and disseminate. The same process is also expected to be made in an automated fashion using machines (i.e. software agents). The Dublin Core Metadata Initiative (DCMI) is an organization aimed at establishing specific criteria for recording and describing the metadata of various kinds of resources by promoting interoperability among metadata standards and development of specialized metadata vocabularies (DCMI n.d.). The initiative started in Dublin, Ohio, and resulted in the creation of the Dublin Core Metadata Element Set (DCMES) that became a standard (ANSI/NISO Z39.85-2012, ISO Standard 15,836–2009, IETF RFC 5013). The motto describing the origins of this well-known standard is "everything can be recognized" (DCMI n.d.). The set of metadata is expressed by 15 descriptive elements that are very flexible and general. Each one can be used more than once and values can be described by another standard, vocabulary or, even, free text. This model is known as Simple or Unqualified Dublin Core.

A relatively recent standard is the ISO/IEC 19788 Metadata for Learning Resources (MLR) (ISO/IEC 2010). ISO MLR is pursuing to provide greater interconnectivity and compatibility with the prevailing standards of IEEE LOM and Dublin Core, by keeping almost all the elements from both metadata schemas. By allowing any country to devise national names for each attribute of the schema, ISO MLR strongly supports internationalization. It is about a promising standard for indexing learning resources that is expected to play an important role in education. The Learning Resource Metadata Initiative (LRMI) is another project for creating a standard way of tagging learning content by establishing a common metadata framework (Barker and Campbell 2014). LRMI is close related to *Schema.org* initiative which is led by Google Bing, Yahoo! and Yandex searching engines and extends the metadata vocabulary of Schema.org regarding educational content. Nowadays, LRMI continues its development through ongoing financial support of DCMI organizational members by working on interoperability with existing dominant standards (http://lrmi.dublincore.net).

Definitely, the ontological enrichment of these standardized metadata element sets can provide added value to existing learning resources. Ontologism is one of the main components of Semantic Web. In Semantic Web, ontologies are used to explicitly and formally specify, annotate and classify terms, concepts, properties and relationships in a knowledge domain and define possible constrains (W3C 2015b). Web applications use ontologies to define vocabularies, share common understanding of the structure of information among people or software agents, enable reuse of domain knowledge or make domain assumptions explicit. Ontologies are commonly encoded using formal ontology languages like OWL (W3C 2012). Since ontologies include machine-interpretable definitions that are understandable to electronic agents, they can enable efficient searching for information (Berners-Lee et al. 2001). Hence, they ideally assort web resources encoding knowledge about them in their metadata and facilitating agent interaction with them. Ontologies based on standardized specifications and adopted for the semantic annotation, representation and inter-relation of data on the Web, enable searching and consumption of resources across domains and administrative borders. Such collections of inter-related datasets on the Web constitute what is referred to as Linked Data (Bizer et al. 2009).

Despite the existence of numerous metadata standards, there is not a single all-encompassing standard to be used in every application. Rather, there are various metadata standards or specifications that can be adapted or "profiled" to meet community context-specific needs (Kraan 2003). The two dominant standards of IEEE LOM and Dublin Core have many similarities but also a structural difference: while IEEE LOM uses a variety of rather rigorous elements to describe the properties of a learning object, Dublin Core adopts individual conditions and flexible rules while keeping abstraction at its main characteristics (Barker and Campbell 2010). This conclusion has led to the emergence of the *Application Profile* (AP) concept. An Application Profile is an assemblage of metadata elements selected from one or more already specified metadata schemas, and its purpose is to adapt or combine existing schemas into a package that is tailored to the functional requirements of a particular domain, while retaining interoperability with the original base schemas (Duval et al. 2002). The DCMI Education community (http://dublincore.org/groups/education/index.shtml) has developed such an Application Profile (DC-Ed n.d.) that provides elements for describing the educational soundness of a resource in accordance to DCMES and IEEE LOM elements. DCMI Education community is a forum organized by DCMI for promoting metadata standards interoperability within the educational domain.

3 Methodology

This section consists of two main parts and describes the corresponding processes for the development of (a) a metadata application profile for educational resources (GrEd) based on existing recognized standards and (b) an ontology for modeling conceptually this application profile. Our work focuses on the process of building models concerning educational resources that are designed to serve the scopes of primary and secondary education in Greece where no official metadata schema dealing with similar resources exists. As stated in the previous section existing metadata schemas, are not adequate enough to express all aspects of a particular domain. Consequently our methodology takes into account specific requirements of elementary and high school education in Greece.

3.1 The proposed application profile GrEd

In the process of building application profiles, different metadata schemas may be used together to form a specific schema in order to meet implementation demands for a particular context. This requires thorough analysis of existing well-defined metadata standards and application profiles used to describe educational resources (Roy et al. 2010). By implementing application profiles based on recognized metadata standards ensures interoperability between communities and services (Nilsson et al. 2008a).

Studying the two dominant models IEEE LOM and Dublin Core we conclude that it is notably painful for a developer to choose one of them. This is strengthened by the fact that there is not a straightforward correspondence between their elements (McClelland 2003). Therefore, we propose a novel practice to combine and adopt the most representative characteristics of the aforementioned standards, in order to define an Application Profile that meets our needs and simultaneously maintain interoperability.

For the design of the metadata application profile for Greek schools, we follow the "Guidelines for Dublin Core Application Profiles" as it is recommended by DCMI and described in (Coyle and Baker 2009). In this guideline it is stated that Dublin Core Application Profile (DCAP) is a document that specifies and describes the metadata used in a particular application. Such a profile should:

- describe what a community wants to accomplish with its application
- characterize the types of things described by the metadata and their relationships
- enumerate the metadata terms to be used and the rules for their use; and
- define the machine syntax that will be used to encode the data

All the above consist the upper layer of the Singapore Framework for Dublin Core Application Profiles which additionally provides the means for the implementation of an application profile (Nilsson et al. 2008a). The middle layer of Singapore Framework defines models/specifications in broader use by communities for structural and semantic stability of the under development application profile and the bottom layer provides the foundation standards (RDF) for building these models/specifications.

The design and the implementation of the profile were initially limited to courses that focus on Information Technology (IT) subjects. Nevertheless it can be enriched with all subjects of curricula in the future. For the categorization of Informatics' subsections we used the current ACM taxonomy (ACM Taxonomy 2012). For defining the functional requirements of the community, as Singapore Framework suggests, we turned to school consultants for IT courses and teachers in elementary schools, middle schools (Gymnasium) and high schools (Lyceum), with the technique of plain unstructured interview, to ensure that ACM taxonomy fits Greek school's curricula and collect their requirements for such a system. Both the vast majority of teachers and the school consultants pointed out that the planned infrastructure should be in line with the following:

- It should be simple to appeal the novice computer and new technologies users (students, teachers, consultants).
- It should mainly assure the search procedure by all users based on specific criteria.
- It should focus on the pedagogical part of taught courses and provide the user the ability to have immediate access to learning objects.
- As a case study was reported the search of objects not by the name or their creator, but based on pedagogical and didactic criteria. For an IT teacher, for example, it would be interesting to be able to seek material associated with the "Computer

Networks" at all levels of education, or to be able to gather all the presentations available for the C Class of a high school. Or even to add a video created for the B Class of a middle school. Or to seek all learning objects that can be taught in 40 min. For a student, on the other hand, it would be useful to be able to search all the material for a particular course, or to be able to find a brief summary of last year's material. Or, even, to study all the material of the class he attends.
- The potentiality of all or only authenticated users to introduce new educational resources or metadata would be extremely useful.

Next step, according to Singapore guideline, was to determine the types of things described by the metadata and their relationships that would be used for designing a domain model. In such a task, we selected to mostly use the DC-Ed application profile (DC-Ed n.d.), assisted by the IEEE LOM standard wherever it is required. This is due to the fact that DCMES is much more abstract and flexible (Barker and Campbell 2010; Harper 2010) and its derivative DC-Ed is education oriented. Based on these conclusions we decided to utilize the majority of characteristics of the DC-Ed community of Dublin Core. In more specific:

- We used the "subject" element to define the theme of a learning object.
- We used the "type" element to describe the nature or the type of the object, selecting a value from the collection, dataset, event, image, interactive resource, moving image, physical object, service, software, sound, still image and text.
- The "audience" element helped us to define the entity for which the learning object is intended or it is useful to, selecting one of the values teacher, author, learner and manager.
- With the "educationLevel" element we described as free text the level of students to whom this object refers to.
- We respectively preserved the "mediator" element for possible extension of the model in tertiary education, as it describes the entity that mediates the provision of a learning object and does not find direct application to Greek primary and secondary education.
- Also, we used the "instructionalMethod" element to describe the teaching method of learning objects with the aid of free text.
- Unlike DC-Ed, we omitted the "conformsTo" element, so as not to limit the objects to specific strict standards.
- We also preserved "Creator", "Contributor" and "Publisher" elements for the special educational roles of the people who contribute to the learning objects as well as the "Language" element for the official language of the object.
- Finally, we used the "Identifier" element to provide the physical address of the learning object.

Furthermore, for a more complete description of learning resources for the primary and secondary levels of education in Greece, we decided to add some new relationships, which did not exist in either standard, following an amendment to them. In all the elements of DCMES lexical restriction is missing, but we recommend using the corresponding vocabulary in LOM, unless otherwise is specified. The IEEE LOM has strict standards and inviolable rules. The values of its relations are strictly and exclusively covered by a specific vocabulary (IEEE 2002). In partial accordance with the DC-Ed we decided to preserve those LOM elements for which there are no equivalents in the DCMES (Abdul Karim et al. 2007). So we kept:

- The "Educational. InteractivityType" which receives one of the values "active", "expositive" and "mixed" and describes the interactivity type of the learning object.
- The "Educational. InteractivityLevel", which takes one of the values "very low", "low", "medium", "high" and "very high", and describes the level of interactivity.
- The "Educational. SemanticDensity", which takes one of the values "very low", "low", "medium", "high", "very high", and describes the semantic density of the object.
- The "Educational. Difficulty", which takes values from very easy, easy, medium, difficult, very difficult, and marks the difficulty of understanding the learning object.
- Finally the "Educational. TypicalLearningTime" that takes values according to the encoding "PT22H20M30S", which means that the duration of teaching the learning resource, is 22 h, 20 min and 30 s.

The table of the element set of our application profile and the correlation between them are presented in Table 1. The matching between DCMI and IEEE-LOM elements follows the draft DC-Ed application profile recommendation (DC-Ed n.d.).

Curricula in primary and secondary education are "class – oriented", that is they are declared according to the teaching class the student attends. So, it was considered necessary to add an extra characteristic which directly indicates the teaching class that can be taught a specific educational resource. This element is called "isTaughtAt" and fills the gap of the IEEE-LOM and Dublin Core in direct statement of the classroom, rather than its designation for the student's age and the type of school. Additionally, we had to activate the "isPartOf" element of LOM, to better trace the connection of every educational resource with the scientific topics to which it correlates.

3.2 The ontology of GrEd

Having decided about the element set which forms our GrEd application profile and the relationships applied on it, we continued to the design of the ontology. This task is accomplished by representing the elements of GrEd application profile as classes and properties and by introducing new classes and properties which best fit in the context of field area. For building and managing the new ontology, we used Protégé (Protégé 2016) as the state-of-the-art ontology design software (Gennari et al. 2003) which incorporates several ontology reasoning tools and we encoded the ontology using the semantic web description language OWL-DL (W3C 2012). This corresponds to the last stage of Singapore Framework for Application Profile.

As a first step for the design of our ontology, we took into consideration the DCMI recommendation for expressing Dublin Core metadata using the RDF (Nilsson et al. 2008b). For a complete ontology that would function effectively within the field area (i.e educational resources for teaching IT courses in Greek elementary and high schools), apart from the element set for describing an educational resource, various issues should be further considered. More specifically:

Table 1 Elements of GrEd application profile

GrEd elements	Comments
DC.subject	Equivalent IEEE LOM element: 1.5:General:Keyword or 9: Classification, 9.1:Classification. Purpose = 'Discipline' or 'Idea'.
DC.type	Vocabulary: collection, dataset, event, image, interactive resource, moving image, physical object, service, software, sound, still image, text Equivalent IEEE LOM element: 5.2:Educational. LearningResourceType
DC.audience	Equivalent IEEE LOM element: 5.5:Educational. IntendedEndUserRole
DC.educationLevel	DC.audience refinement Equivalent IEEE LOM element: 5.6:Educational. Context
DC.mediator	DC.audience refinement Equivalent IEEE LOM element: 5.5:Educational. IntendedEndUserRole
DC.instructionalMethod	There is no equivalent in IEEE LOM but one can use: 5.10:Educational. Description: "Comments on how this learning object is to be used" or 9: Classification with a local vocabulary term defined for 9.1: ClassificationPurpose.
DC. Creator	Equivalent IEEE LOM element:
DC. Publisher	2.3.1 LifeCycle. Contribute. Role
DC. OtherContributor	
LOM. InteractivityType	5.1:Educational. InteractivityType Vocabulary: active, expositive, mixed. No equivalent in DCMI
LOM. InteractivityLevel	5.3:Educational. InteractivityLevel Vocabulary: very low, low, medium, high, very high. No equivalent in DCMI
LOM. SemanticDensity	5.4:Educational. SemanticDensity Vocabulary: very low, low, medium, high, very high. No equivalent in DCMI
LOM. Difficulty	5.8:Educational. Difficulty Vocabulary: very easy, easy, medium, difficult, very difficult. No equivalent in DCMI
LOM. TypicalLearningTime	5.9:Educational. TypicalLearningTime in format like PT22H20M30S Equivalent DCMI element: Format refinement: Extent
DC.language	Vocabulary: el, en, de, it,. .

Table 1 (continued)

GrEd elements	Comments
	Equivalent IEEE LOM element: 5.11:Educational. Language
DC.identifier	Equivalent IEEE LOM element: 1.1:General. Identifier or 3.1:Meta-Metadata. Identifier or 7.2.1:Relation. Resource. Identifier
LOM.isPartOf	7.1 Relation. Kind with value "isPartOf" Equivalent DCMI element: relation
GrEd.isTaughtAt	No equivalent in DCMI or LOM

- We have to rely on the structure of the elementary and secondary Greek Education system and its component courses. To be able to relate the lessons to the teaching classes in which they are taught, we defined the class "School" and below it the subclasses "Elementary School", "Middle School" and "High School". The last class has another classification with the two subclasses "Technical_School" and "General_Lyceum". The teaching classes in each school type were introduced in the form of individuals to be placed in the lower level of the ontology and to be able to associate with each other and with other instances using the aid of the object and data properties of the ontology.
- Moreover, the area of interest (Informatics) of the courses should also be formal represented in our ontology. Consequently, one important process in creating the ontology was to declare in Protégé the class that contains the field of the courses, for which we created the application profile. So we added the "Science" class and we set a subclass called "Informatics". Under this subclass we placed all the other subclasses of Informatics, which apply to elementary and/or secondary education, based on ACM taxonomy, that is the "Computer Applications", "Computer Systems Organization", "Computing Methodologies", "Computing Milieux", "Data", "General Literature", "Hardware", "Information Technology and Systems", "Mathematics of Computing", "Software / Software Engineering" and "Theory of Computation".

The Dublin Core has particularly flexible features and for this reason the developers suggest these elements are introduced in the Protégé in the form of annotation properties (W3C wiki 2015). In this way, however, they do not actively participate in the ontology, but they simply provide additional information of the entities in the form of comments. Therefore, we preferred to introduce the characteristics of Dublin Core, which we decided to use in our ontology in the form of data properties. Data properties refer to the "literal" values that the entities of ontology can get. To distinguish the relations arising from the Dublin Core, we named them with the acronym "DC".

The IEEE LOM has strict rules and leaves no room for maneuver. Thus, some of its elements can be introduced as object properties, whereas the rest as data properties. The object properties are mentioned in the interrelationships between the entities of ontology. In this category we kept the same naming scheme as the original "LOM" for this model, and we added two additional relationships with the acronym "GrEd" from the name of our application profile. As mentioned above, we kept the relationship "LOM.isPartOf" and its reverse "LOM.hasPart" to classify the object in the respective field of science. The LOM defines these relations as object properties.

Furthermore, in accordance to the requirements of Greek education system we embed two extra relationships. The relationship "GrEd.isTaughtAt" features the learning objects according to the teaching classes in which they can be taught, while the relationship "GrEd.isTaught" is the reverse of it and is used to achieve symmetry in the ontology.

By finishing the design of our ontology and representing it in Protégé, we introduce some existing and representative educational resources as snapshots (instances). By instantiating our ontology we had the chance to evaluate our design and ascertain its applicability and potential. We chose to create descriptions of educational resources which are commonly used in elementary and high schools of Greece. A representative instance of our ontology describing an educational resource (Scratch for High School) is depicted in Fig.1 with all fields and all relationships of it pre-filled. By making queries we can retrieve resources among the instances of the ontology according to posed criteria. In Protégé queries can be created by using SPARQL (Prud'hommeaux and Seaborne 2008), which is a semantic query language for data expressed in RDF format.

A graphical overview of the structure of GrEd ontology is shown at Fig. 2 as it appears through the interface of Protégé. In the graph, dashed-line rectangles distinguish ontology's classes while arrows represent the DC, LOM and GrEd relationships between the classes and the instances of the ontology.

4 Implementation

In this stage we developed a web-based application software for the effective administration of our ontology in real conditions. By "real conditions" we mean the exploitation of the created ontology by end users such as authorized consultants who create metadata and teachers or students who would search for appropriate educational resources. That's because using Protégé's interface and tools to manage the ontology is more suitable for developers and researchers rather than end users who are much more familiar with web interfaces, using their browsers. Our system should provide to end-users the means to search for educational resources and authorized insertion of new instances in the ontology, through the web.

4.1 Development tools

The task of developing application software to build an infrastructure on the web for controlling the created ontology was a demanding job, because it required adequate knowledge of programming techniques and specialized expertise on the tools provided by semantic web.

The interface of a web application that communicates with semantic repositories and seeks for metadata through ontologies has become a subject of research by several

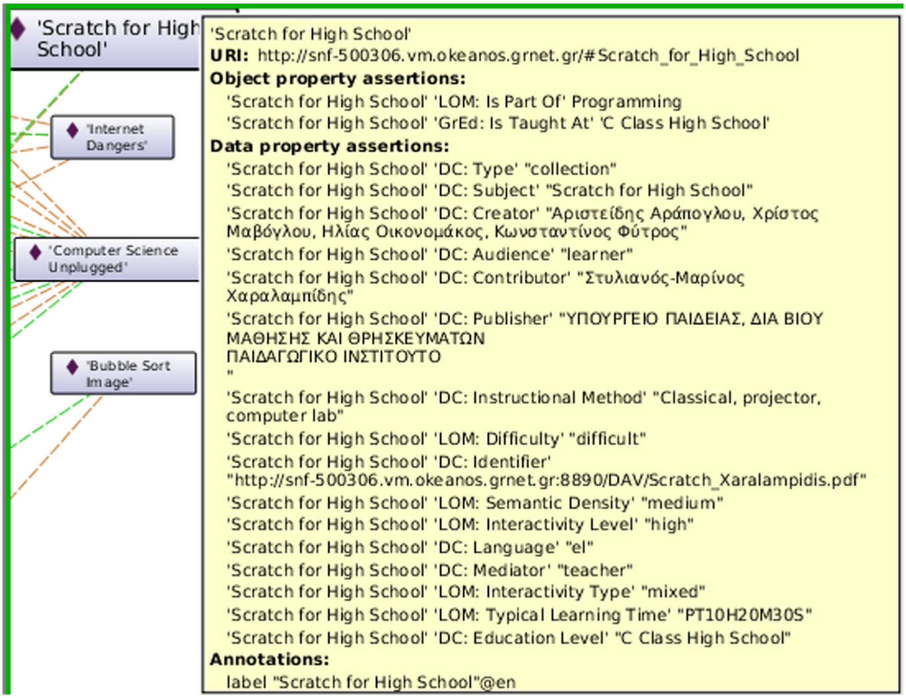

Fig. 1 Metadata of an educational resource from our ontology (protégé view)

scientific groups internationally (Arabshian et al. 2009; Drozdowicz 2012). Our goal was to identify the best practices and implement a pilot system in the semantic web, which will provide the ability not only of searching but also of introducing information about educational resources in the ontology in a safe way, without the risk of spoilage.

The actual files of educational resources' instances could be stored in own server featuring that way a digital repository which should fulfill interoperability standards.

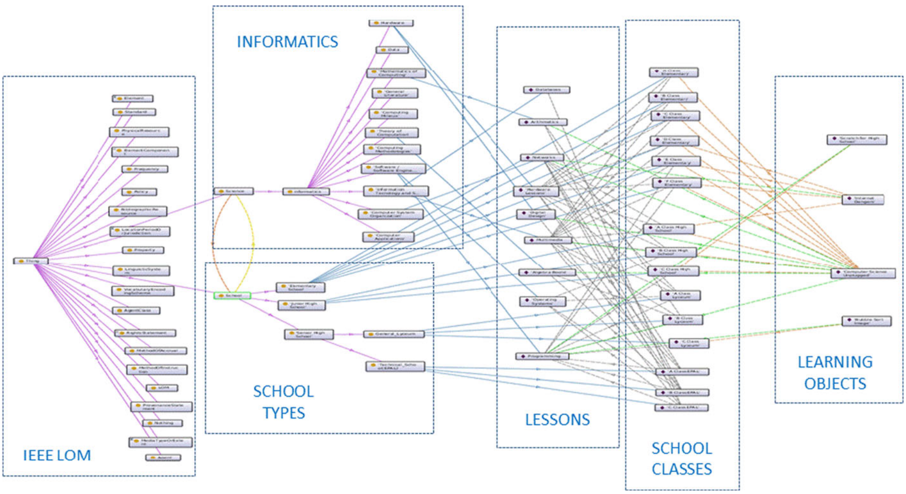

Fig. 2 GrEd ontology overview (arrows represent properties of DC, LOM and GrEd)

Resources' files could also be located in other repositories, as long as their links (URL) are inserted accordingly in order to be accessed through the internet.

For the development of the infrastructure we chose to use the open source edition of Virtuoso Universal Server (http://www.openlinksw.com) a hybrid data management and integration server that combines the functionality of both conventional object-relational database engines and semantic web tools. The programming language is Oracle Java (https://www.oracle.com/java/index.html) while the software development was supported by Apache Jena (https://jena.apache.org) which is an open source java framework for building Semantic Web and Linked Data applications. The developed prototype system was hosted on the virtual machine infrastructure "okeanos" offered by the Greek Research and Technology Network (https://okeanos.grnet.gr).

4.2 GrEd web interface

An attempt was made so that the web interface of our pilot service is kept as simple as possible and even more comprehensive. Our interface design implies at least two use-cases (a) the one use-case concerns the insertion of information which describes new educational resources and the creation of new instances in the ontology while (b) the other concerns discovering suitable educational resources based on specific criteria. The first interface is intended for use by authorized users such as school consultants and the second for schoolteachers and students.

For the school consultants authorized to characterize the educational resources (use-case a), a minimalist way of designing imposed them to have only one screen, which contains both the capabilities of search and import features (Fig. 3). The software ensures that all the elements of our application profile, which receive lexical values, are confined to them, while the rest accept free text as input. There is an explanation (tooltip) on all the fields of the interface, so that even a naive user can receive information about the importance of each field.

Each click of the "Insert" button performs corresponding SPARQL commands on the server for introducing one by one the corresponding properties in our ontology and import the instance. During the import process of each instance in the ontology it is necessary that users should fill all the fields for maintaining the consistency of the ontology, as a notification window reminds the user to do so. An error message is displayed, if all fields are not completed. Once the import process is complete, the application informs the user about the successful import or not.

On the other hand schoolteachers or students (use-case b) make use of the same interface missing the insert button. During the search process, the user can fill-in one or more fields at will. For each field the corresponding SPARQL query is sent to the server. Search results are displayed one by one on the same screen, excluding duplicates. For example, if you look for all school subjects taught in the Third Class of High School, instances of the ontology satisfying the posed criteria, will be returned in separate windows, giving the user the option to have direct access to the object itself (Fig. 4).

If the resource link does not work for any reason, the application informs the user about it. In case of failure to find results a relevant message appears. In case of positive answer, we move to that object through the corresponding program that is set to handle this file type. The implemented Virtuoso server (OpenLink 2015) uses the WebDAV protocol for storing and accessing the files of the resources.

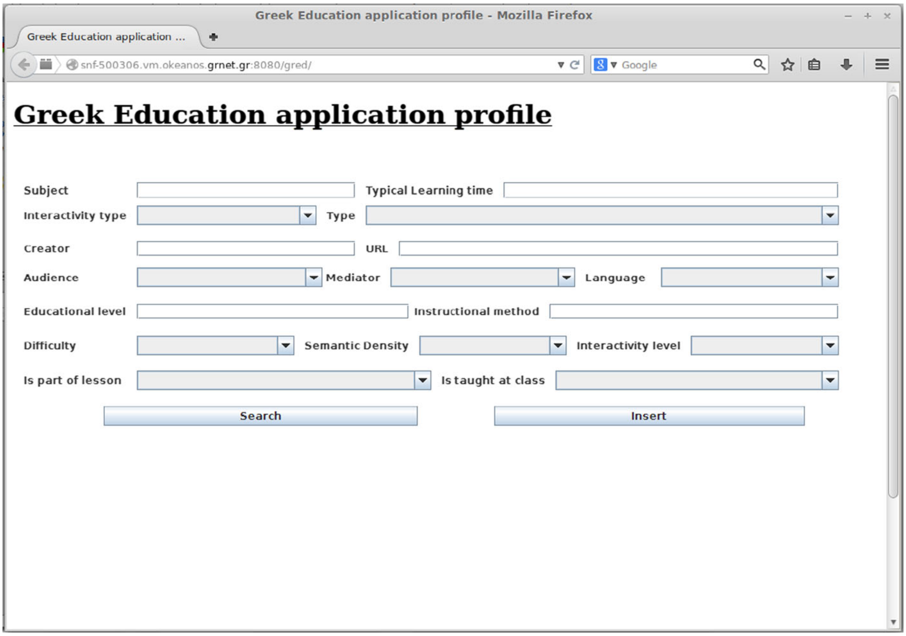

Fig. 3 GrEd interface

The implemented interface could be also easily embedded into any more complex interface. The service is a signed applet, because the only way to import data to ontologies through a simple web form is by using internet's protocol (TCP/IP) requests through a java applet. Obtaining a signature from a trusted certification organization can remove all security restrictions.

5 Discussion – perspectives

After so many years of design and development of standards for the storage and harvesting of educational resources, there is an urgent need for the integration of standards and creating a unified one. This effort is proved difficult, as various applications have exquisite needs, so researchers either end up in over-sized standards,

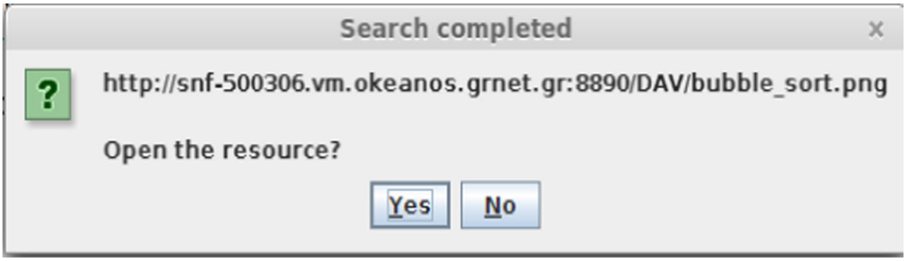

Fig. 4 A query result window

which cover almost all cases or in small and flexible standards, which cannot meet all needs.

Our conceptual implementation for annotating educational resources related to IT courses provides the basic strategy and the tools needed for future adaptation and scalability of the proposed model for all the other courses. The created ontology represents the Greek educational structure and the field of Informatics but it can be expanded further by adding subclasses under "Science" class concerning other scientific fields such as Mathematics, Physics, Chemistry, etc. with the corresponding lessons. Also by adding new classes besides class "Science", such as "Language", "Arts" etc. the entire spectrum of the teaching topics of elementary and high schools of Greece could be represented in the ontology.

Having in mind the potential exploitation of the ontology by end-users, who would not be experts of semantics, we proceeded to the web-based implementation. The interface of the web-based system is simple and subtractive enough. It allows even the most inexperienced end-user to insert or search any learning object she/he wishes, without the intervention of technical instructions and confusing steps. This is a featuring advantage in using the system as instructor's incompetence in digital environments is still a significant barrier (Bingimlas 2009; Prestridge 2012). Upon the execution of a query the access to educational resources is immediate and fast. Furthermore, the possibility of introducing ontologically enriched educational resources through the web is offered for the first time, a pioneering step in future educational applications of the semantic web.

A potential application of our work is on digital educational repositories and more specific on Open Educational Resources (OER) as most of them use metadata application profiles based on international standards and interoperability can be achieved. The implemented semantic web system uses ontological modeling which is also based on well-known standards and consequently it can effortless function in such a context. According to a recent NMC Horizon report (Johnson et al. 2014) OER infrastructures will play an important role in the educational process of primary education (K-12 schools) in the next years. The UNESCO (UNESCO 2014) and other international organizations such as the Organization for Economic Co-operation and Development (OECD) encourage the development of such OER infrastructures and the last decade a large number of OER services are widely used in all levels of education (OECD 2007). With this study we were able to enable the transfer process of searching educational resources in the semantic web framework using specific rules adapted to the Greek schools organization. The same approach could be used in exploiting the dynamics of OER in the context of semantic web.

Emerging Web 3.0 applications necessitate for adding semantic knowledge to educational resources in order to participate in Linked Data infrastructures where conceptually searching is processed automatically by software agents (Bizer et al. 2009). Our system uses open standards such as RDF, OWL, SPARQL etc. and its semantic repository could be easily participate in Linked Data and Open Data initiatives. If the proposed implementation is adopted widely in Greece, then our semantic repository could be an important node in the cloud of Greek Open Data (Kontokostas et al. 2011).

6 Conclusions

In this work we implemented an ontology for representing digital educational resources which could be used in elementary and high school education in Greece to support courses on Informatics. The designed ontology is originated from a metadata application profile GrEd which is based on the well-established standards DCMI and IEEE LOM. Further to the ontological modeling of GrEd we implemented a web-based system for exploitation of the ontology through semantic web.

Throughout this paper we also demonstrate roughly the process of enhancing semantically metadata for learning resources. The design of GrEd application profile proved to be a very painful process, as it required an intensive and detailed analysis of existing standards and similar application profiles. Building the reflecting ontology was also a demanding job, because it involved very good knowledge of semantic techniques. The most difficult, however, part of this work was the implementation of the appropriate software for the effective control of our ontology in real conditions through web-based interface.

The ontology we created fully reflects our GrEd metadata application profile and aims to become the tutorial for its extension in elementary, secondary and possible in tertiary education, where the needs and specificities are similar. The first and most important step, however, should be the enrichment of the ontology with the rest of the subjects taught in schools, according to international standards and practices. Furthermore our implementation may be tied to the Greek Educational System but it is easily expanded to any national educational system. The pilot system we developed for handling the ontology is based on Web 3.0 technologies and offers web-based end-user interface. It can be improved further by adding extra functionality and be evolved to a full standalone service or a node to Linked Data infrastructures.

Most of implemented metadata international standards are based on the desirable attributes of Learning Objects, as they are stated in bibliography (McGreal 2004; Wiley 2001). An open issue is how metadata can be used by software agents to automatically form teaching units, lessons and courses (Churchill 2007). After all among the goals of the Learning Object Metadata Working Group of IEEE is (http://grouper.ieee.org/groups/ltsc/wg12): "to enable computer agents to automatically and dynamically compose personalized lessons for an individual learner". We argue our work could provide a small contribution towards this direction.

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