Improving search and publish of knowledge by means of ontology in a Virtual Learning Environment

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Abstract. Online Problem-based learning environments afford many opportunities engage in collaborative knowledge construction. Problem-based Learning (PBL) is widely collaborative. In PBL, students work in small groups with the guidance of a facilitator learning through solving problem, and reflecting on their experience. The combination of Information and Communication Technology with pedagogical methods produces a new quality that favors the task of generating, transmitting and sharing knowledge The use of ontologies to represent knowledge of specifically domain improves the management of information in the Virtual Learning Environment since it allows the automatic reasoning and it facilitates processes search and recovery of knowledge. In this paper we present a constructivist paradigm for VLE that includes automated mechanisms of search and publish of knowledge integrated in an environment, based on use ontologies that describe learning domain to help students in PBL.

1 Introduction

A Virtual Learning Environment (VLE) increases productivity in education because it provides access to learning materials at any time and at any place. VLE leads from mere information transmission to knowledge construction.

A Constructivist VLE comprises adaptable and contextual spaces that favor an independent work of students, with the purpose of offering non sequential approaches that foment free association of ideas. They are an additional complement for the enrichment of the received education that foments practical ways to design educational activities and to organize information agree to requirements of constructivist approach of education.

Proposals that implement a constructivist approach [1] [2] in the educational process have made emphasis in the experimentation phase of knowledge generation and experiences with their use have shown that it can foment interest in learning and working in group to acquire new knowledge. Nevertheless, its effectiveness is limited because most VLE has no appropriate automated mechanisms to reuse and to integrate the generated knowledge and does not motivate students to search for previously known solutions neither to publish new knowledge.

Although students who use these educational environments also have access to information retrieval tools for the Internet (for example Google, Lycos and CiteSeer), a proliferation of superfluous data obtained under these conditions does not imply any form of validation or trustworthiness. In addition the overabundance of the search results leads to the problem known as *cognitive overload.*

Application of ontology to model related components of learning materials would contribute to effective reuse of knowledge. An organizational structure of generalized knowledge with pedagogical purposes can be helpful when a knowledge repository is incorporated into a comprehensive pedagogical design. However, in the broader literature, there is a lack of formal ontology description of knowledge repository for pedagogical design.

In this paper we present a constructivist paradigm for VLE that includes automated mechanisms for knowledge searching and publishing, based on an ontology that describes a learning domain to help students in Problem Based Learning [3]. Students following a systematic procedure can discover and examine contents using pre-designed devices (Learning Objects, LO) to create, validate and publish new knowledge that can be used in the form of learning objects, with a well defined interface that allows and facilitates its reusability. The main contribution in this paper is on adopting the ontological representation of knowledge for searching and discovering content in known repositories of educative materials.

The rest of paper is structured in the following way. In section 2 "Knowledge representation and management in a Virtual Learning Environment" we analyze the concept of ontology and apply it in a VLE design that delivers instructional materials as Learning Objects. In section "Use of ontology in a guided solution of problem" we show how to describe a problem domain in an ontological structure and how to use this representation to help students in a problem resolution strategy. In section "EnEMoCi: Virtual Learning Environment" we present the EnEMoCi's search and publish mechanism, illustrating it with a case of study. In section "Related Works" we show a related solution. Finally in section "Conclusions" we present some concluding remarks and future work.

2 Representation and management of knowledge in a Virtual Learning Environment

Knowledge management is the systematic process of detecting, selecting, organizing, displaying and using highly structured information originated from an organization, with the purpose of cooperatively operating knowledge-based resources to give the right piece of knowledge to the right person at the right moment.

Ontological models for knowledge management in a VLE specify the generic structure of the learning material shared on a knowledge repository. A VLE that actualizes such a structure allows users to play an active role in pedagogical development through semantically relevant knowledge searching. The purpose of representing concepts in an ontological representation is to standardize and to improve the methods of searching and discovery of knowledge for an agile manner of delivering instructional material.

2.1 Learning Objects to represent knowledge in a Virtual Learning Environment

Learning Objects (LO) are a new way of thinking about learning material. A LO is a unit of digital resource that can be shared to support teaching and learning [4] [5]. Because knowledge can be displayed in many ways, for example by narrative descriptions, graphical illustrations, and program simulations, Learning Objects are suitable to represent them and are used for knowledge sharing in a VLE [6] [7] [8].

In the VLE field, there are emerging standards for describing learning resources, and among them, Learning Objects Metadata (LOM) [9] is gaining acceptance. LOM describes metadata for learning objects and it is gradually becoming the reference standard for educational system managing learning objects of many kind. However this standard lacks flexibility, because it cannot allow interoperability between systems.

2.2 Ontologies as conceptual model in management knowledge in a Virtual Learning Environment

Ontology is the science that studies the explicit formal specification of the terms of a knowledge domain and the relations among them [10] [11]. Many different definitions of the term have been proposed so far. One of most widely quoted and well-known definition of ontology was given by Gruber "Ontology is an explicit specification of a conceptualization" [12].

The use of ontologies in an educational environment is not new [13] [14] [15]. Bloom defines a taxonomy of educative goals in which the category `contents' has a roll that specifies the concepts that were taught in a course [13]. Bloom's taxonomy of education objectives is a framework which has been widely used in all disciplines. The original Bloom's framework includes six levels of learning: knowledge, comprehension, application, analysis, synthesis and evaluation. Given the recent development in the knowledge management field, this description is no longer appropriate in nowadays VLE context.

Nevertheless, investigations that use ontology in a VLE have been focused in two fundamental focuses [16]:

a) Interoperability and classification of the Learning Objects used in Learning Management Systems (LMS) [17]. The ontologies define a vocabulary that is shared by the applications including entries for the Learning Objects it contains.
b) Generation of adaptable Learning Environment [18] [19]. The ontologies describe roles and contents that allow personalizing a learning process.

Ontology has been receiving considerable attention in the learning research community. In the Learning Objects field, ontology is typically a network of semantically related knowledge for a specific instructional domain.

The role of ontologies in a VLE is often underestimated. They can be useful for systems that have to intercommunicate according to an agreed protocol (interoperability) and for the system development process (for specification, reusability, and reliability).

2.3 Ontology versus Learning Objects metadata

There have been metadata standard for Learning Objects, such as those proposed in Dublin Core [20], IEEE LTSC [21] and IMS Guide [22]. These standards are used to represent individual Learning Objects at the collection level, which is similar to library catalogue systems. However, to use Learning Objects to support teaching and learning at the knowledge sharing level for a specific domain, knowledge schema must be applied to a Learning Objects repository for such domain [23] [24]. This is because Learning Objects can be organized in a variety of ways depending upon complex intra-context and inter-context where they can be deployed. When a virtual Learning Objects repository is huge and is distributed on the Internet, the use of metadata and keywords only to search for the needed Learning Objects is inefficient and ineffective since many of the potential associations with the various learning aspects are bypassed [25]. This has lead to approaches to Semantic Web applications that model the relationships between Learning Objects using formal ontologies [26].

While metadata describe the artifacts of Learning Objects that are shared by diverse domains, ontology represent a knowledge domain that shares the relationships of Learning Objects within a specific context. There has been moderate literature on ontologies associated with Learning Objects [19] [27]. However, few research reports have provided explicit generic structure of ontologies for knowledge sharing.

Metadata standards of Learning Objects intend to generalize taxonomies and vocabularies for Learning Objects repositories for all disciplines [20], [21], [22], [28], [29], [30]. There is a tacit ontology behind a metadata standard. Such a tacit ontology is too complicated to present because the semantic relationships between all Learning Objects are hard to be standardized. Without the support of ontologies, tagging all types of metadata and relevant keywords to every Learning Object could be prohibitively expensive and will eventually make any search engine practically powerless. On the other hand, specific domain ontology for Learning Objects repositories serves as a map and suggests paths for retrieving candidate Learning Objects to attain certain pedagogical objectives.

3 Use of ontology in a guided solution of problem

In Problem-Based Learning (PBL), while students are identifying crucial parts of the problem, they are also conceiving possible solutions. These solutions can be characterized according to the description along with the restrictions of the problem domain to guide the student to a good solution.

In all problem domains that are more susceptible than others of having a better formalization exist fundamental concepts that may be classified with the basic ontological relationships of *subclass of* and *part of*.

The ontologies involved in the guided solution of problems organize knowledge in two categories: Concepts and Solutions. The Concepts class describes the problem domain, whereas the Solutions class describes the existing algorithms. For example in a domain of graph algorithms used in computer science, the former class comprises graph, directed graph, shortest path and maximum flow subclasses, whereas the

the latter class comprises the Bellman-Ford, Dijkstra, and Kruskal algorithms as subclasses.

The Concepts class organizes in subclasses concepts describing a problem domain and each subclass has the name and solvewith properties. The name property is used to identify class or subclass. The solvewith property associates concepts with solutions. The Solutions class organizes solutions that solve problems in this domain. Each subclass that belongs to this category has several properties. A description property has a brief narrative description of the solution to the students. The properties enlacePW and enlaceOA contain pointers to educative materials (Learning Objects) that describe solutions. The enlacePW property has a link to the main Learning Objects that describe a solution and it is normally elaborated by an expert. The enlaceOA property has more Learning Objects that further develop a solution description. These Learning Objects are elaborated by students and professors. This links allow navigation to review the educational material stored in a Learning Objects Repository. These materials are implementations of a solution and complement an exposed description solution in the main Learning Object.

4 EnEMoCi: Virtual Learning Environment

EnEMoCi is a VLE that provides high-level services for discovery, searching and publishing of knowledge, though it also provides the functionality of a learning management system to conduct the administrative tasks involved in teaching a course. The knowledge level services facilitate a constructivist approach to education. Besides users can perform knowledge administration upon learning objects by means of a dedicated layer that manage a knowledge involved in solving problems by means of ontologies.

4.1 Searching for knowledge

In EnEMoCi, searching for the set of solutions to a problem given by a query consists on determining the set of Learning Objects that represents an appropriate set of solutions to the problem. Algorithm SEARCH shown in Figure 1 retrieves all the known solutions that can better solve the given problem.

Algorithm Search receives as inputs an ONTOLOGY and a QUERY (an abstract narrative description of the problem), and returns as outputs the set of SOLUTIONS that solves the QUERY according to the ONTOLOGY and the set of LEARNINGOBJECTS associated with the SOLUTIONS. As the ONTOLOGY has a hierarchical structure, the search starts in the top of the structure descending by a breath-first traversal from the most general to the more specialized concept.

The algorithm begins by getting all the WORDS extracted from the QUERY (line 2). The algorithm iterates FORALL WORD IN WORDS (lines 3 through 10) and FORALL CONCEPT IN ONTOLOGY (lines 5 trough 9) to find those CONCEPTS whose property NAME is the root of a discriminating WORD. In case the NAME identifies an abstract CONCEPT in the ONTOLOGY (lines 6 through 8), a new entry in the SOLUTION array is defined to associate the NAME to the SOLUTION obtained from property SOLVEWITH of

CONCEPT (line 7). The set of all final SOLUTIONS are obtained by intersecting all partial solutions (lines 10 through 13) and the set of all LEARNINGOBJECTS are obtained by joining the sets of Learning Objects given by property ENLACEPW of each final solution (lines 14 through 16).

```
ALGORITHM SEARCH
INPUT ONTOLOGY, QUERY
OUTPUT SOLUTIONS, LEARNINGOBJECTS
BEGIN
1  SOLUTIONS, LEARNINGOBJECTS ← Ø
2  WORDS ← SPLIT(QUERY)) \ NONDISCRIMINANTWORDS
3  FORALL WORD IN WORDS DO
4    NAME ← LEXICON.GETSTEM(WORD)
5    FORALL CONCEPT IN ONTOLOGY
6      IF CONCEPT.NAME=NAME THEN
7        SOLUTION[CONCEPT.NAME] ← CONCEPT.SOLVEWITH
8      END IF
9    END FORALL
10 END FORALL
11 FORALL S IN DOM(SOLUTION) DO
12   SOLUTIONS ← SOLUTIONS ∩ SOLUTION[S]
13 END FORALL
14 FORALL S IN SOLUTIONS DO
15   LEARNINGOBJECTS ← LEARNINGOBJECTS ∪ S.ENLACEPW
16 END FORALL
END
```

Fig. 1. SEARCH Algorithm

In this algorithm, function SPLIT(QUERY) returns the set of all WORDS (with no duplicates) that appear in QUERY, function GETSTEM(WORD) returns the root of WORD by using a LEXICON such as WordNet [31]. The algorithm uses dynamic associative arrays (like those found in JavaScript) in which a new entry is defined by assignment (as in line 7). There are no duplicated entries for this array. Associative arrays have an intrinsic function DOM() that returns the set of all elements for which an entry for the array is defined. Predefined set NONDISCRIMINANTINGWORDS contains frequently used words, among articles, pronouns, and verbs, which do not contribute to determine the problem domain. The operations of union (∪), intersection (∩) and difference (\) for generic sets have their usual meaning. The algorithm also uses high-level iterator FORALL that has the form FORALL ELEMENT IN SET DO ACTION END, meaning that variable ELEMENT is instantiated with each member of SET, if non-empty, to perform the given ACTION upon ELEMENT. For the ONTOLOGY, the iterator traverses the hierarchy of nodes in a breath-first manner beginning by the top node, as explained before.

Because a problem generally involves concepts whose solutions may completely differ from others, the algorithm returns no solution when SOLUTIONS is empty. When no solution is found, it indicates that there is some inconsistency in the QUERY.

4.2 Publish of knowledge

Publication consists on augmenting a centralized repository of Learning Objects with the known solutions for the problem. The publication process is lead by an instruction facilitator. In practice, Learning Objects can be either permanent or temporal, according to their duration in the repository. Permanent Learning Objects are elaborated by experts (generally the facilitators) to be used as reference in the subject matter and represents the most complete information available. Temporal Learning Objects are elaborated by students as incomplete, tentative, discardable solutions that arise during the problem solving.

4.3 Case of study

In a Computational Algorithms course it is asked to the students to solve the following problem: "A road map contains information about 20 cities and the roads that connect them have a length given in kilometers. There is always at least one route between any two cities of the map. The problem consists in finding an optimal route between any two cities that minimizes the distance covered by the route. "

Following the PBL methodology, the students start their activities by identifying the learning objectives they have. For this problem, the learning objective can be specified in abstract terms by the query "Finding the shortest path in a directed graph".

Documents related to the specified query were obtained from a search engine like Google [32] that comprises databases containing million of documents organized by classical information retrieval methods. Table 1 summarizes the first ten results the search engine returned to answer the query. From the list of results, the students have to decide which information is most appropriate by examining each result. It was observed that only 30% from the retrieved information is useful for the students, because they contain enough information (theoretical explanations and algorithms) related to the purpose of the query, so that the students can satisfy their learning objectives.

Table 1. Search results from Google. (*) *The link has information useful for students*

Links quantity	Description	Average (%)
1	*Dijkstra's Algorithm Description*	*10 (*)*
2	*Directed weighed Graph theory and Dijkstra's Algorithm Description*	*20 (*)*
5	*Data structure exercises*	*50*
1	*Floyd's Algorithm application paper*	*10*
1	*The link could not be shown*	*10*

Nevertheless, if the learning objective that the students have identified can be situated in an ontological domain of Computational Algorithms, then more precise results to that query could be obtained by using the RIbONTOMiddleware, a nonconventional search engine based on ontology containing those abstract terms. The results obtained by using the RIbONTOMiddleware to the same query are summarized in Table 2.

Table 2. Search results using RIbONTOMiddleware.

Solutions
Bellman-Ford Algorithm
Floyd-Warshall Algorithm
Dijkstra Algorithm

By using this search engine based on context ontology the following conclusions can be derived: (1) 100 % of the retrieved information is useful for the students, and (2) the number of links was reduced significantly with respect to the results obtained from the Google search engine.

5 Related work

Snae propose the O-DEST system [19] that comprises ontology for e-learning process, such as course syllabus, teaching methods and learning activities. However the description only refers to pedagogical rolls and activities, and it does not approach the use of knowledge search mechanisms. In [33] a revision of the Learning Management System (LMS) concept is presented. It proposes ontology based on the most recent definitions that facilitate the evaluation, selection and implantation of a LMS, but it cannot able to extent to other domains. In [34] is presented COFALE, a system to support a flexible learning. The system support to implement problem based learning allows an adaptable use of: presentation of learning contents, pedagogical resources and evaluation generation. Nevertheless, these systems do not include search and discovery knowledge mechanisms, that they allow the reusability of the generated knowledge.

6 Conclusion

In this paper we present the EnEMoCi Virtual Learning Environment that approaches problem-based learning, guides students through the problem solving activities and implement a methodology for searching and publishing of knowledge. The domain description is based on ontology that optimizes the application of knowledge based systems, development and interoperability.

The use of EnEMoCi has demonstrated that a retrieval mechanism based on context ontologies reduce the links amount that students should navigate.

An ontological model would help a user to search learning objects by reducing the mental search space. Our proposed ontological model has explicit descriptions of pedagogical intentions. In comparison with general topic maps, the semantic network represented by ontological model is formalized for problem solving in the pedagogical development domain. From the viewpoint of knowledge sharing, our ontological model can be considered as a framework for pedagogical development based on common pedagogical design patterns.

Ontology does not replace individual learning objects metadata, rather it adds explicit relationships between learning objects that would help the user to conduct unstructured pedagogical development. As a result, the use of ontology would allow students to utilize well-known knowledge in an efficient manner. A formalized learning objects category can help a community in developing aspects of its ontology, especially when the learning objects repository is incorporated into a learning system.

The future work is focused in improving response time to query and a development of appropriate update services for generated knowledge automation publication in a Learning Objects Repository.

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References

1. H. Zhuge, and Y. Li, (2004), Active E-Course for Constructivist Learning, Proceedings of the 13th International World Wide Web Conference, pp: 246-247.
2. L.P. Maia, F. Berenger, and A.G. Pacheco, (2005), A Constructivist Framework for Operating Systems Education: a Pedagogic Proposal Using the SOsim, Proceedings of the 10th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education, pp: 218-222.
3. H.S., Barrows, (2000), Problem-Based Learning Applied to Medical Education.
4. D.A. Willey, (2000), Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy, In D.A. Wiley (Ed.), The Instructional use of Learning Objects.
5. D.A. Willey, and E.K. Edwards, (2002), Online self-organizing social system: The decentralized future of online learning, Quarterly Review of Distance Education, 3(1):33-46.
6. E.B. Cohen, and M. Nycz, (2006), Learning objects and e-learning: An Informing Science Perspective, Interdisciplinary Journal of Knowledge and Learning Objects, 2:23-34.
7. B. Collis, and A. Strijker, (2003), Re-usable learning objects in context, International Journal on E-Learning, 2(4):5-16.
8. G. Singh, L. Hawkins, and G. Whymark, (2007), An integrated model of a collaborative knowledge building, Interdisciplinary Journal of Knowledge and Learning Objects, 3:85-105.
9. C. Knight, D. Gašević, and G. Richards, (2006), An ontology-based framework for bridging learning design and learning content, Journal of Education Technology & Society: Special Issue on Current Research in Learning Design, 9(1):23-37.
10. T. Gruber, (1995), Toward principles for the design of ontologies used for knowledge sharing, International Journal of Human and Computer studies, 43(5/6):907-928.
11. N. Guarino, (1995), Formal ontology, conceptual analysis and knowledge representation, International Journal of Human and Computer studies, 43(5/6):625-640
12. T. Gruber, (1993), A translation approach to portable ontology specifications, Knowledge Acquisition, 5(2):199-220.

13. B.S. Bloom, (1956), Taxonomy of educational objectives. The classification of educational goals, Handbook I: Cognitive domain, New York, Longmans, Green.
14. I. Friss, J. Azpiazu, and A. Silva, (2003), Use of Ontologies in a Learning Environment Model, Proceedings of Computers and Advanced Technology in Education (CATE'03), Greece.
15. A. Dong, and H. Li, (2005), Ontology-Based Information Integration in Virtual Learning Environment, Proceedings of IEEE/WIC/ACM International Conference on Web Intelligence (WI'05), pp. 762-765.
16. J. Breuker, A. Muntjewerff, and B. Bredeweg, (1999), Ontological Modeling for Designing Educational Systems, Proceedings of the Workshop on Ontologies for Educational System.
17. P. Mohan, and B.K. Daniel, (2004), A New Distance Educational Model for the University of the West Indies: A Learning Objects Approach, Proceedings of the IEEE International Conference on Advanced Learning Technologies, pp: 938-942.
18. K. Verbert, D. Gaševič, J. Jovanovič, and E. Duval, (2005), Ontology-based Learning Content Repurposing, In Proceedings of WWW'2005, pp: 1141-1141.
19. C. Snae, and M. Brueckner, (2007), Ontology-driven e-learning system based on roles and activities for Thai learning environment, Interdisciplinary Journal of Knowledge and Learning Objects, 3:1-17.
20. Dublin Core Metadata Initiative, Retrieved from http://dublincore.org
21. IEEE Learning Technology Standards Committee, Retrieved from http://ieeeltsc.org
22. IMS Meta-data Best Practice Guide for IEE 1484.12.1-2002. Standard for Learning Object Metadata Version 1.3 Final Specification, Retrieved from http://www.imsproject.org/metadata/
23. K. Harman, and A. Koohang, (2005), Discussion board: A learning object, Interdisciplinary Journal of Knowledge and Learning Objects, 1:67-77.
24. A. Koohang, (2004), Creating learning objects in collaborative e-learning setting, Issues in Information System, 4(2):584-590.
25. P.N. Mustaro, and L.F. Silveira, (2006), Learning objects: Adaptive retrieval through learning style, Interdisciplinary Journal of Knowledge and Learning Objects, 2:35-46.
26. M.A. Silicia, and M. Lytras, (2005), On the representation of change according to different ontologies of learning, International Journal of Learning and Change, 1(1):66-79.
27. A. Zouaq, R. Nkambou, and C. Frasson, (2007), An integrated approach for automatic aggregation of learning knowledge objects, Interdisciplinary Journal of Knowledge and Learning Objects, 3:135-162.
28. V.N. Convertini, D. Albanese, A. Marengo, V. Marengo, and M. Scalera, (2007), The OSEL taxonomy for classification of learning objects, Interdisciplinary Journal of Knowledge and Learning Objects, 2:125-138.
29. N. Friesen, (2005), Interoperability and learning objects: An overview of e-learning standardization, Interdisciplinary Journal of Knowledge and Learning Objects, 1: 23-31.
30. K. Yordanova, (2007), Meta-data application in development, exchange and delivery of digital reusable learning content, Interdisciplinary Journal of Knowledge and Learning Objects, 3:229-237.
31. WordNet, Retrieved from http://wordnet.princeton.edu/
32. Google, Retrieved from http://www.google.com.mx/
33. G. Diaz, and M.A. Perez, (2006), Towards an ontology of LMS: A Conceptual Framework, 8th International Conference on Enterprise Information System, pp: 161-164.
34. V. Minh, (2006), COFALE: An Authoring System for Supporting Cognitive Flexibility, Proceedings of Sixth International Conference on Advanced Learning Technologies, ICALT'06.