Learning Ontology Construction for Enhancing Learning Outcomes of Student in Higher Education

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Abstract

A class is the interaction between an instructor and students. An instructor provides learning materials in order to achieve learning goals of the class and students acquire knowledge and experience in the train of the active learning works of them. However, in the most of all classes students learn in passive manner because there is no interaction between an instructor and students. In this paper, we propose an effective method for enhancing learning effect of students through constructing learner ontologies in which knowledge discovered by students is conceptualized and organized. The learning ontology of a certain course is composed of an ontology made by a teacher and many ontologies made by students. The learning ontology is used in discussion, visual presentation, and knowledge sharing between instructor and students. We used the learning ontology in two lectures in practice and found that the learning ontology enhances learning effect of students in according to the analysis of feedbacks of students.

Introduction

There was many works applying Semantic Web and ontology technology to computer-aided education field. The work of Mizoguchi[4,5] proposed a ontology-based solution to solve several problems caused by intelligent instructional systems. Another works defined metadata of learning objects and learning path including curriculum based on ontology engineering technology[3,6]. These works concentrated on management of learning objects and materials and performance enhancement of instructional systems.

Ontology technology, however, can be used to make the knowledge structure, which improves the interaction among teachers and students and enables spontaneous learning of students, of teaching contents and learning materials of students based on semantic information[7]. In this paper, we propose an effective method for enhancing learning effect of students through constructing learner-based ontologies in which knowledge discovered by students is conceptualized and organized.

Learner-based ontologies can be merged into teacher-based ontologies which conceptualize teaching contents in classes. Thus, our learning ontology is composed of teacher-based ontologies and learner-based ontologies. Teachers and students share and understand knowledge of learning materials based on learning ontologies.

This paper is structured as follows. Section 2 provides an overview of the related work in the domain. We describe the hierarchical structure of learning ontology in Section 3. Section 4 shows the experimental result and in the end the paper presents our conclusion in Section 5.

Related work

The researches applying ontology technology to education field are classified into education ontology creation, ontology-based learning object organization, and ontology-based learning contents retrieval. The studies for education ontology creation include curriculum ontology creation[8] and personal learning ontology creation[1].

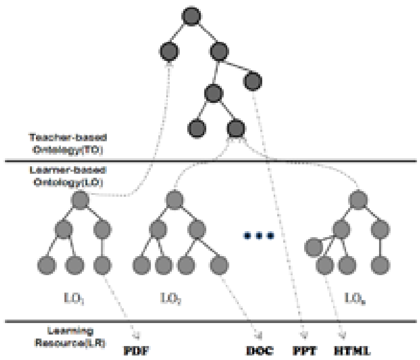
ACM Computing Curricula 2005(CC2005) is representative of curriculum ontology research. CC2005 defines the standard curricula of computer science undergraduate course to be referred to other computer-related educational institutions or universities. CC2005 classifies curricula of computer science into introductory course, intermediate course and advanced course. In addition, CC2005 defines computer-related knowledge as 14 areas, 132 units and 950 topics.

Personal learning ontology conceptualizes and organizes knowledge of learned by a person. A person can extend, modify, or retrieve his/her learning ontology using an ontology management system. In this paper, we propose an extended version of person learning ontology to include teachers and students in classes. The goal of our learning ontology is improvement of learning outcomes of students, active communication among teachers and students and self-initiative learning of students.

The structure of learning ontology

The hierarchical structure of learning ontology is depicted in figure 1. Learning ontology is composed of one or more of teacher-based ontology, several learner-based ontologies and learning materials. Teacher-based ontology contains learning concepts and knowledge structure to be studied in a class. Also, teacher-based ontology is schema ontology to be referred by learner-based ontologies. Learner-based ontology contains concepts and knowledge structure created by students. When a teacher presents learning subjects, students investigate the subjects and extract meaningful concepts and knowledge structure to create a new learner-based ontology or extend existing learner-based ontology during their learning process.

Figure 1: The hierarchy of learning ontology



Learning ontology is described as following 5-tuples, <C, P, I, RH, RC>. The symbol C, P, I, RH and RC represent class, property, instance, hierarchy relation between classes and association between classes individually. We explain the structure of teacher-based ontology and learner-based ontology based on above 5-tuples in following some paragraphs.
Entities of teacher-based ontology are classified into following 3 categories:

1) Learning Concept – Main topics will be described in a class for a semester. This category includes fundamental concepts, advanced concepts, related concepts, examples and exercises.
2) Learning Structure – Learning concepts organized as a semantic network to describe knowledge structure of topics. In addition, learning path and schedule represented in syllabus added to the learning structure.
3) Learning Material – Teacher collects useful resources like web pages, images, audios, and videos and creates lecture notes using the resources. These lecture notes have connections to relevant concepts.

Figure 2 shows an example of teacher-based ontology describing knowledge of "data structure" learning subject. In figure 2, each node represents a learning concept which has one or more of concept types. For example, "Stack" and "Queue" have a fundamental concept type and "Call Stack" has a example type. Table 1 shows a part of classes, properties and relationships of learning ontology.

Figure 2. A teacher-based ontology representing knowledge structure of 'Data Structure'

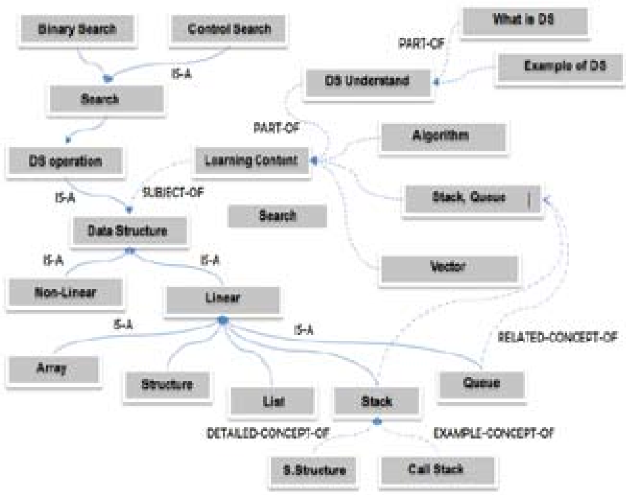


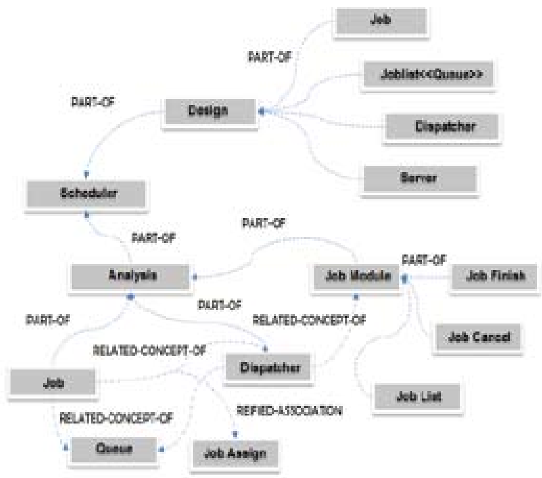
Table 1. Classes, properties and relations defined in teacher-based ontology

Type	Name	Description
Class	Learning Concept	Root class
	Fundamental Concept	Conceptualization of fundamental topics of learning subjects
	Advanced Concept	Conceptualization of advanced topics of learning subjects
	Related Concept	Conceptualization of additional topics of learning subjects
	Example	Conceptualization of example topics of learning subjects
	Exercise	Conceptualization of exercise topics of learning subjects
Property	Name	Concept name
	Alias	Alias of concept name
	Definition	Definition of concept
	Description	Description of concept
	Expression	Expression of concept
	Value	Value of concept
	External Resource	Addressable external learning resources using URLs
	Internal Resource	Stored internal learning resources such as lecture notes, images, audios, videos, etc
Relation	Fundamental-Concept-Of	A is fundamental class of B Reversed relation is Has-Fundamental-Concept
	Advanced-Concept-Of	A is advanced class of B Reversed relation is Has-Advanced-Concept
	Related-Concept-Of	A is related concept with B Reversed relation is Has-Related-Concept

	Example-Of	A is example class of B Reversed relation is Has-Example
	Exercise-Of	A is exercise class of B Reversed relation is Has-Exercise
	Same-Concept	Both concepts have same semantic
	Diff-Concept	Both concepts have opposite semantic

Learner-based ontology, which is created by students, conceptualizes knowledge acquired in the process of solving the problem presented by a teacher. Students create reified associations to represent semantic relation between concepts. Figure 3 shows an example of learner-based ontology which represents knowledge structure of job scheduler's function of operating system.

Figure 3. A learner-based ontology representing knowledge structure of 'Job Scheduler'



Implementation of learning ontology

In this paper, we implement learning ontology based on Topic Maps[9] and Ontopia Knowledge Suite which is a topic maps management system developed by ontopia company. Topic Maps are new ISO standard which allows to describe knowledge and to link it to existing information resources. Topic Maps are designed to enhance navigation in complex data sets. Although Topic Maps allow us to organize and represent very complex structures, the basic concept of this model is simple, i.e. topic, occurrence, and association. RDF/S and OWL[2] are ontology languages for agent systems in the Semantic Web but Topic Maps are used to construct ontologies for knowledge and information management.

Topic Maps are more appropriate to represent ontologies for knowledge and information management because RDF/S is URI resource-oriented description scheme but Topic Maps are subject-oriented description scheme. Topic Maps can describe semantic information of subjects without their resources. We use Topic Maps for explicit specification of learning ontology because many subjects of the ontology do not have any digitalized resources.

A topic maps management system, Ontopia Knowledge Suite, consists of a topic maps editor named as ontopoly, a generic navigator named as omnigator, and a visualizer of topic maps. Using OKS, teachers and students create and manage their partial learning ontologies and publish them into the integrated learning ontology merging partial ontologies.

We applied our method to a class, Understanding Data Structure, to evaluate the effectiveness of learning ontology-based education. We collect and analyze two kinds of experimental data like feedbacks from students and test data such as midterm exam, final exam, quiz, homework, and so on. Feedbacks of students are acquired by the interview with students. Table 2 shows the result of feedbacks of students.

Table 2. The feedback from students about learning ontology-based education					
Question	(1)	(2)	(3)	(4)	(5)
1) Students have good understanding of ontology-related technologies.	_				
2) Student can extract meaningful concepts from learning materials, essays created by themselves, or textbooks.		_			
3) Students can define new concepts in learning ontologies.		_			
4) Students can relate new concepts with other existing concepts based on semantic relation types.			_		
5) Students identify and describe competency questions easily.			_		
6) Students familiar with discussion and presentation based on learning ontology.	_				
7) Students can understand the meaning of concepts defined by other students.		_			
8) Students can understand the knowledge structure of learning ontology.		_			
9) Learning ontologies are useful for representing and sharing of knowledge owned by students.		_			

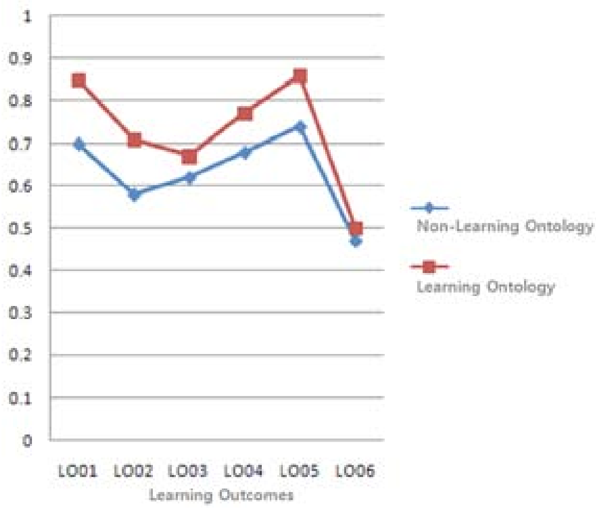
In table 2, numbers like (1), (2), (3), (4), and(5) represent the level of agreement. (5) means extremely agreement but (1) means extremely disagreement. 5 questions from 1) to 5) survey the feedbacks from students about the difficulties in creating learning ontologies. The other 4 questions from 6) to 9) survey the effectives of learning ontologies during presentation and discussion of learning knowledge in classes.

From analysis of the feedbacks of students we know that students understand the fundamental concept of ontologies and the way of applying ontologies to learning. However, creating of learning ontology is somewhat difficult work but it is useful to present, discuss, and share of studied subjects of students.

The graph depicted in figure 4 shows the values of learning outcomes before and after applying learning ontologies to class. We compute the values of learning outcomes of students through evaluating of quiz, exams, homework, and so on. We define learning outcomes as follows:

LO1 – Understand fundamental concepts of learning subjects
LO2 – Understand semantic relationship between concepts of learning subjects
LO3 – Problem understanding and solving ability
LO4 – Knowledge structure identifying ability
LO5 – Knowledge representing and sharing ability
LO6 – Critical thinking ability

Figure 4. Learning outcomes before and after applying learning ontology to class



Conclusion

Active learning is one of methods to obtain higher learning outcomes of students in class. In this paper, we propose a method to lead active learning and self-leading learning of students. Our method includes creation of learning ontology, discovery and sharing of knowledge based on learning ontology. The learning ontology is composed of teacher-based ontologies and learner-based ontologies. Teacher-based ontology contains learning concepts and knowledge structure to be studied in a class. Also, teacher-based ontology is schema ontology to be referred by learner-based ontologies. Learner-based ontology contains concepts and knowledge structure created by students.

We applied our method to a class, Understanding Data Structure, to evaluate the effectiveness of learning ontology-based education. We found that learning ontology-based teaching and learning enhances the learning outcomes of students through interviewing from students, defining specific outcomes, and comparing outcomes of students before and after applying learning ontology to the class.

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