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Learning Concept Sequencing through Semantic-based Syllabus Design and Integration

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Abstract

The semantic web, which has been evolving continuously, has focused into the conceptualization and semantic relationships of data to enable the web of data rather than human-readable web. E-learning also has been evolving through incorporating various web technologies like information representation and retrieval, social networking, and cooperative communication. There are many ontological approaches that have been suggested to construct the semantic relationships between learning materials. In this paper, we consider the semantic representation of the fundamental information of learning domains like curriculum and syllabus. We propose a layered structure of learning ontologies, which are composed of curriculum ontology, syllabus ontology, learning subject ontology and learning concept ontology. In addition, we define a semantic structure of syllabus to support adaptive learning sequencing based on the syllabus.

Keywords: Curriculum, Learning Ontology, Sequencing, Syllabus

1. Introduction

As the rapid progress of the Internet and Web technologies, e-learning technologies also have been improved by applying these new web technologies for the last decades. Similar to the evolution of Web technology, the evolution of e-learning technology can be categorized into e-learning 1.0, e-learning 2.0, and e-learning 3.01. In e-learning 1.0, learning content created, stored and distributed on the Web for viewing the content online. E-learning 1.0 made learning objects available online to support easy and convenient access.

E-learning 2.0 incorporates the capability that students can access learning material passively as well as share their opinions by writing notes. E-learning 3.0 is characterized with the both of collaborative and intelligent[2]. In e-learning 3.0, students can have self-organized or personalized learning based on the application of the Semantic Web technology.

Until now, there are many researches that have been considered the combination of e-learning technologies and ontological engineering to build intelligent e-learning services[3]. These approaches can be classified into the ontology model creation of curriculum and syllabus[4], ontological representation of metadata of learning materials and ontology-based learning objects organization and retrieval[5]. To create intelligent instructional systems of e-learning domain, ontological engineering, tools and applications can be applied[6].

For example, ontology creation methodologies, like Methontology, Tove methodology, and On-To-Knowledge, can be used to build ontology models for many different kinds of learning objects and learning paths[7]. However, these ontology-based annotation

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approaches are describing metadata of learning objects rather than learning concepts. The integration of multiple ontologies and conceptualization of learning subjects should be provided to enable a higher quality of intelligent e-learning services.

Curriculum sequencing denotes the organisation of learning units, i.e. courses, in an appropriate order for those students can learn their subject areas and learning tasks. In e-learning filed the previous studies have proposed the approaches to construct adaptive learning paths for suitable for students individually. However, they are concerned only courses as learning units rather than more detailed learning concepts, which are described in learning materials or lectures, to be ordered with curriculum sequencing[8].

The syllabus is created by an instructor for students in order to introduce the teaching course and provide useful information and learning materials. Most students may use the course syllabus to recognize course purpose, policies, assignments, tests, out-comes and so on. The course syllabus is an important entity as a skeleton of course, but most syllabuses only organize general information about the course like title, description, instructor, grading policy, textbook, schedule and so on. To enable syllabus-based intelligent services, the textual unstructured syllabus should be transformed into the well-designed semantic model[9].

Our ongoing e-learning project has a goal to develop a learning ontology model which integrates different kinds of learning entities like curriculum, syllabus, learning subjects and learning materials based on a layered structure. In addition, we have been developing ontology-based services, which are curriculum aligning, syllabus classification, semantic retrieval of syllabuses and learning concepts, and adaptive learning path recommendation. In this paper, we propose a layered structure of learning ontologies, which are composed of curriculum ontology, syllabus ontology, learning subject ontology, and learning concept ontology. In addition, we define a semantic structure of syllabus to support adaptive learning sequencing based on the syllabus.

2. The Integrated Learning Ontology

We consider a curriculum as the top-level information of educational data entities of a university. Generally, a curriculum is composed of a list of courses, which are scheduled for education period. A course can be defined as a set of syllabuses, teaching and learning activities, lecture materials, assessment and so on. A syllabus, which is a blueprint of a course, includes various important information describing instructor, learning objective, assignment, policy, teaching schedule and so on.

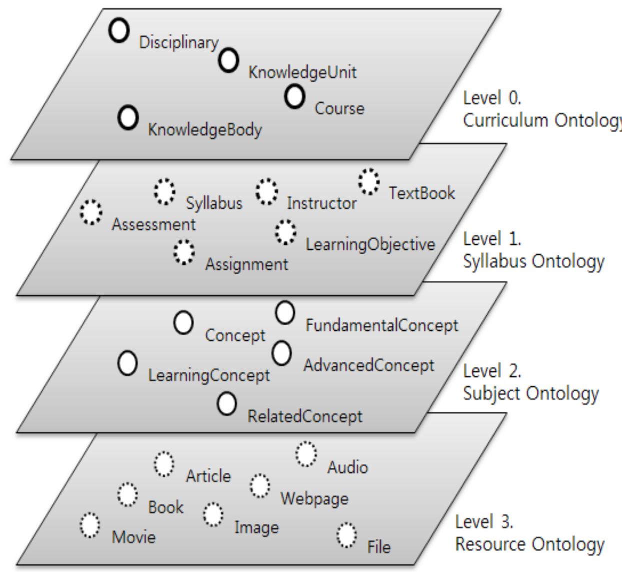

Figure 1. Four-layered integrated learning ontology.

A weekly teaching schedule represented in a syllabus contains the core topics that students should learn in a semester. Each topic can be conceptualized with a series of learning concepts and relationships between them, which has specific learning materials and objects, such as paragraphs of textbook, multimedia items, web pagesand so on. All above mentioned educational information should be integrated and interlinked to provide the intelligence services on e-learning environment. Figure 1 shows the four-layered learning ontologies, which are composed of Curriculum Ontology, Syllabus Ontology, Subject Ontology and Resource Ontology.

3. Curriculum Ontology Design

Current most curriculum management systems of universities provide only a list of open courses and credit information about them for each department. The goal of our curriculum ontology is in the provision of a complete representation of the knowledge areas of disciplines for educators, curriculum designers, education jurisdictions and students. Thus, the curriculum ontology can be used to support curriculum development through curriculum matching, interlinking and classification between relevant disciplines. In addition, it covers a set of syllabus ontologies, linked to course classes defined in the curriculum ontology.

In order to design the curriculum ontology, we referenced Computing Curricula 2013[10], which is an international curricular guideline for undergraduate programs in computing related disciplines created by ACM and IEEE-Computer Society. As shown in Table 1, classes defined in the curriculum ontology represent not only the existing curriculum structure, but also knowledge structure defined in CC2013. Table 1 describes a partial list of classes defined in the curriculum ontology.

Figure 2 represents some relationships of the curriculum ontology established between classes, which are including has Body of Knowledge, has Knowledge Area,

Table 1. The classes of curriculum ontology

Class	Label	Superclass	Subclass of	Definition
Discipline	Discipline	-	Body of Knowledge	Field of study
Body of Knowledge	Body of Knowledge	Discipline	Knowledge Area	Main knowledge body of the discipline
Knowledge Area	Knowledge Area	Body of Knowledge	Unit of Knowledge	Subjects of a body of knowledge
Unit of Knowledge	Unit of Knowledge	KnowledgeArea	Course	Category of a knowledge area
Course	Course	Unit of Knowledge	Elective Course, …	Course
Competency	Competency	-	-	Learning competency
College	College	University	Department	College of a university
Department	Department	College	-	Department of a college

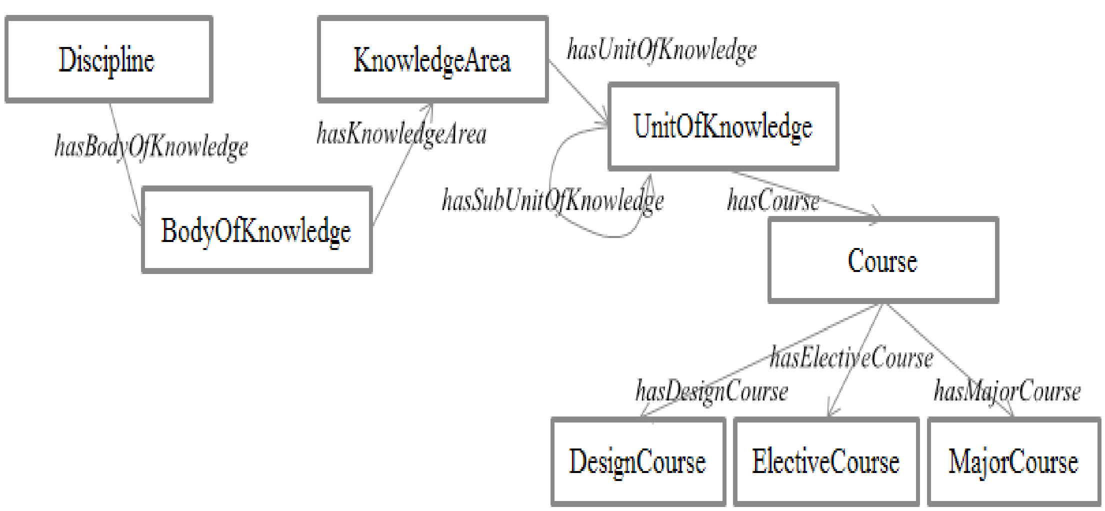

Figure 2. Relationships between classes of the curriculum ontology.

has Course, has Major Course, has Elective Course and so on. For example, a specific course titled as "Understanding Java Programming" has a subsumption relation with an instance of Unit of Knowledge class titled as "Java Programming".

The curriculum ontology in which all relevant concepts and relationships between the concepts of the discipline are formalized can be served as a knowledge base for supporting curriculum review, development and progress. More specifically, two curriculum ontologies can be aligned and compared to performing the existing ontology matching approaches to figure out the similarity and dissimilarity of them. The result of aligning and comparing is useful as a reference for improving the current curriculum.

4. Syllabus Ontology Design for Learning Concept Sequencing

The syllabus is a kind of blueprint of a course to guide students. A teacher creates a syllabus for introducing his/her course, which will be taught in the upcoming semester, and helping students to register and ready the lecture. Much important information like learning objectives, outcomes, grading policy, assignments and learning topics is described in detail using predefined formats or templates. Nevertheless, students underestimate the value of the syllabus. They read and reference syllabuses only for preparing the courses, which will be taken by them in next semester. If syllabuses can be represented as well-structured and machine-readable formats, the following intelligent services for supporting teaching and learning can be developed.

- Syllabus matching and interlinking.
- Syllabus versioning and history tracking.
- Syllabus recommendation.
- Syllabus-based adaptive learning pathway.
- Syllabus knowledge bases with semantic searching and browsing.

We design syllabus ontology after performing the analysis of textual syllabus formats, which are available on the web and defining classes, properties and semantic relationships to describe a unified format. Table 2 shows a partial set of defined classes in the syllabus ontology. The top most abstract class is Syllabus, of which subclasses are extracted and defined from the existing formats after inventing a standard structure. The class hierarchy rooted

Table 2. The classes of syllabus ontology

Class	Label	Superclass	Subclass of	Definition
Syllabus	Course Syllabus	Course	Instructor, …	Core concept
Instructor	Instructor	Syllabus	Teacher, Assistant	Course instructors
Learning Objective	Learning Objective	Syllabus	-	Description of learning objectives
Learning Material	Learning Material and Object	Syllabus	Text Book, Article, …	Learning materials including textbooks
Teaching Method	Types of Teaching Method	Syllabus	Lecture, …	Different kinds of teaching methods
Learning Method	Types of Learning Method	Syllabus	Reading, Writing, …	Different kinds of learning methods
Assignment	Assignment	Syllabus	-	Assignments
Exam Quiz	Exam and Quiz	Syllabus	-	Exams and quizs

with Syllabus class has multiple descendants, which are connected with part of relations in different depths.

To measure the achievement of students, we formalize and design the structured format of learning objectives. Most of all learning objectives in the current syllabuses are described as textual format. For example, learning objectives, a course syllabus titled "Understanding Java Programming" may be described as follows:

- Understand the syntax and semantic of Java programming language.
- Design a class through defining properties and methods.
- Implement programs in the object-oriented perspective.

Teachers and students read and understand textual learning objectives. However, the textual description should be formalized to perform machine-readable processing and achievement calculation automatically. We design a learning objective class and relationships depicted in Figure 3. As you see in Figure 3, learning objectives have connection with assignments, exams including quizzes and learning subjects.

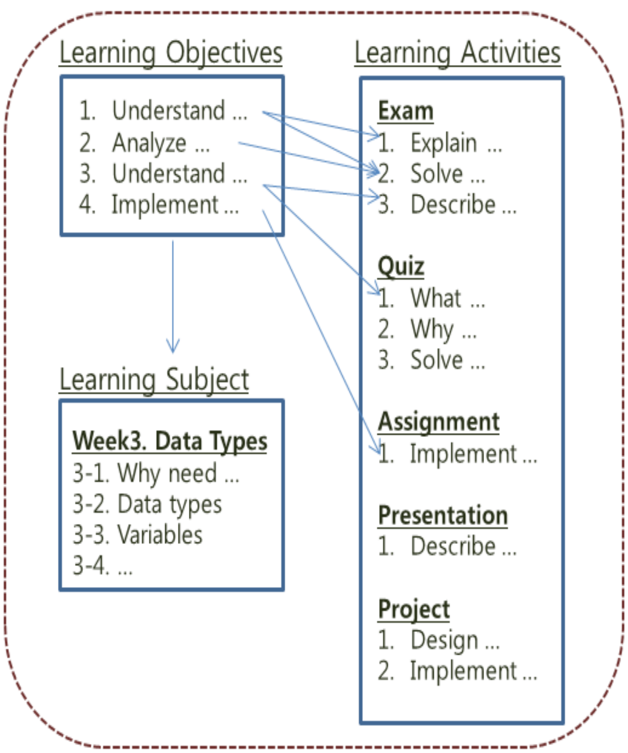

Figure 3. Learning objectives should be related to learning subjects and activities to measure the learning achievement of students.

First of all, we reference the Boom's taxonomy and define the structure of learning objective class as the following tuple which is composed of five elements, identifier, learning objective, cognitive level, attitude level and skill level.

$$\langle ID, obj_i, C_j, A_k, S_p \rangle \quad (1)$$

obj: each sentence of learning objectives.

C: a specific cognitive level related to obj_i

A: a specific attitude level related to obj_i

S: a specific skill level related to obj_i

To create interlinks between learning objectives and assignments, we add identifiers of learning objectives to the related each of the assignments. For exams and learning topics, we did the same process to connect with learning objectives. In addition, we create an achievement matrix in order to measure the learning achievements of students for learned topics weekly as well as the entirety of a course as depicted in Figure 4. In the achievement matrix, the columns are learning objectives and rows are students. Each cell has a value representing the degree of achievement of a certain student against a specific learning objective.

From the achievement matrix, we can figure out students who have a lower achievement for each learning objective than a specific threshold, which means a minimum requirement. These unfulfilled students can be guided to study the unachieved topics by the generation of adaptive learning paths. The adaptive learning paths can be generated in different granularity. The high-level learning path can be created using syllabuses and their relationships. The low-level learning path can be created

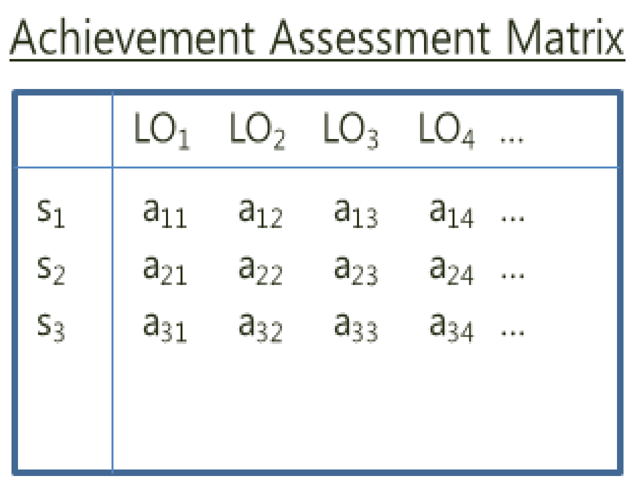

Figure 4. The achievement assessment matrix.

using learning concepts and their relationships defined in the subject ontology.

5. Conclusion

In the education fields, both of curriculum and syllabus are very important for teachers and students. They can understand what they teach and learn for each semester from curricula and syllabuses. The goal of our research is the improvement of the usability of curriculum and syllabus through the design and implementation of learning ontologies. We designed the semantic model of curriculum with the purpose of organizing knowledge areas and subjects for each discipline rather than laying out courses. Curriculum ontology can be used to integrate different curricula of departments of same discipline or enable the convergence of multiple disciplines.

Our focus on design of syllabus ontology is the development of the standard knowledge structure to be used for creating syllabus repository. We created the schema of syllabus ontology to include multiple subject ontologies which conceptualize learning concepts be taught in lectures. In this paper, we present a syllabus classification scheme as well as learning ontologies. This scheme can be used to transform unstructured syllabus into an instance of syllabus ontology and then store the instance into a syllabus repository.

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