Toward a model to describe Semantic Learning Objects

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Abstract

The main objective of our work is to present a model to describe Learning Objects. This model is to consider all the aspects of the LO. The LO description we promote complies with the current standards of e-learning and includes the following: metadata, scenarios the objects are used in, and the objects they are composed of. We improve this representation by taking into account the semantics of learning object contents.

Keywords: *e-learning, learning object, standards for e-learning, ontologies.*

1. Introduction

A learning object has been defined by the IEEE-LTSC working group (Learning Technology Committee Standards) as, "Any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning" [1].

Developers of learning-object authoring tools have incorporated structured components such as type of learning object, text area, and media.

Representation of learning objects involves both content and metadata. Like many other digital objects, learning objects have structures filled with content components such as learning objectives, procedures, concepts, practice, and assessment. They also need metadata to describe who the creators are, what the learning objects are about, and who has what right over the learning objects. The metadata practice is typically a distributed effort in today's network environment, which results in two contradictory forces in the creation and use of learning objects. On the one hand, creators of learning objects do not use a controlled vocabulary for labeling the content components and structures. As a result, learning objects come in a wide variety of structures with various labels even for the same type of objects in the same subject area. This makes metadata representation extremely challenging. On the other hand, learning objects need metadata to be found and selected by users. Because of the unstructured content and inconsistent naming of content components, automatic metadata generation is difficult, if not impossible, especially for finer metadata representation.

In this article, we attempt to develop a guiding framework for the learning object domain based on a review of the facets of learning objects and examination of current metadata standards related to education. We also examined the limitations of metadata standards in representing structural components in learning objects, which justifies the need for ontology. We will describe our approach to constructing and validating the learning object ontology through query log mining.

2. Learning Objects

Learning objects in our vision refer to digital materials created for learning or educational purposes. The creation and use of learning objects involves a broad base of participating communities. Each community defines the concept of learning objects in their own context and uses a set of terminology to define their view on learning objects. Studying these views will help us understand the differences and relations between them and gain insights into building an educational ontology. We summarize the research on learning objects from three different views in the following subsections.

2.1. The Structural View

The structural view reflects the way that educational institutions structure their academic programs. As shown in Figure 1, for example a curriculum consists of modules, a module contains module element, a module element contains chapter, a chapter includes sections, and so forth. The IEEE LOM working group of Learning Technology Standards Committee (LTSC) maintains that a learning object may be a course, or one of its assignable units such as a lesson, section, and component object. The structural view serves the need for academic programs to deliver systematic knowledge and training in a discipline or subject domain.

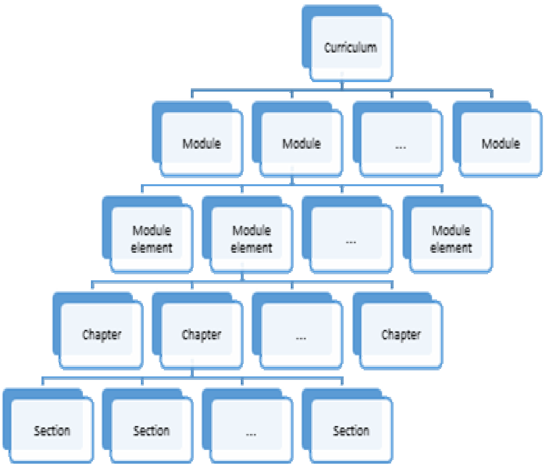

Fig. 1 The structural facet of learning objects.

2.2. The Functional View

The functional view of learning objects is closely related to instructional design and technology. Rather than building learning objects as courses, the functional view treats learning objects in the context of "unit of study." [2] proposes an integrated model of learning object types as shown in Figure 2. In this model, each unit of study plays the role of a framework and encapsulates various types of learning objects such as learning objective, prerequisite, role (learner and staff), activity, and environment. Each type may contain subtypes. For example, the Environment type has eight subtypes, each of which performs a different function (Figure 2).

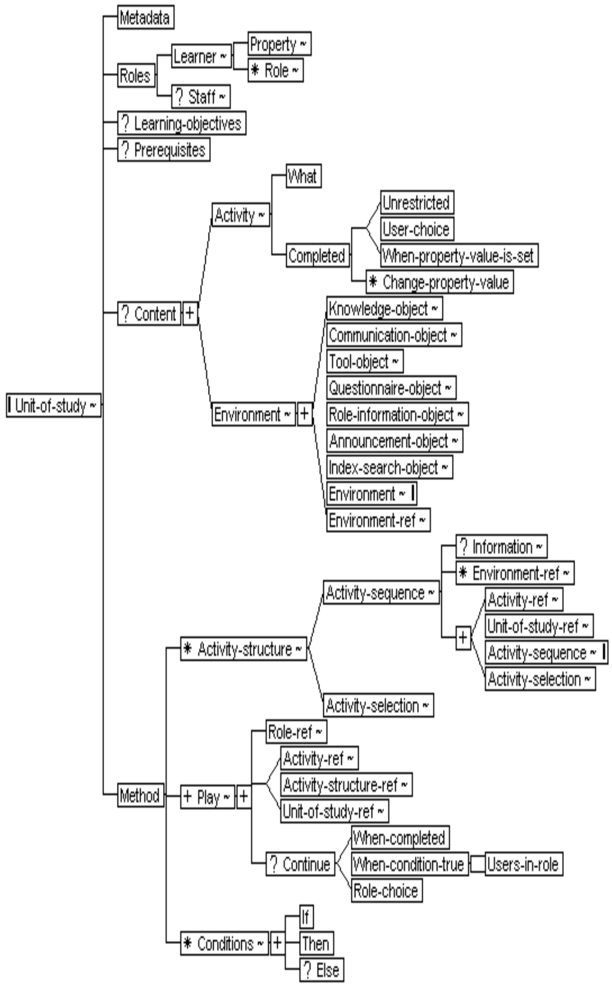

Fig. 2 The functional facet of learning objects (Koper, 2001).

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2.3. The Production View

The production view covers the form or format aspect of learning objects, including whether or not there are any component objects in a learning object, how they are produced (individual or aggregated), and in what form they will be delivered and used. Wiley [3] offers his taxonomy of learning objects based on the characteristics summarized from how learning objects are physically produced—dynamically assembled from multiple smaller media objects or otherwise static objects (Figure 3). The column on the left side of Figure 3 is a list of production attributes summarized by Wiley [3], characterizing learning objects from fundamental to generative-instructional. The column on the right contains attributes of use and reuse that are applicable to make further categorization of learning objects by each of the production attributes.

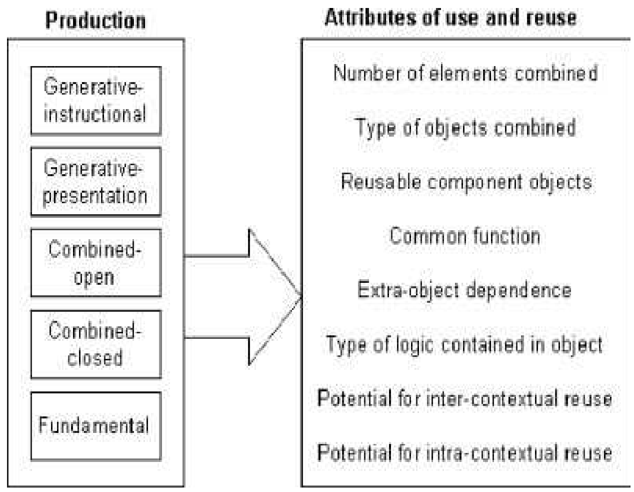

Fig. 3 The production view of learning objects (Wiley, 2000)

3. Metadata For Learning Objects

Various standards have been defined to help the development of training systems. Friesen [4] presents an overview of e-learning standards, the goal of which is to ensure interoperability, portability, and reusability. These systems handle learning objects, their representation, and their relationship. The use of these standards, which are considered as common description languages of digital educational [5], guarantees not only the interworking but also the quality of systems to facilitate the usage of the learning objects no matter the platform or the technological environment used.

The standards are mainly used to ensure:

- Interoperability: towards the content exchanged and handled by different systems and the interaction between learning management systems.
- Re-use: not only towards the rapid assembly of contents and codes but also the assembly and objects use in new contexts.
- Adaptability: the system can be configured to have extended functionality for new goals.
- Durability: ability to use learning objects in any educational context, to adapt to changes in the runtime environment, and to provide for lasting use of these resources

Among e-learning standards, LOM, SCORM and IMS-LD are the most important. LOM focuses on describing resources (objects), SCORM on the structure of objects, and IMS-LD on the teaching scenario.

3.1. LOM

LOM [6] (Learning Object Metadata) is a standard for learning object annotation with metadata. It specifies the syntax and semantics of the metadata describing educational digital or non digital resources and defines the attributes necessary for a complete description of the educational resources. LOM standardizes indexing of learning objects in e-learning systems by giving specific information on the object.

Metadata are classified into nine categories as follow:

1. **General**: characteristics that are independent from the context, such as the identifier, the title, the language of the resource, etc.
2. **Lifecycle**: groups the features related to the history (Version) and current state (Draft, Final, Revised, Unavailable) of this learning object and those who have affected this learning object during its evolution.
3. **Meta-metadata**: characteristics of the description, such as Identifier, Contribution (persons having participated in the elaboration of the metadata), Catalog, language, etc.
4. **Technical**: technical requirements and technical characteristics, such as the format (of the necessary software to reach the resource), size of the learning object, etc.
5. **Educational**: groups the educational and pedagogic characteristics of the learning object.
6. **Rights**: the intellectual property rights and conditions of use for the learning object; Costs, copyrights, description.
7. **Relation**: defines the relationship between a learning object and other related ones.
8. **Annotation**: provides comments on the educational use of the learning object and provides also information on the author and the date on which comments were created.
9. **Classification**: describes the learning object in relation to a particular classification system, such as purpose, reference classification, path, etc.

However, most of the participants in the standardization make some criticisms about LOM [7]:

- Some inconsistency between the generic definition of learning objects as proposed by IEEE and the elements to describe them, due to the consideration of non-digital entities.
- The fact that the indexing unit is a file, which represents a technical unit but not an educational one;
- The fact that a complete lesson is indexed in the same way as a unique exercise or an image;
- The fact that some ambiguities remains in metadata;
- The ambiguities in the model make difficult its usage.

To solve these problems, they propose using LOM application profiles. In an application profile, the mandatory elements provide a minimum of information for a given resource while the optional ones simplify the indexing. An application profile is an instance of a model, as LOM, in a particular context; it is composed of a metadata subset adapted to the needs of the groups or of a particular application, while remaining interoperable with the original LOM schema.

LOM standard and application profiles are useful to assure access to pedagogical resources. Though, they do not specify the semantic content of resources. For this reason, we complete a LOM description with a content representation based on theme ontology.

3.2. SCORM

SCORM (Sharable Content Object Reference Model) [8] of Advanced Distributed Learning (ADL) is a suite of technical standards that enable web-based learning systems to find, import, share, reuse, and export learning content in a standardized way.

SCORM treats the following elements:

- Packaging: It has for its objective the transmission of contents between platforms and handling the structure the educational objects. A SCORM package is a ZIP file which contains: 1. Elements under varied formats (HTML, JPEG, Flash Animations, Word, PPT…). 2. Metadata: they came from LOM and their objective is to share the standard information which describes the nature and the objective of the contents. This information can be used either for helping object searching or for managing the users' rights and for technical needs. 3. Communication or environment of execution: determines the communication with a Web environment. The notion of environment is also present in IMS-LD. 4. Sequence and browsing: defines a method of representation for browsing the learning objects. Specifically, it describes connections and streams of learning activities in terms of trees of activity. 5. Content Aggregation: it distinguishes three levels of resources: The elementary digital resource (Assets) establishes the basic elements of learning resource; it can involve a simple document (JPEG image or GIF, WAV sound or MP3, web page) but also any set of information which can be released to a Web client (Flash document, Javascript code, etc.). A Shareable Content Object (SCO) is a coherent set of Assets. Respecting the SCORM protocol of execution, it represents the lowest level of resource granularity. A Content Aggregation is a set of educational resources structured in a coherent way within an entity of higher level, such as a lesson, a chapter, a module, etc.

The structure of the contents of the course modules according to the SCORM model allows them to be reused in others modules for various training formations or systems. Furthermore, it improves the dialogue between the learning objects and the system on one hand, and between the actors and the system on the other hand.

SCORM defines what the mandatory characteristics of learning objects are as follows:

- Reusability: the contents are independent of the context of learning and can be used by several learners.
- Accessibility: the contents can be identified and located at any time.
- Interoperability: the contents can be read and used in any environments (Hardware and software)
- Durability: the contents do not require modification further to a change or an update of the operating system.

In addition, the learner's progress is supervised and reported back. In our model, SCORM is used to represent learning resource structure and to insure interoperability.

3.3. IMS-LD

A Learning Design is a description of a method allowing to a learner to reach some objectives by the performance of some ordered educational activities in a learning environment [9]As a supplement to SCORM, IMS-LD (Instructional Management System Learning Design) is a standard which aims at bringing elements of pedagogy into an elearning system. It is a language to model learning process. Based on the work of Koper [2], it is designed to define learning scenarios and interaction for content creators. It helps the designers to model the teaching scenario organization like: "who makes what, when, and with which resources and which services to realize objectives of learning?"

The IMS-LD standard aims at helping to design any teaching-learning process in a formal way. It structures learning units through play, act, and role-part elements. The play element (that is often unique) contains several act elements. These acts are run in sequence; each one being triggered by the end of the preceding one. The play is complete when the last act is finished. The transitions between acts thus form a set of synchronization points for all the participating roles (teacher, learner…).

In order to facilitate the production and its implementation, LD has been divided into three levels:

- Level-A: contains all the basic structures including: Activities, Environment, Components, Proceedings, Roles, Services,
- Level-B: adds Properties and Conditions to A. This allows more advanced customization, sequencing, and interaction based on the profile of each learner,
- Level-C: adds the notifications to level B. A notification is triggered by the completion of a result and makes an activity available and executable for a given Role. Each level is represented by separated XML files.

In the proposed model, IMS-LD is used to define interaction between learners and computers during the phase of execution and use of the learning objects.

These standards solve several problems, such as interoperability and use in pedagogical scenarios, but for Varlamis and Apostolakis [11], to achieve better co-operation between e-learning components it is important to define standards which cover all the e-learning process. However, reuse and access (how to find the most relevant resources) are not solved. Another problem is how to assign the same meaning to given metadata. Finally, the links and relations, such as the content, sequencing, and dependence of prerequisites between every learning object, must be mentioned to allow the system to effect treatment or automatic tasks on these objects.

4. UML Design

4.1. SCORM and LOM description

A learning object is a semantic unit of an educational resource. It can be an exercise, an examination question, a definition, examples, a lesson, etc. Each learning object can gather elementary components (such as an image) named Component (called "Assets" in SCORM standard) which can be in different digital (.DOC, .PDF, .JPG etc) or physical formats.

The metadata we consider for representing a learning object are presented in Figure 4. A Learning Object can be composed of other Learning Objects. A learning object is a LOM Object and consists of SCORM Assets. As proposed in LOM, the object is annotated with different Elements or metadata, such as the Right associated to the object, Technical (the technical requirements and technical characteristics of the object), Educational (the educational and pedagogic characteristics of the learning object), etc. (See the section on LOM for more details). All metadata can be filtered according to a Profile.

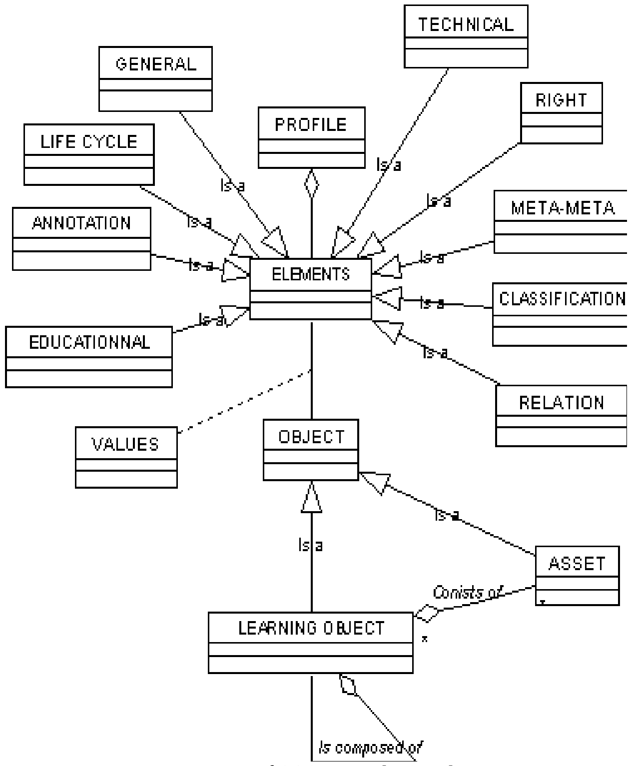

Fig. 4 UML representation of SCORM and LOM descriptions

When an object is used in a given course, some values of metadata associated with the course itself are automatically filled in for the associated learning objects.

4.2. Learning design description

IMS-LD proposes to model the sequencing of activities allotted to each role to attain the goal of the course while following a well defined pedagogy. Knowledge that must be taken into account is of various types as follows:

- Knowledge about actors involved in the course (learner, teacher …). It is represented by the Role. Each role has some activities.
- Knowledge about scenarios in which learning objects are used. It is called Method; it can be composed of plays. A play is composed of acts which are composed of role-parts. A role-part associates a role with an activity.
- Knowledge about the activities in which a learning object is used. In our model, Activity describes the tasks a learner performs (exercise, lecture…).
- Knowledge about the context in which a learning design is used. A learning object may be used differently in different activities. The context makes it possible to describe the use of a given learning object in an activity.

All this knowledge is represented thanks to an ontology, as shown in Figure 5.

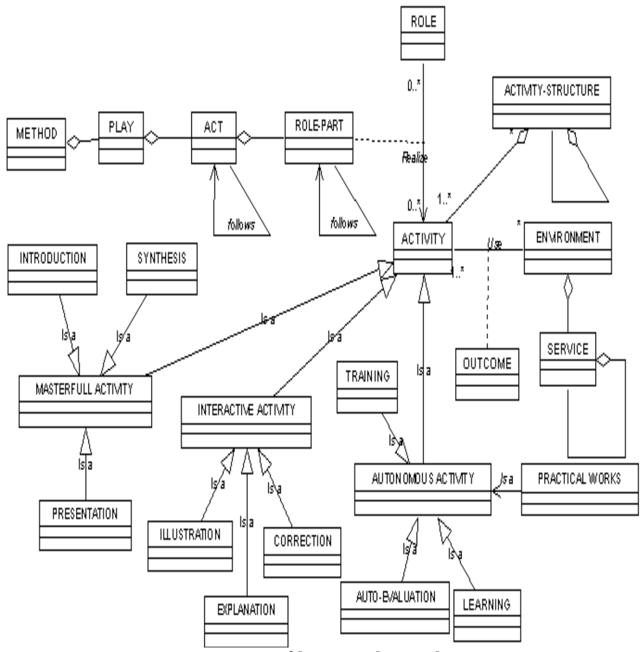

Fig. 5 UML representation of learning design description

5. Constructing A Learning Object Ontology

We implement the ideas that are presented through the model using the Reload CP Editor; we also used the Protégé software.

5.1. Ontologies

An ontology describing the concepts such as the people (students, tutors, secretaries…) and the documents (books, presentation slides, web pages…) is called ontology of the training field for Lenne et al. [12] and target ontology for Gasevic and Hatala [13]. Mitrovic and Devedzic [14] also use an ontology to represent the domain of each tutor.

Ontologies are implemented using OWL (Web Ontology Language) [15] using the Protégé resource [16]. Regarding the domain ontologies, they are manually built (meaning that we choose the concepts to include).

Ontologies provide semantics for content, presentation, and applications by defining concepts and their relationships in a domain. At various stages of learning object production and use, ontologies can contribute to:

- Modelling the structure of a learning object through classes and class properties
- Normalizing structural element names through a controlled vocabulary
- Establishing concept relationships through the hierarchical structure and cross-references
- Providing consistent semantics and structures for database schemas, interfaces for search and browsing, and presentation of content

5.2. LOM and Application Profile

Parameters from Reload CP Editor have been set in order to take into account the application profile. For doing this we modify two files: the profile file and vocabulary file.

The application profile we defined is composed of the LOM enriched by the vocabulary associated with the « Learning object type » metadata which considers pedagogical functions. This metadata implements the link between the ontology of the educational theories and learning objects.

The metadata we added is the « Notion » which takes its values from the domain ontology. Thus, this metadata implements the link between the domain ontology and learning objects.

Both the « Learning object type » and the « Notion » are defined as mandatory in the application profile. Figure 6 is an extract of the application profile vocabulary description.

```
<!-- RELOAD Metadata Profile -->
<!-- This is the default Profile - do not edit or delete!-->
<profile vocabfile="AARAB_Vocab.xml"
schemahelperfile="AARAB Helper.xml">

<group name="General">
<element name="Identifier" path="lom/general/identifier"/>
<element name="Title" path="lom/general/title/langstring"/>
    <group name="Catalog Entry">
    <element name="Catalog"
    path="lom/general/catalogentry/catalog"/>
    <element name="Entry"
    path="lom/general/catalogentry/entry/langstring"/>
    </group>
<element name="Language" path="lom/general/language"/>
<element name="Description"
path="lom/general/description/langstring"/>
<element name="Keyword"
path="lom/general/keyword/langstring"/>
<element name="Coverage"
path="lom/general/coverage/langstring"/>
<element name="Structure"
path="lom/general/structure/value/langstring"/>
<element name="Aggregation Level"
path="lom/general/aggregationlevel/value/langstring"/>
</group>
<group name="Life Cycle">
<element name="Version" path="lom/lifecycle/version/langstring"/>
<element name="Status"
path="lom/lifecycle/status/value/langstring"/>
    <group name="Contribution">
    <element name="Role"
    path="lom/lifecycle/contribute/role/value/langstring"/>
    <element name="VCard"
    path="lom/lifecycle/contribute/centity/vcard"/>
    <element name="Date"
    path="lom/lifecycle/contribute/date/datetime"/>
    </group>
</group>
```

Fig. 6 Extract of file profile AARABEProfile.xml

5.3. LOM ontology

With regard to the thematic description of learning objects, in addition to ontologies we need a process to make the link between the domain ontology and the learning objects. This link is made by automatically indexing the learning objects by the concepts of the domain ontology. To implement this, we will construct the ontology of LOM.

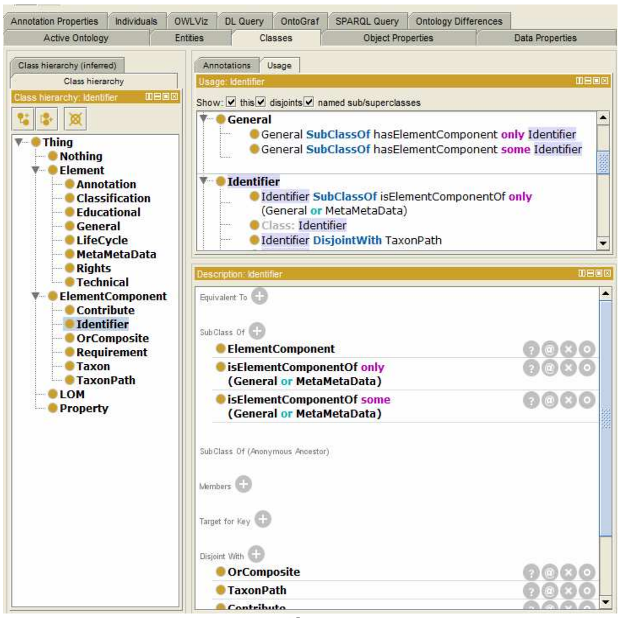

Fig. 7 Classes

There are two top classes (figure 7) in the ontology, including element, and element component. Each class may have subclasses. A class may have its own properties (local properties) or inherit properties from an upper class. It may also have direct instances that bear some properties (figure 8).

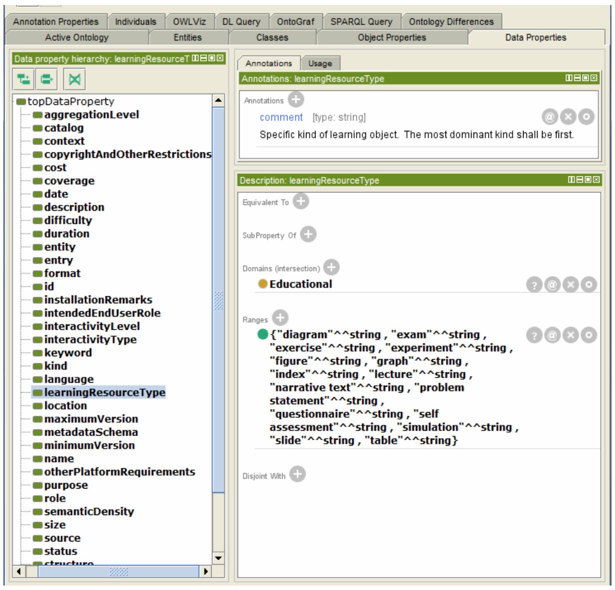

Fig. 8 Data proprieties

6. Conclusions

The proposed model can be applied to any electronic document which has an educational objective. It can be integrated into any model of learning (synchronous or asynchronous distance learning…). It also presents the possible use and adaptation for any type of course because it was not conceived within the framework of a specific training.

The model is based on a multi-facet representation of documents by using three ontologies: ontology of theme, ontology of the tasks, ontology of the educational theories and a LOM/SCORM description. The proposed ontologies are represented in OWL and based on the syntax RDF (Resource Description Framework) / XML. OWL makes it possible to explicitly represent the meaning of the terms of vocabularies (labels and concepts) and the relations between the associated concepts.

One of the key points of the model is that the ontologies enable all of the life cycle of a learning object to be covered: from its conception by the teacher to the search for pieces of information on a given notion by learners. It makes it possible to develop a system that helps the designers of learning objects and lessons. The different actors of the system (teachers, learners) and their various tasks are considered. The model includes the flexibility of a semantic representation and search for relevant learning objects by the use of the LOM application profiles. Complying with the standards of on-line courses guarantees interoperability with other systems.

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