Developing curriculum sequencing for managing multiple texts in e-learning system

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Abstract — *Current curriculum sequencing is making a text sequence rather than a curriculum sequence. In an e-learning system, the "one course-multiple texts" is a popular phenomenon to provide flexible alternative. E-learning system is therefore expected to provide an integrated curriculum sequencing to manage various sequences from multiple texts. However, each text may have different editing and cataloging in its contents. Besides, multiple texts imply their sequencing knowledge such as connection between contents is distributed in publishers. Thus, developing curriculum sequencing for managing multiple texts becomes problematic. This study utilizes an ontological mechanism in terms of a knowledge intensive approach to create general course sequence for planning the learning based on multiple textbooks. Ontology is an emerging technology for implementing semantic knowledge that has been applied in expert systems. Ontology is typically utilized to establish taxonomy of a task domain and mold it into a conceptual structure. The proposed approach includes two components: (1) OWL-based ontology is used to represent abstract views of content sequencing and course materials; and (2) added semantic rules are used to represent relationships between individuals. Following knowledge base creation, both practical curriculum sequences and course materials can be inserted as factual knowledge. A reliable knowledge base can be established using inference power. Some examples regarding the courses of elementary school are presented to demonstrate the effectiveness of the proposed design. Experimental lessons show that ontological approach can make curriculum sequencing flexible and integrate multiple texts to a sequence successfully. Consequently, the knowledge intensive approach can manage intricate information such as curriculum content sequencing problems.*

Index Terms — *Curriculum Content Sequencing, E-Learning, Knowledge Model, Ontology*

1. INTRODUCTION

Course planning is an important pedagogical services and practical issues. Two common categories of course planning are scheduling and sequencing. Course scheduling relates to the need to assign courses taught in a given semester an instructor, classroom and time period (Combs *et al.*, 2005). A course syllabus is the example of scheduling. Course sequencing involves managing a learning route for learners to help them reach a course goal. A typical learning route outlines the specific learning objects required along with the order in which they must be taken. Because students have distinct backgrounds and preferences, creating adaptive learning routes for individual learners is a challenge (Marjanovic, 2007; Brusilovsky & Vassileva, 2003). In most country, education is compulsory for children. The competent authority of education usually develops a standard guide to instruct teachers, students and publishers for reaching a same learning goal.

In a face-to-face classroom, an instructor teaches a course simply using a syllabus that covers the course in sequence. Instructors usually design a learning route primarily based on a single material source such as a textbook rather than multiple sources. Students then follow a fixed list of study contents. Since students have minimal alternatives among which they can choose, individual interests and preference are generally ignored (Chen *et al.*, 2006). On the other hand, education reformation is continuously under development. In most countries, education departments had developed a high level course standard both to the instruction that teachers may follow to teach in a given domain and to the publishers that may be used to develop course materials. The one guide-multiple text policy is an example for providing multiple texts to course learning. Owing to inconsistency in materials editing and cataloging, the alternative is usually in texts rather than in contents.

With the progress of the information technology, electronic learning (or e-learning) is an instructional platform that relies on the Internet as the communication and presentation media. Researches have shown that e-learning provides effective and convenient solutions that facilitate sharing, integration and reuse of courseware (Alexander, 2001; Cloete, 2001; Lin & Hsieh, 2001). Recently, e-learning is rapidly growing in education applications, which do not require the physical presence of learners. E-learning is a current trend in providing enhanced services capable of outperforming traditional classroom teaching (Kaltenbach & Guo, 2001; Zhang *et al.*, 2004). E-learning brings changes not only in digitalized materials but also in learning styles and pedagogical activities. New services and requirements such as course sequencing for integrating multiple sequences of textbooks are worth discussing. Owing to the inconsistency in text contents, assembling learning sequences from multiple materials incurs sequencing complexity. Text independent problem-solving methods may help create an abstract model from small-grained reusable common components

2. RESEARCH QUESTIONS

Curriculum planning is an important pedagogical services and research issues. E-learning provides a flexible access environment that represents a cost-effective modern pedagogic method. E-learning treats every individual as unique and different, having their own individual learning routes (Huang *et al.*, 2007). Though e-learning systems provide rich learning objects for selection, naïve users have fewer pedagogical experiences to use in planning the learning route on their own. Thus, it is better for sequencing experts to determine content sequencing than for users to do it.

Human learning is complex mental processes and cognitive transition. The typical cognitive process includes six dimensions, including knowledge, comprehension, application, analysis, synthesis and assessment. Curriculum content sequencing thus must be performed by experienced experts who can divide the course into segments based on high level guidelines associated with achieving a curriculum goal. The Essential Academic Learning Requirements (EALR) is an example, which provides an overview of what the knowledge students should have attained in grades K-12 (http://www.k12.wa.us/curriculuminstruct/). Numerous curriculum sequencing activities exist worldwide for developing practical standards, particularly for compulsory education. Such guidelines not only cover the curriculum content to be taught but also the editing of the course. To exploit an e-learning environment, a flexible learning route should incorporate learning objects from diverse publishers. There are four main participants in curriculum content sequencing system development. Issues related to these participants are detailed below.

- E-learning system: How does the system learn the content sequencing knowledge? How does the system consistently manage learning objects? What is the best method of developing a durable knowledge base and maintaining a reliable system?
- Sequencing experts: How is sequencing expertise captured as systematic knowledge? How are specific sequences provided for inclusion in the knowledge base as factual knowledge?
- Materials providers: How do materials providers connect their learning objects with the nodes of specific sequences and identify corresponding substitutions from other providers?
- Users: How do users interact with the system to obtain a learning route based on their curriculum competences?

The course sequencing logic is easily to understand, but complex enough to implement when the learning objects are given by a wide range of sources. The questions then arose about what features (including characteristics and behaviors) a sequencing mechanism would be interested in and how sequence can be generated from the information. Our hypothesis is that ontology can be used to provide formal basis for representing the semantics of knowledge elements and rules for representing relationships between practical instances. To resolve the above sequencing difficulties it is necessary to develop an abstract model to capture the knowledge of these issues. Consequently, the abstract model of content sequencing requires the cooperation of the above characters.

3. RESEARCH DESIGN

To computerize the course sequencing, the abstract views of problem solving are captured and stored in knowledge base and then be retrieved based on Web-based applications. Fig. 1 shows the designed framework of knowledge-based system. An ontological knowledge-based system typically consists of application ontology plus instances (an extension of the ontology). Asserted instances are concrete objects conforming to the definition of ontology. In ontology community, an instance is also called an individual or factual knowledge. Application ontology can be divided into two kind ontologies including domain ontology and problem-solving method (PSM) ontology. Domain ontology managed essential knowledge elements such as concept, characteristics and relationships of a specific application domain. For example, courses, texts and publishers are the scope of our application domain. On the other hand, problem-solving methods are abstract models of how to solve certain problems. Thus, PSM ontology assembles the propositional knowledge to reach the answers required to solve specific tasks. PSM ontology is usually domain-independent and reusable (Eriksson *et al.*, 1998). Developer specifies the correspondences between domain ontology and PSM ontology by means of explicit mapping relations.

Above design is a typical framework of an ontological knowledge-based system. Ontology is as similar as taxonomy that consists of the concepts and relations in a domain. Developers usually cooperate with experts to acquire expertise to get the domain ontology done and define the role in which domain knowledge is used. Some software editors such as protégé provide engineering environment that allows developers to create ontology into computers and to represent ontology using formal language such as Web Ontology Language (OWL). Once the ontology has built, domain specialists can then utilize ontology as a knowledge acquisition tool to gather instances for knowledge bases building. With the help of inference engines, the knowledge-based system enables to solve tasks by implementing reasoning functions. The performance of knowledge inference is dependent on the expertise available to the problem solver.

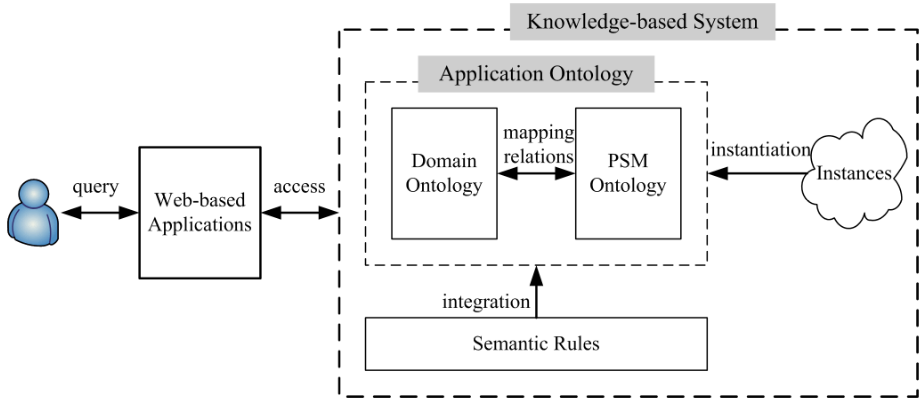

FIGURE 1
THE FRAMEWORK OF AN ONTOLOGICAL KNOWLEDGE-BASED SYSTEM

3.1 Identifying course sequencing tasks

Tasks are goal oriented activities in the real world that a computer system is supposed to accomplish. Before creating ontology, identifying the task of KBS is essential step. Task analysis can be simplified as finding the problem as well as the inputs and outputs of the problem solving process. The course sequencing task refers to arranging learning objects in a particular order. In formal education, a course is a set of subjects that specify what is needed to students for getting a pedagogical goal. Owing to modern education reform emphasized that a course can be carried by various selections of texts, it is certainly important to distinguish between a text and a course. Thus, course sequencing is expecting to define a standard sequence for multiple texts to organize their corresponding contents.

The primary purpose of the course sequencing problem formulation particularly focused on generating a course learning route automatically in e-learning system. The route contains ordered nodes representing specific topics that assemble corresponding learning objects from available texts rather than a single text. Inside a topic, learning object sets based on distinct text can then substitute each other. In problem domain perspectives, two important roles that developers must explore during the task analysis are courses and texts. Each role contains the detailed characteristics and relations limited to the needs of curriculum sequencing. On the other hand, the solving process can be analyzed as the followings:

- Sequencing: The main work is to define common roles and behaviors of how a course sequence can be made. Typical sequence roles are various node types including start, end, predecessor and successor. Course sequence behaviors are similar as flow-based patterns including sequence, merge, split and accessory. Since course sequencing is used to define a course rather than a text, course experts or educators are responsible to instantiate the roles and behaviors of a topic as a node. A course sequence can then be made by computing the ordered information of available nodes.

- Mapping: There is no individual text sequence in this study. Text is attached to a corresponding course that a course sequence comprises the mapping relations between text contents and sequence nodes. An important result of this study is providing the selection and substitute of learning objects between texts. Since each text owned its style in both editing and cataloging, an intermediary design is developing to assemble relevant learning objects for individual text. The intermediary creates the symmetry between a set of learning objects and course sequence node. Text publishers or editors required to instantiate the mappings from text contents into the intermediary.

Task analysis identifies the problems and input-output requirements to determine what assumptions the problem-solving methods can make. A course sequencing task can be concluded as making a course-level sequence which produced a standard reference based on the activities in common roles, behaviors and intermediaries. The task results generate a course sequence accompanied with available text contents and substitutes in a specific topic based on multiple texts.

3.2 Ontology Design

Ontology is an emerging approach in the knowledge-based community that the technology provides an explicit specification of a conceptualization to express high-level perspectives of a domain of interest. This section explores the ontology design in terms of the core of knowledge-based system. Two ontologies are discussed including curriculum (working domain) and sequencing (problem-solving). Ontology defines not only a knowledge framework but also a knowledge-acquisition tool that can instantiate events into a knowledge base. Knowledge holders such as instructors and publishers are responsible to maintain the KB by continually giving instances. Ontology is usually interpreted by a knowledge model that can be used as an intermediary between the real world and IT systems. As illustrated in Fig. 2, the top part is a curriculum model including two sub-models (course and text). The bottom part is a sequencing model designed for making curriculum sequence. The model is drawn using simple flowchart components including the circle representing a concept and the line arrow denoting a property. Each line arrow marks a property name describing relationships between concepts. Two categories of line arrow are “is-a” and “has-a”. The “is-a” represents inheritance between a super concept and a sub concept. The “has-a” is a relationship where one concept is a part of (or member of) another concept. The “has-a” is a user defined property such as “has_SD”. The start of line denotes the “Competence Indicators” (domain) while the arrow represents the “Specific Details” (range). Detailed design is discussed as below.

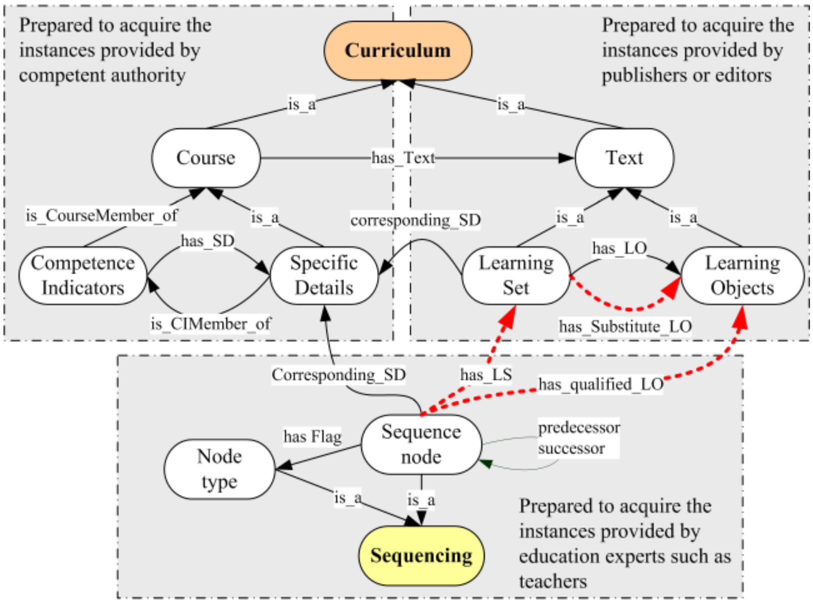

FIGURE 2
THE COURSE SEQUENCING MODEL

The curriculum ontology aims to assemble basic knowledge elements to describe the curriculum domain. In course characteristics gathering, this study consulted several curriculum standards of compulsory education. In most counties, compulsory curricula are designed by educational experts. These curricula are carefully defined by what contents should be involved and how to split, merge and connect contents. The general features of these curricula are then identified as common concepts and attributes. Two sub-concepts including Competence Indicators (CI) and Specific Details (SD) are identified as describe courses. Competence indicator represents high-level principles that are standardized requirements for an individual to reach a learning goal. Specific details describe what the concrete abilities or skills an individual obtain. A competence indicator may contain one to many specific details. Between these two concepts, “has_SD” and “is_CIMember_of” are identified as properties that are inversed of each other. In text model development, we surveyed multiple texts used in school education. Common concepts and attributes are obtained using the analysis in generalizing text editing and cataloging. Two sub-concepts including Learning Set (LS) and Learning Object (LO) are identified to describe texts. Learning object is a modular building block for a learning activity or lesson. Learning set consists of learning objects to accomplish a specific topic similar as a specific detail. Two properties including “corresponding_SD” and “has_LO” are used to describe relations with “Specific Details” and “Learning Object” respectively. A special property “has_Substitute_LO” drawn by dashed line is used to infer what equivalent learning objects of other texts.

On the other hand, sequencing ontology is designed for problems solving of how a learning sequence can be generated and what text contents should be assigned. Two sub-concepts including “Sequence Node” and “Node Type” are identified. Sequence Node concept is used to define common node’s behaviors such as predecessor, successor and corresponding SDs. Educational experts such as teachers are able to give proper knowledge as instances into node concepts. Two properties, “has_LS” and “has_Qualified_LO”, drawn by dashed line are used to receive inferred knowledge from inference engines. Node Type concept is used to indicate some annotation flags including start, end and regular.

3.3 Representing ontological knowledge model using OWL

After developing the curriculum sequencing model, Web ontology Language (OWL) is utilized for knowledge representation. OWL is an XML-based language, developed by the World Wide Web consortium (W3C). According to

OWL specifications, three increasingly expressive sub-languages are designed for different levels of usability, namely Lite, DL and Full. The most popular version is OWL-DL, which is based on description logics (DL). OWL-DL supports inference systems with computational completeness and decidability. OWL represents the knowledge elements of a model using class, property and individual, which correspond to ontology concept, role and instance respectively. The class is a general idea derived from specific instances. A class usually contained specific properties used to distinguish with other classes. Two property types are employed in OWL including "data property" and "object property". Data property can be regarded as class features that only allowed using the XML-based data-type as property value format. Object property creates the connection (or so called relationship) among concepts required for a mutually related structure. Identifying connections between concepts mainly requires specifying the ''domain" and ''range" specified inside a property.

3.4 Establishing individual relationships using SWRL

Knowledge reasoning is important in ontological knowledge base development. Researchers have reported several limitations and issues OWL in syntax and computation, especially in relationships between role chains, causing indeductibility, logical undecidability, by embedding the word problem in inferences (Horrocks & Patel-Schneider, 2004; Mei & Boley, 2006).The rules apply the syntax "Antecedent→ Consequent". Both antecedent and consequent are conjunctions of atoms of the form "$atom_1$^ .. ^$atom_n$", where a variable is indicated by a question mark (for example, ?x). However, adding such rules to the description logic inference engine results in the inference problem becoming undecidable. Golbreich (2004) noted that (1) DL and rules expressiveness are different, while (2) each paradigm better fits some specific type of knowledge and supports specific reasoning services. SWRL is an emerging technology developed to address the above difficulties. SWRL is based on a combination of OWL and Rule Markup Language (RML). SWRL extends the set of OWL axioms to include Horn-like rules, enabling the combination of SWRL rules with an OWL knowledge base. SWRL is typically used to transfer object properties, or to infer the existence of new instances of OWL classes. Developers can write SWRL rules in XML, and integrate such rules into OWL ontologies.

Semantic rules define reasonable inference steps for deriving answers, each rule can be implemented iteratively when the rule engine feeds enough facts. To understand detailed operations of the rule, Fig. 3 shows the steps of successive changes in performing inference. The purpose of this example is finding qualified learning objects from texts into corresponding nodes of a curriculum sequence. The inference needs various known facts as supporting evidences. Owing to the rule development is based on the experience in human problem solving; a problem might be addressed by different methods. In this figure, the ovals represent concepts, the circles represent instances and the line arrows represent properties. The following two rules marked by different digit symbols implement the same purpose. Each atom is attached to one or more parameters represented by a question mark and a variable

- Rule-1 is finding qualified learning objects of a specific node in a learning route. The atom sequence is denoted by digit symbols started from (1) to (5). Each atom is attached to one or more parameters represented by a question mark and a variable (e.g., ?x) that allow instances substitute it in run time. Assuming the following values (node1), (sd1), (ls1) and (lo1) are instances of (?x), (?y), (?a) and (?b) respectively. From the first atom of Rule-1, a sequence node (node1) has its corresponding specific detail (sd1); a learning set (ls1) also has its corresponding specific detail that the value must be as same as the (sd1), the learning set (ls1) has available learning object (lo1), and finally the node (node1) obtains learning object (lo1) as the inference result of property "has_Qualified_LO".
  ```
  [Rule-1]: Sequence_Node(?x)∧ Node_Corresponding_SD(?x, ?y)∧
  Learning_Set(?a)∧ LS_Corresponding_SD(?a, ?y)∧ has_LO(?a, ?b)→
  has_Qualified_LO(?x, ?b)
  ```
- Rule-2 accomplish same purpose as Rule-1 did. Compare to Rule-1, a special property "has_LS" belonging to "Sequence_Node" are unknown initially. Prior to implement Rule-2, another rule must generate the contents of "has_LS" to promise inference performance.
  ```
  [Rule-2]:Sequence_Node(?x) ∧ has_LS(?x, ?a) ∧ Learning_Set(?a) ∧
  has_LO(?a, ?b)   → has_Qualified_LO(?x, ?b)
  ```
  (Rule-2)

The last step of developing semantic rules employs an editing tool and inference engine to connect OWL-based ontology. Protégé software provides a SWRL-based rule editor using software plug-in called "SWRLTab". A rule inference engine such as JESS (Java Expert System Shell) can be embedded into Protégé to perform SWRL-based rules. The three JESS components are a rule base, a fact base and an execution engine. Consequently, performing rules can help ontology-based systems infer more implicit knowledge.

4. CASE STUDY

The curriculum content sequencing system is primarily developed for e-learners to obtain an adaptive course learning route. However, without the participation of factual knowledge providers, the knowledge base is incapable of supporting runtime needs. The applications framework contains knowledge maintenance and knowledge retrieval, as described in the followings.

- Knowledge maintenance. Two knowledge maintaining interfaces are developed for asserting curriculum sequences and course materials, respectively. For example, curriculum experts determine the CI, SD, and sequential relationships of a specific course as factual knowledge. Meanwhile, publishers upload their materials and annotate required facts to describe the corresponding materials. Following factual knowledge is given to the knowledge base; inference mechanisms are invoked to identify a new knowledge network. This updated knowledge base is assumed to contain all the knowledge necessary to solve curriculum content sequencing problems.
- Knowledge retrieval. On the user side, knowledge retrieval is similar to traditional information query. Users are asked to provide criteria for invoking knowledge retrieval functions. This study requires users to give the system their curriculum competences for specific courses. The application then retrieves the knowledge base and develops a learning route, accompanied by corresponding course materials.

4.1 Knowledge maintenance

This study developed the sequencing model by gathering general characteristics of curriculum competences. Curriculum experts must determine the sequence of a specific course by identifying competence items and connecting them in an orderly manner. For example, Figure 3 shows that a sequence of the first grade mathematics course is as the presented linked list. The listed nodes and connecting relationships are considered known facts of curriculum experts.

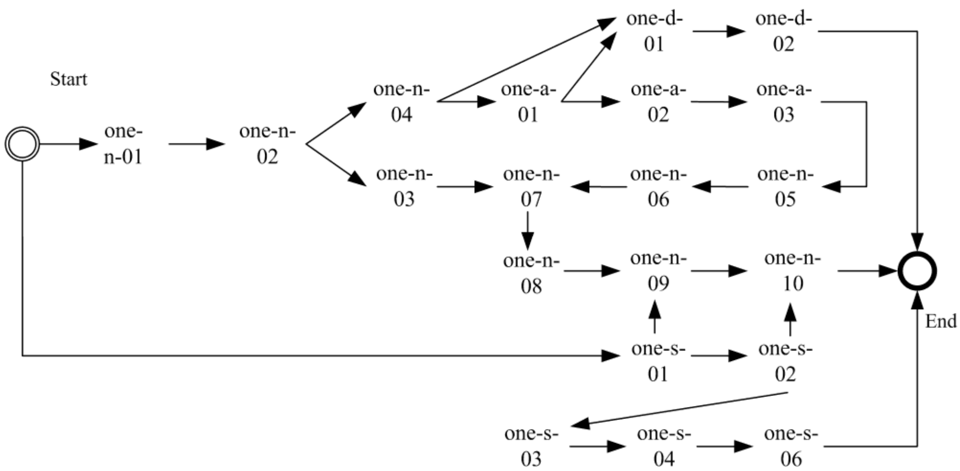

FIGURE 3
A LEARNING SEQUENCE EXAMPLE OF 1ST GRADE MATHS COURSE

This study has created interfaces that permit curriculum experts to provide both competence indicators and specific details regarding knowledge base. The interface requires curriculum experts to describe a SD and its properties. For example, curriculum experts enter “one-n-03” as the name of a SD, and three values, such as “N-1-01”, “one-n-02”, “one-n-07”, into the corresponding properties “Subordinate_to_CI”, “Pre_SD” and “Post_SD” respectively. Both “Pre_SD” and “Post_SD” denote sequential orders, where “one-n-03” has a pre-node “one-n-02” and a post-node “one-n-07”. The interface thus can be used to represent a high level view of a specific curriculum content sequence.

After defining the first grade mathematics course sequence, course publishers can annotate descriptions of materials as factual knowledge. Two stages exist in providing factual knowledge of course materials. The first stage is used to enter required descriptions of learning units. A learning unit “KH_1_n_03” has several facts such as “Kang_Hsuan_Education_Publishing” and “one-n-03” that correspond to properties “Publisher” and “Subordinate_to_SD”. The second stage involves entering required descriptions of a practical material. For example, a practical material “KH_V2U1_Count_to_50” comprises a chapter or section of this learning unit. The publisher has to insert “Kang_Hsuan_Education_Publishing” and “KH_1_n_03” into the corresponding property fields such as “Publisher” and “Member_of”, respectively. This practical material thus can be mapped to a specific sequence through inferring its “learning_unit” and then an SD can be inferred based on the “Learning_unit”.

4.2 Knowledge retrieval

To obtain a learning route from the curriculum content sequencing system, users must answer their competence status regarding specific curriculum. This study has devised an interface that lists all summaries of SD. Users simply check their capabilities and then use them as system criteria. For example, this study assumes that the user has selected two SD such as “one-n-01” and “one-n-02”. Based on the provided criteria, the retrieval application then examines the knowledge base and creates a new sequence by removing these two items. The new sequence then includes practical course materials in the corresponding node via the learning units. A new learning route is arranged using a linked list. Each node of the list is a SD that contains several course materials grouped by different publishers using the ‘#’ symbol. For example, the node “one-n-04” includes two groups such as“#Kang_Hsuan Education Publishing” and “#Nani Publishing Group”. Group course materials are required to achieve the competence needs of a specific SD. Thus, each node within a group can easily be substituted by another group.

5. DISCUSSION AND CONCLUSION

Creating a flexible course learning route for Internet learners is challenging. Before composing appropriate course materials to produce a learning route, the system needs the full knowledge required to guide the composition. The curriculum sequencing knowledge is primarily determined by content sequencing experts. Content sequencing experts provide high level views of the curriculum to ensure that students achieve standard learning goals. For practical implementation, learning goals are represented via several competence assessments such as competence indicators for validating student progress. On the other hand, course publishers edit their material contents based on competence requirements. Owing to the looseness of the sequence knowledge and content editing/cataloging knowledge, composing a flexible learning route across multiple course publishers leads to sequencing complexity.

This study utilizes a knowledge-intensive approach to gather and model curriculum contents sequencing expertise into a knowledge base. This study shows how semantic rules can be used in combination with ontologies to create sequences and practical course materials in a general abstraction model. Knowledge engineering, including expertise acquisition, knowledge modeling and knowledge representation, is implemented to establish the ontological knowledge base. The major works involve the following steps: (1) Gather the common characteristics and functions of curriculum content sequencing. This study utilized “The general guidelines of Taiwan for grade 1-9 curriculum” as the sequencing knowledge resources. (2) Identify abstract models including curriculum sequence and course materials. (3) Utilize the OWL ontology to represent the above models and the SWRL rules to identify relationships between individuals. This study has developed a curriculum content sequencing system based on Java that integrates the OWL ontology, RacerPro engine and JESS rules engine. The presented system provides knowledge maintenance mechanisms that both curriculum experts and course publishers can use to contribute factual knowledge. Users employ the knowledge retrieval interface to obtain their learning routes based on given criteria regarding their curriculum competences. Consequently, the combination of semantic rules with ontologies can manage intricate information such as curriculum content sequencing problems.

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