Ontology Based Teaching Domain Knowledge Management for E-Learning by Doing Systems

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Abstract: This paper is about an ontological representation of a teaching domain (a discipline) in the case of an e-learning by doing purpose. Going from our precedent works about using ontologies for modeling specific domains such as algorithmic and relational databases, we show in this paper that it is possible to generalize our approach to any domain based on e-learning by doing mode. The model introduced here shows a domain through two points of views: the specification view given by the ontology and the resources view generally known in e-learning as learning objects. The specification ontology is a granular model where the knowledge of a considered domain is stored, making the use of the ontology for resources retrieval (web semantic use) or for any other learning or teaching activity guided by the domain semantic. This model has been successfully implemented in different learning by doing systems for computer science domains in particular for linear programming in addition to algorithmic and relational databases learning. Among the novelties of this model, we have the possible propagation of the learner's evaluation results to each defined components of the expert domain allowing adaptive content generation. The second novelty is related to the integration of pedagogical resources descriptors described using some data elements from the LOM standard metadata scheme. This will give connection between the ontology concepts (considered at the instance level as semantic annotations) to the domain pedagogical resources, what makes the model significantly more powerful.

Keywords: Ontologies for learning, learning by doing, teaching domain modeling, semantic Web and e-learning

1. Introduction

In the traditional teaching approaches, most class (face to face one or virtual one) time is spent with the professor lecturing and the students watching and listening. It is what is called *teacher centered teaching* of *deductive* approaches as defined by Aristotle. Bowers and Flinders (1990) identified teacher-centered model as an industrial production in which student is a product without much attention to his/her needs and profile. The second main teaching direction is the student centered *teaching* also called *inductive learning*. Richard Felder has written or co-authored a number of papers about the use of active, cooperative, and inductive instructional methods in college science and engineering courses. Among these works, we have (R.M. Felder and R. Brent; 2009) and (M.J. Prince and R.M. Felder, 2006). This teaching direction is that one already defined at the end of the 19th century by John Dewey (Westbrook R. B, 1993). This last introduced the concept of "learning by doing" developed today to be used as a resource in methodologies such as project-based learning, learning by group or solving problems. The learner is, therefore faced to, from one side to the theoretical and technical knowledge and from another to practice in order to acquire the ability to create links between practice and taught domain. Among several ways to "learn by doing", we find simulation, serious games and problem resolution. We consider this last way in the current work, and refer to "problems" as "evaluation units". To solve problems, the learner has to combine domain components and learns from the returns of his/her actions. This way of learning helps to avoid shallow learning and facilitate removal of misconceptions. In addition, research on skill acquisition has revealed a power relationship between the amount of practice and performance (Nokes, T., Schunn, C., & Chi, M.T.H., 2010).

Besides the interest to learning by doing mode, the growth of the use of computers and networks in learning these last years, has been changing the sight on teaching domains modeling: different points of views have to be considered to get a good representation, easy to exchange, adapted to a distant use, adapted to complex learning activities such as evaluation, completely or partly reusable from a domain to another and from an Learning Management System (LMS) to another.

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The existing meta-models for teaching domains (integrated in standards as SCORM, LOM[1] …) are more adapted for resources (documents, videos, courses, etc), commonly called learning objects, representation. These standards are very useful for course generation, resources management and even for evaluation with testing. However, they can be improved to become more "cognitive" and to give a better support to automated learning activities such as automated learners evaluation or adapted content generation. Indeed in our previous works about automated evaluation (Bouarab-Dahmani F. & al., 2009) (Bouarab-Dahmani F. & al., 2010), we have noticed the impact of teaching domains modeling on the learners' knowledge evaluation (especially summative and formative ones) and finally on his/her progression.

In most of the proposed models, teaching domains representations are reduced to pedagogical resources descriptions and the semantic contained essentially in the links between the domain components; very useful for some learning activities, are not modeled. In fact, a domain component can be learned using different learning objects. Besides, the domain semantics is very important for a semantic retrieval of learning resources and has to be considered in a more attentive way.

Starting from this issue and from our precedent works (Bouarab-Dahmani F. & al., 2009) (Bouarab-Dahmani F. & al., 2010), we propose in this paper a general way to operate an ontological modeling of teaching domains for e-learning by doing. This model describes a given domain with *Concepts*, *links*, *pedagogical resources descriptors* and *rules,* a priori, valuable for each discipline. This representation will help designers to easily define, for each domain, its specific knowledge base by a semi automatic instantiation process. Our objective is a domain representation both appropriate for information retrieval and for "cognitive" and complex automated teaching activities such as learners' evaluation by reasoning on detected errors when there are open questions. Indeed, a discipline which is represented using the proposed ontology will be in some way capitalized and digitalized so that new computer programs can be easily added to implement learning activities in general and learning by doing ones since among the knowledge of the discipline we integrate evaluation units (exercises, questions, projects…), errors, examples … These last will sensibly help to get speed and quality of learning by doing material engineering. This is valuable in the case of e-learning or blended learning modes.

This model was first implemented with a Self learning relational database and used by PHP and JavaScript programs for different complex learning activities such as errors diagnosis and learner's marking. After that, for an easier and more efficient use via the Web with the Semantic Web tools, we undertook an implementation with OWL (Ontology Web Language).

What follows is first a general view about related works and then some details on our generic proposed model, which implementation and evaluation is discussed at the end. After that, we present our conclusion on this approach.

2. Related Works

The works related to modeling teaching domain in e-learning are mainly dedicated for numerical pedagogical resources management. In (Fresno-Fernandez V. & al., 2004), the objective is the automatic generation of what the authors call WLMs (Web-based Learning Materials) on the Web from content. Content can be an animation, sound, a question, an exercise, etc and is coded in XML (for structure) and XSL (for format presentation). In (Liu Q & al., 2004), granularity and taxonomy for reuse of learning objects are presented and discussed. In this work, a learning content, considered as a pedagogical resource, is represented as a tree at four levels (from top to bottom): course, unit, lesson and knowledge unit. In (K. Verbert & al. 2005) [7], ontology is developed for learning object (LO) construction going from more granular LO which are pedagogical resources initially stored in a resource base. The same work is developed in (J. Jovanović & al., 2009) [8] with different other ontologies for learner's modeling and domain representation but only with concepts proposed by SKOS (Simple Knowledge Organization System Reference)[2], a W3C recommendation for sharing and linking knowledge organization systems via the Web. IMS-QTI[3] (Tian-Wen Song & Ting-Ting Wu, 2006) is another formalism produced by the IMS consortium to provide a data model to represent questions, test data and to report their corresponding results. We finally have to notice that these works use metadata. Indeed, metadata are fundamental in e-Learning applications for describing learning materials and other knowledge information (B. Liu & B. Hu, 2006).

[1] http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf
[2] http://www.w3.org/TR/2009/REC-skos-reference-20090818/st version:
[3]Instructional Management Systems- Question and Test Interoperability:
http://www.imsglobal.org/question/qti_v2p0/imsqti_oviewv2p0.html

We find more interest for modeling teaching domain structure as it is the case in (Suraweera P. & al., 2004) and (Hatzilygeroudis I. & Prentzas J. ,2004) on the side of Intelligent Tutoring Systems (ITS). In (Hatzilygeroudis I. & Prentzas J. ,2004), about intelligent tutoring systems knowledge requirements, a teaching domain is composed of two types of knowledge: course units and domain elements, ones defining the structuring of domain concepts, others being related to the teaching components such as courses, pages displaying exercises, images, simulations, ... so pedagogical resources.

As in (Angelova G. & al., 2004), we claim that without explicit domain knowledge, the semantics of the learning objects can be described in general terms only. In our view, the domain ontology is required as part of advanced learning solutions as:

- It structures the learning content in a natural way and provides a backbone unifying the granularity of all kinds of learning objects,
- it enables knowledge-based solutions to complex tasks (e.g. checking the correctness of learner's solutions in natural language),
- it allows for clearer diagnostics of the learner misconceptions and supports a consistent, domain independent strategy for planning the adaptive behavior of the system,
- it provides annotation markers that might facilitate the interoperability and exchange of learning resources,

The Semantic Web (SW) (Berners Lee T. & al., 2001) is an evolving extension of the WWW that allows expressing information in a machine-interpretable form and it is expected to revolutionize scientific publishing and sharing of data on the Internet (Bianchi S & al., 2009). It is an emerging domain in the web technologies world that is founded on ontologies for knowledge representation. This last represents knowledge with concepts, links and in some cases also with rules/axioms and functions. Thus, the main goal of SW is automated reasoning on knowledge connected to documents. The main tools used in SW technologies, summarized in (Dehors, S., 2007), are used for editing formalized knowledge as ontologies, annotating and/or indexing pedagogical resources, visualizing knowledge and ontology components and information retrieval by navigating through knowledge and resources.

The term "ontology" comes from the field of philosophy that is concerned with the study of being or existence (Gruber T., 2008). In the context of computer and information science, ontology may be defined as "a formal and explicit specification of a shared conceptualization" (Studer R & al., 1998). In the context of Semantic Web, Handler defines ontology as "a *set of knowledge terms*, including the vocabulary, the semantic interconnections, and some simple rules of inference and logic for some particular topic" (Hendler, J., 2001). Ontology's are typically specified in languages that allow abstraction away from data structures and implementation strategies existence (Gruber T., 2008). OWL is the language developed by W3C for representing ontology's on the Web.

For an ITS, ontology's can play the following important roles in authoring tools (Chen, W. & al., 1998):
help to formalize the process of constructing an ITS,

- provide primitives facilitating description of knowledge at conceptual level,
- help to construct an explicit model,
- Provide axioms directing the build of the ITS.

Different ontology's have been developed for computer based teaching/learning systems. Among these works we have:

The ALOCOM ontology presented as an abstract content model for documents and their components (Jovanović & al., 2005). The model defines content component at different levels of granularity and relationships between components. This ontology uses metadata to describe some general features of teaching domain, but only from existing or "discovered" resources point of view.

The task ontology presented in (Mizoguchi, R. & al., 1992) is composed of some control structures specific to respective tasks used for knowledge acquisition data and also integrated in (Ikeda M. & al., 1997) for an authoring tool development. It is a domain expert (teaching domain for us) description from "process" or "task" point of view.

The LOCO (Learning Object Context Ontology) (Knight, C. & al., 2006) is an IMS-LD-based ontology. It provides an ontological framework that can be used for the development of Semantic Services as "learning designs" using the ALOCOM ontology learning objects representation. The teaching domain is not directly concerned by this ontology. It is the same fact for the LOCO-Cite) (Knight, C. & al., 2006) which is ontology for bridging the learning object content (ALOCOM) and learning design ontologies (LOCO).

OMNIBUS ontology is described in (Hayashi, Y. & al., 2009) as a solution for the noticed disjunction between learning/instructional theories and standard technologies. It aims to support the development of learning content by providing developers with environments that ensure that learning/instructional theories can be easily incorporated within IMS LD scenarios. The OMNIBUS ontology deals more with a pedagogical point of view.

Around 2006, several works were published in the e-learning community to use SW for e-learning systems improvement. However until now, there has been no concrete results about the impact of automated reasoning in e-learning platforms and the documents approach remains the main way to describe a teaching domain. Thus, the use of domain ontologies is still essentially for document retrieval, annotation and construction.

3. Modeling teaching domains

Teaching domain (or discipline) model construction is among the priorities when developing any education or training system. The material to teach is the essence of the system, because if it is poorly represented, it will be always poorly presented to learners and the efficiency of the other system modules will not help anyway. Several formalisms have been tried (logic, production rules, semantic networks …) before the advent of Information and Communication Technology that have changed the sight on information, its use and its needs. One of the most important concepts that have been introduced by ICT in this domain is related to the use of ontologies, which are nowadays, more and more used in learning systems.

This paper is about the domain knowledge "decompilation" (cf. Figure 1) (Mizoguchi, R. & al., 1992) that can be connected in future works to tasks ontologies. Although, we describe the "decompiled" domain knowledge as generic concepts, relations and rules valuable to help teaching domains knowledge bases construction and use. This proposition is for any kind of leaning approach, however the "expertise" in our work will be a 'learning by doing expertise" where some elements are added to an easy use for learning by doing tasks such as error diagnosis, profile definition, data mining of learner's errors...

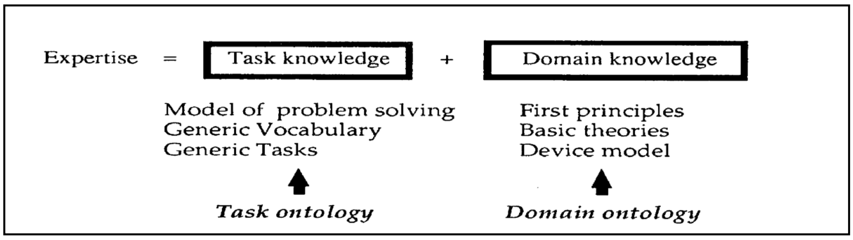

Figure 1: Expertise decompilation (mizoguchi & al., 1992)

The domain ontology described in this paper includes the "domain knowledge" of Figure 1 and a set of knowledge (more than generic vocabulary) of task ontology commonly used for learning by doing tasks. It will remains specific knowledge for each of learning by doing tasks that can be represented as task ontologies. We think indeed that the task ontology described in (Ikeda M. & al., 1997) can be broken on two parts: one is "problem solving domain" ontology (which fits the present work) and the other corresponding to "problem solving tasks" ontologies.

Our aim is to define a standard formalization of teaching domain ontology with SW tools to provide a computational ontology that can be used by different learning systems such as e-learning platforms and Web-ITS. Each use will be *a* web service using knowledge deduced by a semantic reasoning based on the teaching domain ontology. This model is dedicated for an e-learning by doing context.

In addition, instead of developing different ontologies for different learning domains, we propose here a metamodel (going from already developped ontologies for different teaching domains) where the most used concepts, necessary for learning by doing activities, are integrated.

Going from these assumptions and what was already proposed in (Hatzilygeroudis I. & Prentzas J., 2004) about domain decomposition, we define two parts for describing TDO (Teaching Domain Ontology): the *specification* of that domain and the *pedagogical resources (PR)* (see Figure 2). The specification is a set of knowledge used for domain characterization by defining its components, links and rules. PR are a collection of learning materials saved as files with different possible formats (documents, pictures, video, sounds, ...) and used during teaching activities. Of course, links between these resources can be defined using those between the concepts to which they refer to. We just notice indeed that the automated definition of these links by tools remains a research problem (Allard D. & al., 2008). Nevertheless, the works about that are often about "indexing learning objects" or resources annotation. Some of them, such as (Fontaine D. & al., 2006) have deeply studied the navigation among resources using the links described in the domain specification.

In this paper, we focus more on general semantics of a teaching domain to define the main concepts, links and rules. Hence, for the PR representation, we can use ALOCOM model, as we can equally think to improve the LOCO model by replacing "resource description" class by a "domain description" class, composed of the classes “specification” and "resource description"(PR Class). Doing this, one can use LOCO-cite ontology when it is needed to connect LOCO and ALOCOM ontologies as explained in (Knight, C. & al., 2006). In the other hand, TDO can be integrated to OMNIBUS ontology (Hayashi, Y. & al., 2009) as a “what to learn” class that is in the “World of cognition” part. OMNIBUS model can also be viewed as the pedagogical context for an expert domain described with TDO.

Finally, we can say that the interest has to be focused on the domain **that will be taught** and not on this domain in a general way. For example the “pediatric teaching domain” is not the same as the “pediatric domain” since teaching pediatric requires additional components. More precisely, a concept such as “pediatric diagnosis errors” will not be a part of the “pediatric domain” representation, when it has to be explicitly mentioned in the “pediatric teaching domain” model, if we want to avoid these mistakes in the practice of pediatrics by students.

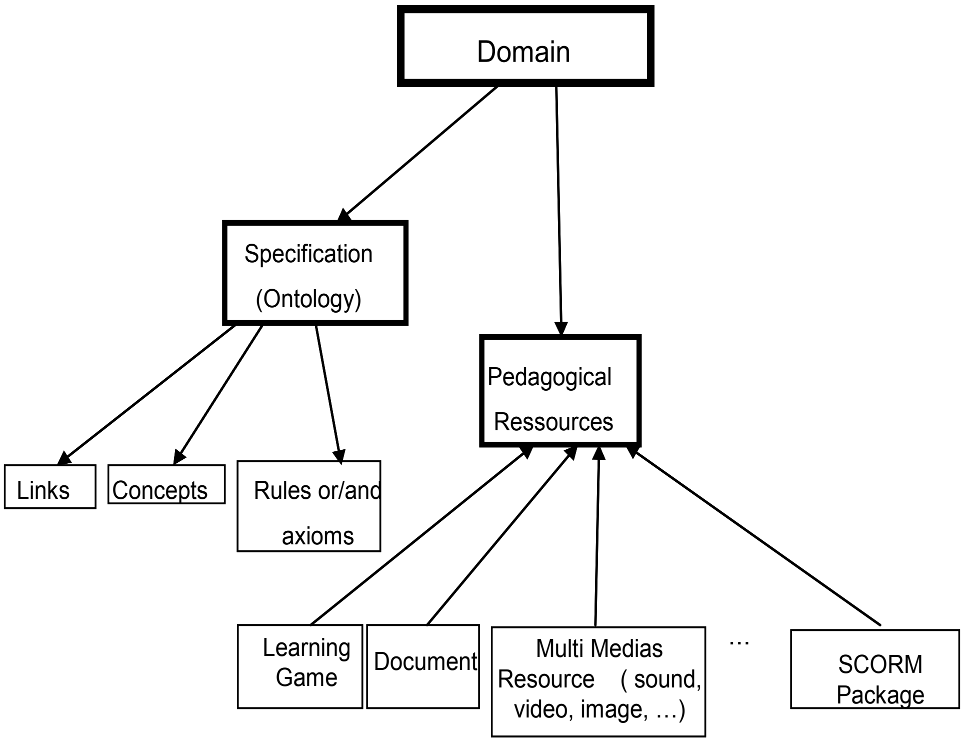

Figure 2: The two main parts of a domain

In our approach, in order to teach a domain, we start from the domain specification and let pedagogical resources to be linked in a second time. We obviously consider that domain expert is able to produce at least one possible resource (book, course etc) to make effective the learning activity, in particular in the case of distant learning.

Besides, to make the considered domain more exploitable in learning sessions, we recall that its knowledge is always combined with pedagogical knowledge on one part and knowledge about learners on other part. Indeed, one has to be careful to correctly distinguish domain concepts from those related to learners or pedagogy.

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4. The Tdo description

To build teaching domain ontology for an e-learning by doing purpose, we need in one hand some concepts and semantic relations common to any kind of learning or e-learning activity such as structural components, pedagogical resources descriptors and the prerequisite or composition relations. In the other hand, other concepts and relations are added for learning by doing purpose. These last are shown in Figure 3 as "nonstructural components". As result, the proposed ontology can be used, completely or partially, for other types of learning than learning by doing. In our works until now, we validate it for the case of problem based learning systems for some computer science trainings disciplines. As it is detailed below, the main concepts added for learning by doing are: *Evaluation units* and *Errors*.

Figure 3 gives a general sight about the taxonomy got with the "is a" link between the ontology concepts. The different elements (*concepts* and *semantic relations)* of the proposed ontology are presented in what follows.

4.1 Concepts

A. 1. The components class

These are the teaching domain components required to learn or teach the domain. We propose two sub classes for a component:

The "structural component" class: These are components of the teaching domain structure which define the core of the domain. All other sub-concepts will be defined to help in learning these structural components. For this class, the first main defined concept is called a *notion*. A notion, if it is complex, can be broken down into several (*sub-) notions. At the lowest level*, we have elementary or granular notions, called *knowledge items* (KI), what constitutes the second main concept. At this stage of our research, this domain decomposition is defined under the responsibility of a human expert. We therefore recommend strictly hierarchical trees (see Figure 4) of notions. Indeed, in our works about algorithmic teaching, we put on the assumption about the possibility to have a KI that can fit into the composition of different notions. However after the use of the algorithmic ontology for an automated learner's evaluation (Bouarab-Dahmani F. & al., 2009), we got some difficulties to manage this multi-inheritance for KI that, in fact, rarely exists in practice.

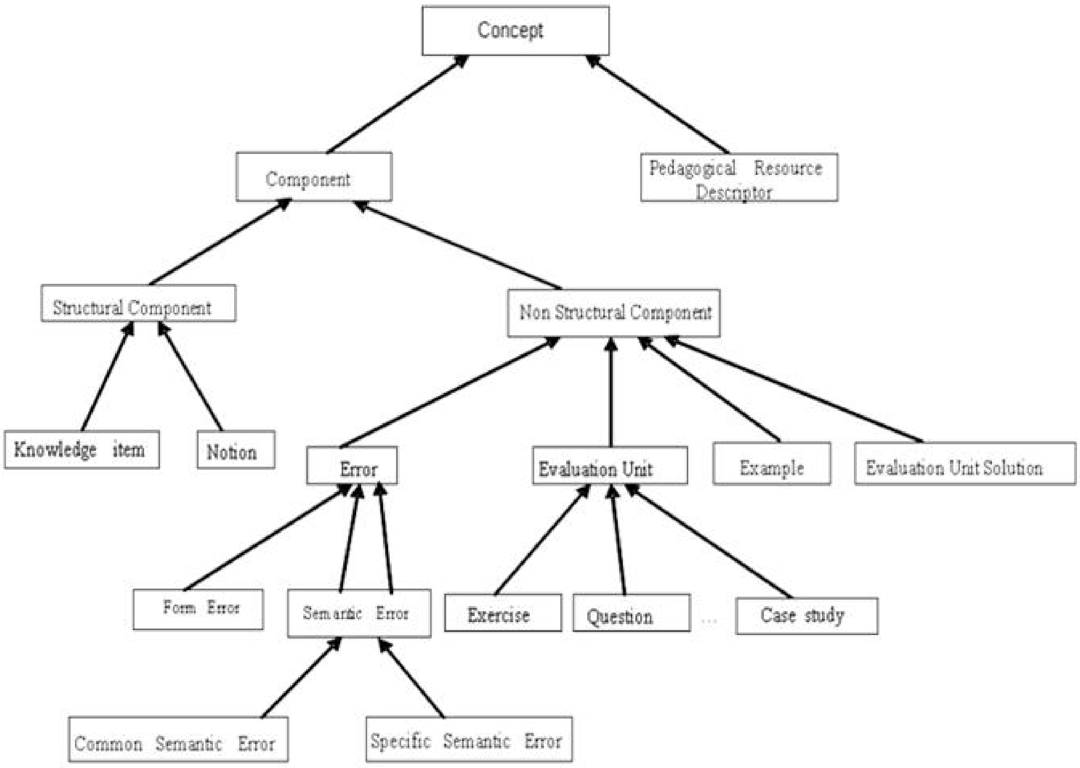

Figure 3: The class concepts hierarchy (with the relation "Is A") proposed by TDO

The "nonstructural component" class: These are didactical "tools" defined by an expert, who can teach the considered domain according to a given pedagogy. Nonstructural components can be different according to the kind of learning, learning objectives, pedagogical constraints, specificities of the area to teach, ... In our current case of learning by doing based teaching, we consider the main nonstructural concepts commonly used in academics, which are evaluation units (exercises, questions, …), examples, solutions and errors. A nonstructural component can be presented as *a "projection"* on structural components (see Figure 5) since it is dedicated to reinforce their learning. The main proposed concepts for this subclass are:

An *evaluation unit* is constructed to allow evaluation of structural components comprehension by the learner. This will require definition of a range of items, which are expected to appear in the formulation of the learner's solution, to make it correct, what corresponds in fact to retrieve in this solution notions that appear at different levels of the domain's ontology. To fix this issue, in the description of an evaluation unit, we introduce links pointing required notions, and focus on those pointing knowledge items. We also introduce other features as data structures such as difficulty level, the degree of importance of each component and so on. On other hand, the description of an evaluation unit contains links to adequate pedagogical resources that can be one of the IMS- Instructional Management Systems - Question and Test Interoperability resources. This way, a TDO question can be an IMS-QTI item and an exercise can be an IMS-QTI section or assessment, making our concept of evaluation unit more general than IMS-QTI data structures, since it can be an open question (exercise), a case study, or even a mini-project, for instance.

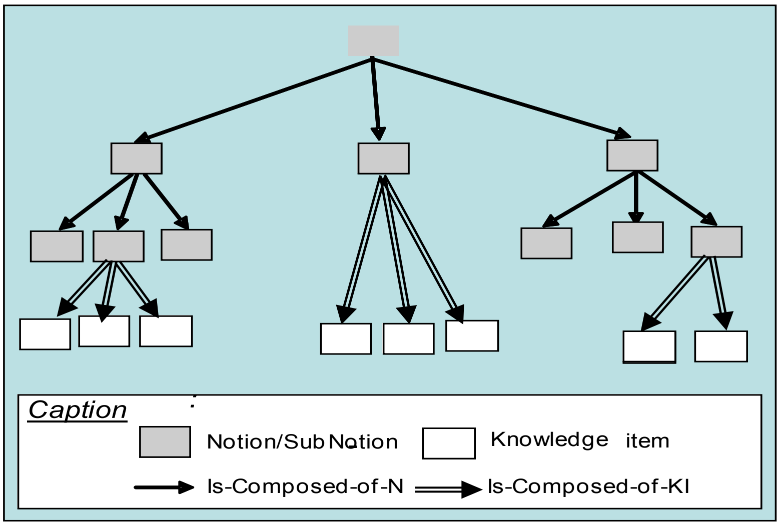

Figure 4: Structural decomposition of a teaching domain

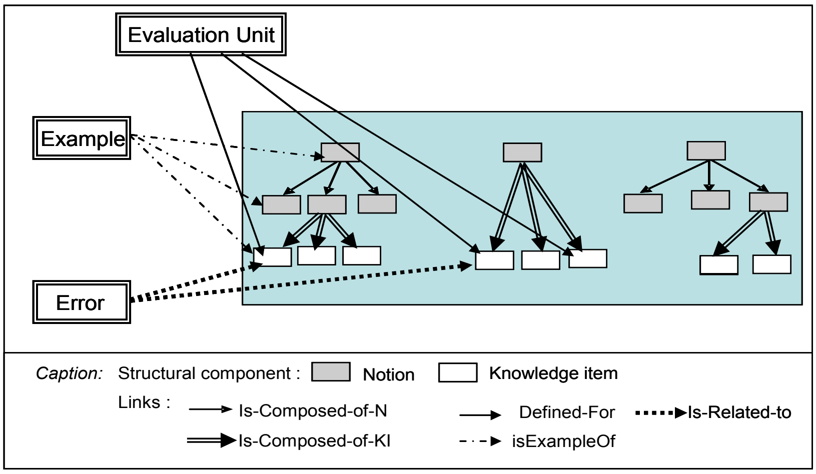

Figure 5: Nonstructural components and their projection by semantic links on structural components

An *error* is an abstract knowledge of the domain that can appear when learning a domain by solving evaluation units. A learner's error is generally symptomatic of misunderstanding of domain notions. An error (or a mistake) is considered as an unintentional wandering or deviation from accuracy, or right conduct[4]. Misconceptions (bad understanding of domain notions) are one of the main causes of students' errors and "bugs" (wrong way of resolution).Our purpose here is that learner's errors have to be exploited to allow improvement of learner's skills and progression , and to increase the speed of the learning process. To increase the effectiveness of the error detection process, we suggest a hierarchical taxonomy of possible errors (as shown in Figure 4). Indeed, we consider that two main types of errors (Bouarab-Dahmani F. & al., 2009) can occur in a solution proposed by a learner: the *form errors* related to the learner's solution form or presentation and the *semantic errors* relate to the sense of the learner's solution, such as a logical expression and/or scheduling tasks inadequate to the proposed evaluation unit. A semantic error can be *common semantic error* (CSE) when it can be found in different solution of respectively different evaluation units so do not depend on exercise's statement, or a *specific semantic error* (SSE) when it is about characteristics expected in a solution not expressed in the learner's solution.

In fact, we name each reference in an evaluation unit *i* to a knowledge item *KIj,* a characteristic (a feature) *Cij* of the evaluation unit (Bouarab-Dahmani F. & al., 2009), to which is associated at least one specific semantic error as a potential error.

An *example* is an illustration of a structural component use. This illustration must be as simple as possible to help the structural component understanding.

A *solution* gives, for an evaluation unit, one of the correct ways to solve it. The solution is not defined to be used by the error diagnosis process but only for display.

A. 2. The pedagogical resources descriptors class

It is dedicated to PR description. This class describes the main metadata about a PR stored in the local server or on the Web such as the URL, the title, the main ideas … These metadata can be inspired from existing models such as the LOM standard or ALOCOM. PR descriptors are essentially defined to index the PR chosen by the domain expert. It is also the proposed way to connect PR to the ontology components by creating annotations.

4.2 Semantic Relations

Semantic Relations between concepts, in this paper are defined as connections between the linked concepts senses or meanings. We distinguish between two basic categories of semantic relation: *hierarchical* ones and *associative* ones. A hierarchical link between two concepts indicates that one is in some way more general than the other. An associative link between two concepts indicates that the two are inherently "related", but excludes existence of a hierarchical relation between them. The main semantic relations considered in our purpose are synthesized in the UML class diagram of Figure 6. We define in particular:

[4] Dictionary.com Unabridged Based on the Random House Dictionary, © Random House, Inc. 2012.

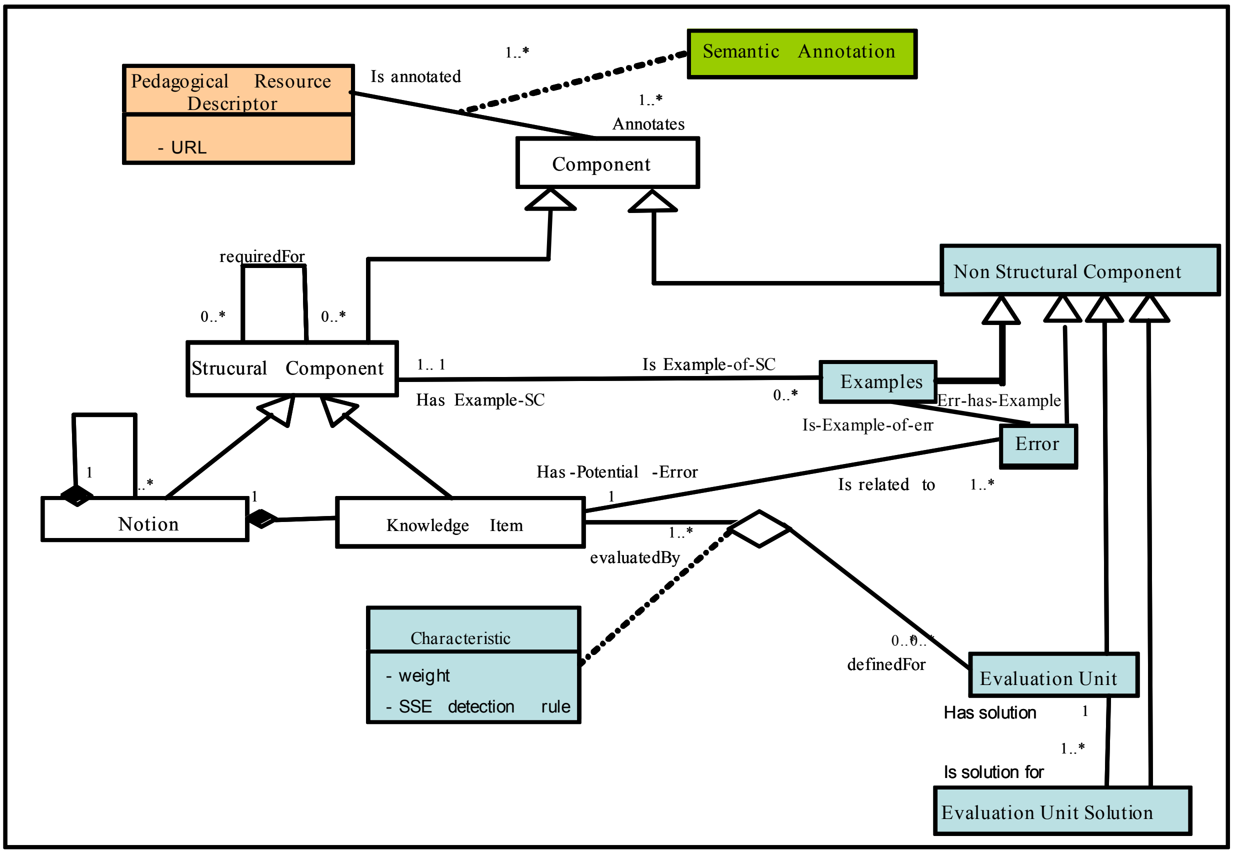

Figure 6: The UML class diagram of TDO

B.1. Hierarchical semantic relations

It includes:

- *Composed of* relations (denoted by filled diamonds on the UML representation)*:* These are structural and taxonomic links representing the composition relationships between the domain's structural components. We define two kind of composition relation:
  - *N-Composed-of-N*: relating a notion to its sub-notions, and *N-part-of-N,* the inverse relation. This Parthood as a relation between instances is transitive (for all p, p1, p2, if p *N-part-of-N* p1 and p1 *N-part-of-N* p2, then p *N-part-of-N* p2). anti-symmetric (for all p, p1, if p *N-part-of-N* p1 and p1 *N-part-of-N* p then p and p1 are identical);
  - *N-Composed-of-KI* links a notion to its knowledge items; the inverse relation in this case is *KI-part-of-N*.
- *Is A* relations*:* These taxonomic links define sub classes for a given class of concepts. This is the link "Is A" known in the object-oriented approach as inheritance link. The "Is A" link is transitive. Figure 4 represents the hierarchy produced by the 'Is A" link with TDO.

B. 2. Associative relations

Each associative relation is defined by two roles (the relation and its inverse). The main associative relations defined in the proposed ontology and shown by Figure 6 are given in what follows. The inverse relation name is put between brackets:

- *Is related to (Has-Potential-Error):* This is a relation between an error and a KI. It is a didactic relation because it may change from an educational context to another.
  We have chosen to link each possible error to a knowledge item, knowing that these links can be propagated (as for the evaluation units) by bottom transitivity to all nodes of the tree representing the domain's structural decomposition. Thus, a given item may have several

possible errors. However, we assume that every error may relate to only one item. This assumption imposes a domain's structure as detailed as possible, which could lead to define new items, corresponding to new errors, what finally leads to the building of a more precise domain.

- *Is required for (Requires):* It is a didactical association between structural components (notions and KI). It indicates that a structural component *x* must be known before another one *y* (*x* is required for *y* or *y* requires *x*) because the first component is necessary to allow understanding of the second one. This link is particularly used with learning systems, and is a transitive.
- *Evaluated By (Defined for):* It defines an association between an evaluation unit and knowledge items called in Figure 6 "Characteristic". This relation is described by a coefficient (an attribute) expressing the importance degree of the KI for the concerned evaluation unit. This coefficient will be linked to some specific semantic errors detection rules that may be used by semantic analyzer of error diagnosis module.
- *Is example of-SC (Has example-SC):* It defines a link between an example and a structural component.
- *Is example of-err (Err-Has example):* Is a link between an example and an error. This relation is proposed to add examples related to errors to explain how an error can be done.
- *Is solution for (has solution):* It is the link going from a solution to its corresponding evaluation unit, knowing that an evaluation unit may have different solutions.
- *Is annotated (Annotates):* It is an association between the PR descriptors class and the components class one (see Figure 6). A semantic annotation (SA) in this case defines which part of the PR (or which PR) is about the pointed component. This class description will depend on the PR structure and the PR descriptors. We anticipate different sub classes for the SA class and plan to present them in future works.

B.3. Inferred relations

When combining some TDO relations (two or more), we can get significant inferred relationships with which we can deduce interesting knowledge. We have the combination of the same relations (e.g. transitivity) and those where different relations are combined. Hence, domain-independent rules can be integrated with TDO such as the following examples given from a set of possible significant deduction rules combining different semantic relations of TDO:

Rule-A1*: **if** n1 N-Composed-of-N n2 **and** n2 N-Composed-of-KI n3 **then** n1 N-Composed-of-KI n3*

Rule-A2*: **if** n N-Composed-of-KI k **and** k EvaluatedBy x **then** n EvaluatedBy x*

Rule-A3*: **if** n N-Composed-of-KI k **and** k Has-Potential-Error e **then** n Has-Potential-Error e*

Rule-A4*: **if** n1 N-Composed-of-N n2 **and** n3 Is Required for n2 **then** n3 Is Required for n1*

Rule-A5*: **if** n N-Composed-of-KI k1 **and** k2 Is Required for k1 **then** k2 Is Required for n*

5. Use cases and discussion

As we mentioned in the introduction, a TDO based model has been used first in different domains for e-learning by doing such as algorithmic, relational databases and linear programming. The knowledge bases respectively obtained for these domains are managed with a reusable interface called *author space* (see Figure 7). The platforms for algorithmic e-learning and relational databases e-learning are developed by computer science engineers of our university using mainly PHP, Mysql databases server for the ontology implementation and management. The UML classes and associations are implemented as relational tables. The different rules are integrated in PHP scripts so are implemented in a procedural way. After the generalization of the TDO model in order to make it domain-independent, what was our goal at this stage, its instantiation and use was relatively easy, even for complex tasks as learners' evaluation, for the twenty four (24) developers who used the model since 2006: eight (8) for relational databases, fourteen (14) for algorithmic and two (2) for linear programming. The author interface was first used with the algorithmic platform and reused for relational databases and linear programming platforms what made these last's development faster. We just recall indeed that, for the moment, the instantiation of TDO for a specific domain is done by a human expert according to TDO concepts before the use of the author interface.

The resulted learning by doing systems were successfully experimented with students and teachers of our university where the domain ontology was used for different learning tasks in particular learners' evaluation (Bouarab-Dahmani F. & al., 2009) (Bouarab-Dahmani F. & al., 2010) and adaptive exercises selection (Bouarab-Dahmani F. & al., 2011) [28]. Other domains are currently under experiment to confirm efficiency of this approach and to improve the ontology concepts, semantic links and rules. However, when we attempt the implementation of some web services to use the ontology operationnalized as a data base, we faced some compatibility problems especially when using Java language. This last has the advantage to have different API to help faster services building. We noticed that this current implementation of TDO is not easily accessible to all possible e-learning uses, such as resources retrieval, knowledge visualization, reasoning, data mining tools etc. The *ontological dimension* of the teaching domain model is thus biased and its use over the Web is limited. To remedy this, we are actually considering an implementation using Semantic Web tools, so that, the implemented ontology could be reusable and sharable for different Web services.

Figure 7: Reusable Author interface for TDO management seen with WebSiela system for algorithmic e-learning

We have built an operational version of TDO in the computational language OWL. Proposed by the W3C, OWL is actually the most used standard for this purpose. Thus, the main step of this implementation is the translation of the TDO model (the UML one and the added rules) to the OWL language. The chosen sub languages are OWL-DL for concepts and semantic relations and SWRL for the rules.

The principles that we have used to map the UML diagram into an OWL file, are compliant with the UML to OWL mapping rules defined in the ODM (Ontology Definition Metamodel) of the OMG (ODM, 2009). This compliance is important to provide in the future an automatic generation of the OWL ontology according to the MDE (Model Driven Engineering) approach (Djuric D. & al., 2005).

Thus, the concepts classes and the associative relations ones of TDO are translated as OWL classes. The links are represented as OWL object properties.

We have used the editing tool Protégé 3.4.4. to get the OWL file of the TDO (see Figure 8 where the classes hierarchy is shown). The Obtained file can be used with protégé (instantiation, reasoning, SPARQL request for the knowledge base interrogation …) or by Java projects using special frameworks such as Jena[5].

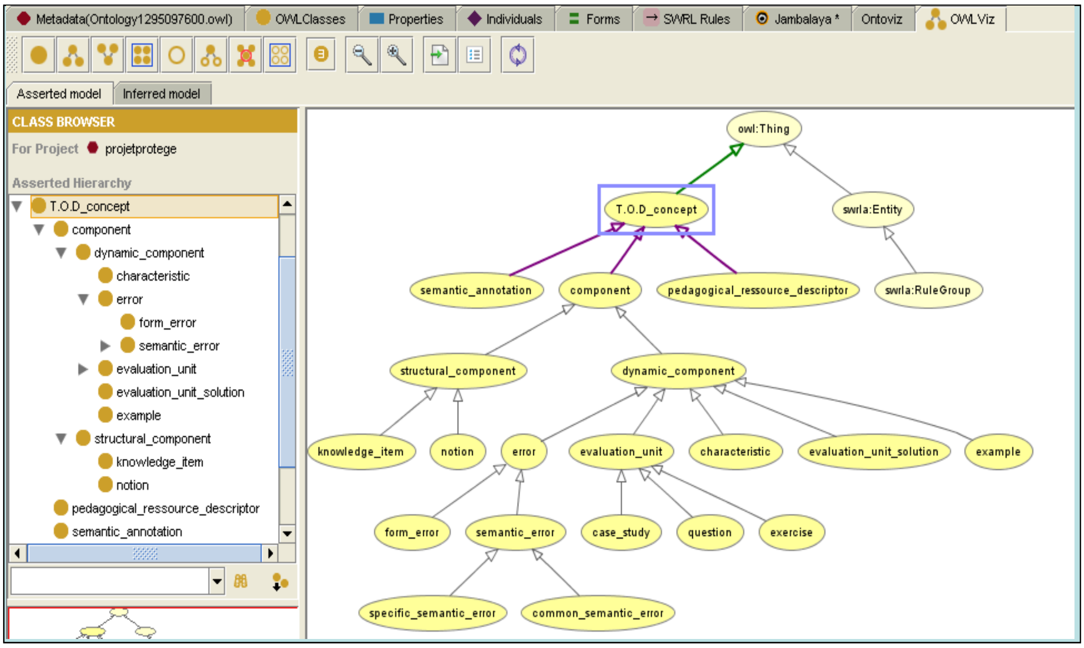

Figure 8: Class hierarchy of TDO in Protégé 4.4 Tool

The OWL file created by the tool describes the concepts and the relations respectively as OWL classes or OWL object properties (see Figure 9 for examples). It contains also the rules descriptions with the SWRL language.

This OWL file can be used for those uses that we have already implemented with a data base with a larger sight and also for some other web services that we couldn't easily develop with the precedent implementation. For more clarity, the following example (see Table 1) shows an evaluation unit instance (for the Exercise subclass) extracted from the relational databases teaching domain knowledge base (which is an instance of TDO ontology) (Bouarab-Dahmani F. & al., 2010). From Table 1, we can see the semantic relations between the evaluation unit "Exercise 2", notions (from the first and the second levels) and knowledge items at the most granular level. Table 2 gives some specific semantic errors with specifying related knowledge items by giving the corresponding numbers. This shows how we can easily get, for example, the domain components evaluated by exercise 2. However, to know which are the errors committed by a group of students when solving exercise 2, or the knowledge items and/or notions concerned by the most detected errors after an exercise session, we need an inference engine since the necessarily knowledge to make such deductions is not enough structured so that we can represent it in a database.

[5] http://jena.sourceforge.net/tutorial/index.html

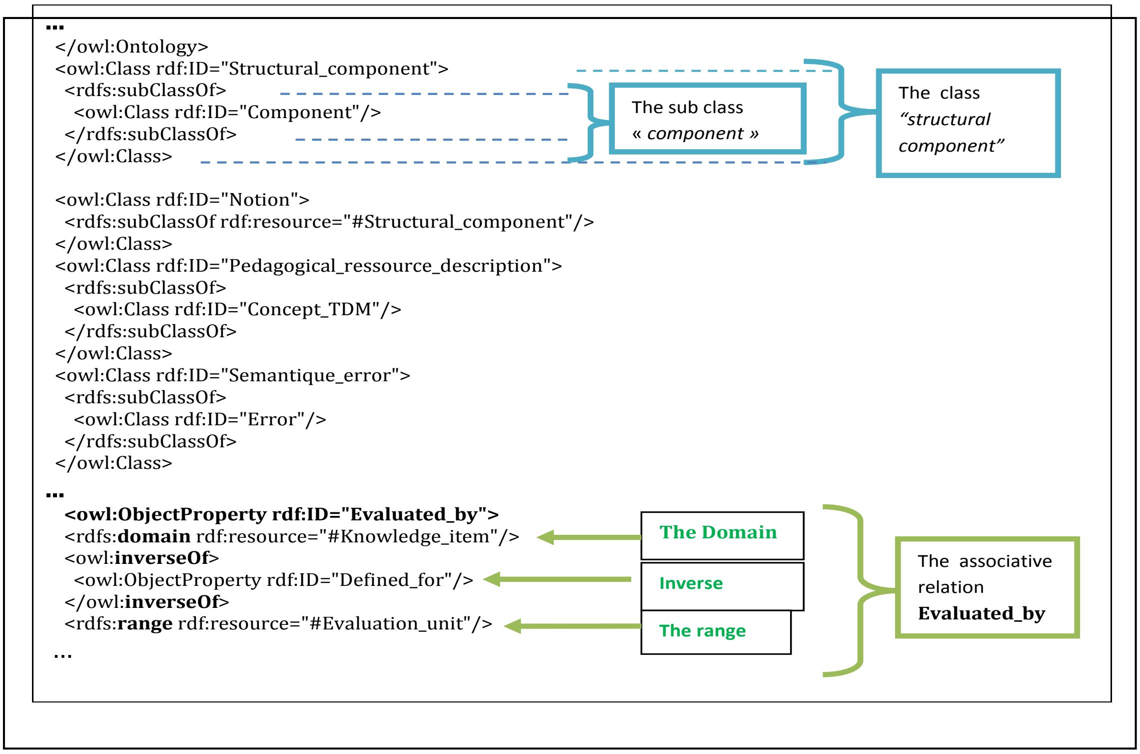

Figure 9: Extract from the generated OWL file by the Tool Protégé 4.4

Table 1: Example of bond Exercise-knowledge items-Notions in the case of Relational databases teaching

Exercise 2 Statement	First level Notions	Second level Notions	knowledge items
"Going from the following relational diagram about an AIRBASE : -PILOTE(NUMPIL, NOMPIL, ADR, SAL) -PLANE(NUMAV, NOMAV, CAP, LOC) -FLY (NUMVOL, NUMPIL , NUMAV, VILLE_DEP, VILLE_ARR , H_DEP, H_ARR) Answer with algebraic operators this request : *What are the planes (number and name) located at Toulouse and those that have already fly to Singapore"*	- Introduction to the relational model -Relational algebra	-The relation concept -Algebraic operation -Binary operators -Monadic operators	6. Definition of a relation 7 Attribute of a relation 8 Degree of a relation 9 Key of a relation 10 Diagram of a relation 19 Principle of monadic operators 20 The selection operator 22 The projection operator 24 Syntax of monadic algebraic operation 25 -Principle of binary operators 26 - The union operator 34 Syntax of a binary algebraic operation 35. Syntax of a condition in an algebraic operation 36. Lexicon of the words 37.Syntax of an algebraic operation

Table 2: Examples of Specific semantic errors extracted from the errors base of the Relational databases teaching domain

Num Error	***Error text***	***Num Knowledge Item***
23	The complement algebraic operator found whereas it is not envisaged by the exercise	21
24	The projection operator is not found in the solution	22
2 6	The intersection operator not found whereas it is envisaged by the exercise	28
2 7	The complement algebraic operator not found whereas it is envisaged by the exercise	21
28	The second attribute identifier used in the projection operator is not the good	22
29	The relation identifier used for projection operator is not the suited one	22
30	The number of attributes in the projection operator is different from two	22
31	The first relation identifier in the union operator is not the good	26
32	the second relation identifier in the union operator is not the good	26
34	the first relation identifier difference operator is not the good	27
35	the second relation identifier difference operator is not the good	27
…	…	…

In the end, the TDO ontology is more "accessible" as an OWL file, which has been successfully used for simple requests (using Java servlets, Jena and SPARQL), for resources retrieval and for the ontology management (such as knowledge base instantiation of TDO for specific domains) as shown by Figure 10. Our aim is now to use TDO implemented as OWL file for more complex learning activities implemented by different Web services (see Figure 11) such as those already experimented with databases and script languages (adaptive exercises generation, learners' evaluation, …) and for other learning activities that need reasoning and data exploration to get recommendations for e-learners.

Figure 10: Using the OWL ontology by a web service to TDO management

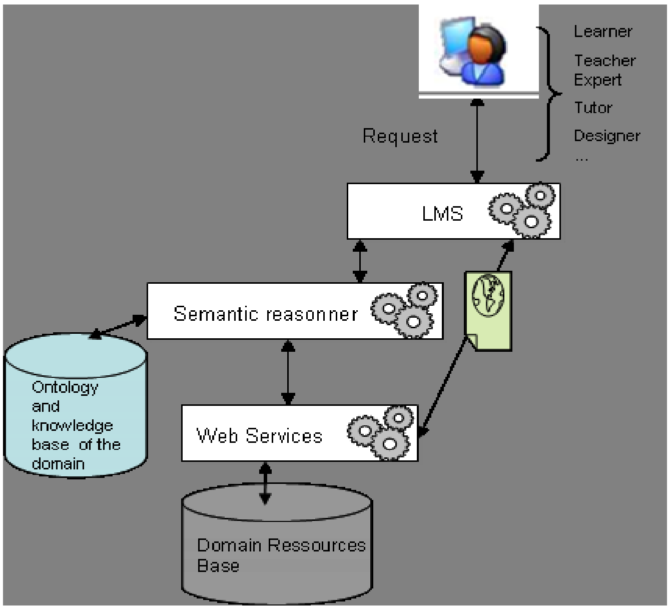

Figure 11:Using TDO for an efficient response to user's queries

6. Conclusion

We have presented in this paper an ontological model for the representation of teaching domains. It integrates pedagogical resources descriptors and semantic annotations that can be used by learning by doing systems to execute different learning activities and to connect resources anywhere through the Web. This ontology has been first implemented using relational tables and scripts languages for different learning domains and was successfully evaluated. After that, we attempt an implementation with Web semantic technologies.

Our results show that the ontological model that we have implemented on specific domains teaching, as presented in our previous works, can be generalized to provide a kind of *metamodel* that becomes reusable for domain knowledge that complies with the structuring process we have defined.

For the moment, the TDO model was particularly used for pedagogical resources retrieval in a prototype developed using Java servlets in NetBeans[6] environment (where the resources are already described by PR descriptors and stored in the local server). We are currently developing more complex Web services using the OWL file such as learners' evaluation or automatic knowledge acquisition.

References

Allard D., Bourdeau J., Mizoguchi R.. Towards modeling knowledge of cultural differences and linguistic influence in Computer Assisted Language Learning (CALL). Proceedings of the Culturally Aware Tutoring Systems (CATS) Workshop, ITS Conference, Montreal, Canada, June (2008), 11-22.

Angelova G., Kalaydjiev O., and Strupchanskaref. A. Domain Ontology as a Resource Providing. Adaptivity in eLearning R. Meersman et al. (Eds.): OTM Workshops 2004, LNCS 3292, pp. 700–712, 2004. Springer-Verlag Berlin Heidelberg 2004

Berners Lee T., Hendler J., Lassila O. (2001), The Semantic Web, Scientific American

Bianchi S., Mastrodonato C., Vercelli G., and Vivanet G.. Use of Ontologies to Annotate and Retrieve Educational Contents: the AquaRing Approach. Journal of e-Learning and Knowledge Society. Vol. 5, n. 1, February 2009 (pp. 211 - 220).

Bouarab-Dahmani F., Si-Mohammed M., Comparot C. & Charrel P. J. Learners automated evaluation with the ODALA approach, ACM-SAC2009 (Human Computer Interaction Track) International Conference, Honolulu, Hawaii, USA, March 08-12, 2009.

Bouarab-Dahmani F., Si-Mohammed M., Comparot C. & Charrel P. J. Automated Evaluation of Learners with the ODALA Approach: Application to Relational Databases E-learning, International journal of computational intelligence systems, IJCIS, Vol.3, N. 3, (September 2010), 357-369, published by Atlantis press.

Bouarab-Dahmani F., Si-Mohammed M., Comparot C & Charrel P. J. Adaptive Exercises Generation using an Automated Evaluation and a Domain Ontology: The ODALA+ Approach, International journal of emerging technologies in learning, IJET, Vol.6, Issue 2, June 2011, 4-10, doi:10.3991/ijet.v6i2.1562

Bowers, C. A., & Flinders, D. J. (1990). Responsive Teaching. Teachers Collage Press: New York.

/ [6] http://fr.netbeans.org/

Chen, W., Hayashi, Y., Kin, L., Ikeda, M., & Mizoguchi, R. (1998). Ontological Issues on an Intelligent Authoring Tool. Proceedings of the ECAI'98 Workshop on Model-Based Reasoning for Intelligent Education Environments, Brighton, England.

Dehors, S. (2007) Exploiting Semantic Web and Knowledge Management Technologies for E-learning, Ph. D. Thesis, University of Nice-Sophia Antipolis, INRIA, France.

Djuric D., Dragan Gazevic D., Devedzic V., Ontology Modeling and MDA, University of Belgrade, Serbia and Montenegro Journal of object technology, Vol. 4, No. 1, January-February 2005.

Felder R.M. and Brent R.. "Active Learning: An Introduction." ASQ Higher Education Brief, 2(4), August 2009. A short paper that defines active learning, gives examples of activities and formats, and answers frequently-asked questions about the method.

Fontaine D., Benayache A., Abel M.E. L'accès aux ressources d'une formation guidé par les ontologies, International Journal of Technologies in Higher Education, 3(3), 2006. www.profetic.org.

Fresno-Fernandez V., Montalvo-Herranz S., Peréz-Iglesias J., Urquiza-Fuentes J., Velazquez-Iturbide J.A. An approach to the use and automatic generation of web-based learning materials, W. Liu & al. edition, ICWL 2004, LNCS 3143, pp. 201-208, 2004

Gruber T. Ontology. Entry in the Encyclopedia of Database Systems. Ling Liu and M. Tamer Özsu (Eds.), Springer-Verlag, 2008.

Hatzilygeroudis I., Prentzas J. Knowledge representation requirements for intelligent tutoring systems, Proceedings of the 7th international conference, ITS 2004, Brazil 2004

Hayashi, Y., Bourdeau, J. and Mizoguchi, R.: "Using Ontological Engineering to Organize Learning/Instructional Theories and Build a Theory-Aware Authoring System", International Journal of Artificial Intelligence in Education, Vol. 19, No. 2, pp. 211-252, 2009

Hendler, J. 2001. Agents and the Semantic Web, IEEE Intelligent Systems, 16, (2), 30-37

Ikeda M., Kazuhisa S., and Mizoguchi R.. Task Ontology Makes It Easier To Use Authoring Tools. Proc. of IJCAI-97, pp.342-347, also as Technical Report AI-TR-97-3, I.S.I.R., Osaka University, 1997.

Jovanović, J., Gašević, D., Verbert, K., and Duval E. (2005). Ontology of learning object content structure. In Proceedings of the 12th International Conference on Artificial Intelligence in Education, edited by Looi, C.-K. and McCalla, G. and Bredeweg, B. and Breuker, J. (Amsterdam: IOS press), pp. 322-329. http://ariadne.cs.kuleuven.be/alocom/papers/AIEDsubmission.doc.

Jovanović J., D. Gašević, V. Devedžić. TANGRAM for Personalized Learning Using Semantic Web Technologies. Journal of Emerging Technologies in Web Intelligence, 2009. ISSN: 1798-0461, pp. 6-21.

Knight, C., Gašević, D., & Richards, G. (2006). An Ontology-Based Framework for Bridging Learning Design and Learning Content. Educational Technology & Society, 9 (1), 23-37.

Liu B.and B. Hu. Migration of the Semantic Web Technologie into E-Learning Knowledge Management. G. Wang et al. (Eds.): RSKT 2006, LNAI 4062, pp. 638–642, 2006. Springer-Verlag Berlin Heidelberg 2006

Liu Q., Yang Z., Yan K., Wu D. Reusable Learning Object and its strategies for e-learning, W. Liu & al. edition, ICWL 2004, LNCS 3143, pp. 386-392, 2004.

Mizoguchi, R., TijerinoY. And Ikeda M. (1992). Task ontology and intelligent training system use in a task analysis interview system--Two-level mediating representation in MULTIS. In: Proc. Of the JKAW92, 185-198. http://www.ei.sanken.osaka-u.ac.jp/pub/miz/JKAW92.pdf.

Nokes, T., Schunn, C., & Chi, M.T.H. (2010). Problem solving and human expertise. In P. Peterson, E. Baker, & B. McGaw (Eds.), International Encyclopedia of Education (3rd Edition) (pp. 265-272). Oxford: Elsevier. (PDF)

ODM, 2009. Ontology Definition Metamodel. Version 1.0 Specification, Object Management Group, Inc., Needham, MA, May 2009. Available at: http://www.omg.org/spec/ODM/1.0/PDF

Prince M.J. and Felder R.M.. "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases." J. Engr. Education, 95(2), 123-138 (2006).

Studer R., Benjamins VR. & Fensel D. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering (DKE), 25(1-2):161-197, 1998.

Suraweera P., Mitrovic A., Martin B., The role of domain ontology in knowledge acquisition for ITSs, Proceedings of the 7th international conference, ITS 2004, Brazil 2004.

Tian-Wen Song, Ting-Ting Wu. An Assessment Authoring System for Generating IMS QTI Compliant Questions. International Conference on Business and Information, July 12-14, 2006, Pan Pacific Hotel, Singapore

Verbert K., Gasevic D., Jovanovic J., Duval E.. Ontology-based Learning Content Repurposing, WWW 2005, May 10-14, 2005, Chiba, Japan. ACM 1-59593-051-5/05/0005.

Westbrook R. B. John Dewey (1859-1952). Revue trimestrielle d'éducation comparée, vol. XXIII, n° 1-2, 1993, p. 277–93.