An Enhanced LTSA Model Providing Contextual Knowledge for Intelligent e-Learning Systems*

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Learning objects along with their sequencing are being studied to support efficient e-learning systems. They could solve the problem of costly reproduction of learning materials for e-learning systems. The problem arising here is related to the size and complexity of methods used to achieve the appropriate composition of learning objects in order to generate courses with pedagogic efficiency and value. We concentrate our attention on the adaptive and intelligent composition of learning objects. It is the main theme of instructional design, a major concern of which is the representation and organization of subject contents to facilitate the learning process. We believe that modeling the structure of subject contents, i.e., *contextual knowledge*, in an e-learning system can help an instructional designer to design and implement an adaptive and intelligent sequence of learning. A metadata-based ontology is introduced for this purpose and added to the IEEE LTSA model. Further, UML is used to design of an ontology-based educational contents model based on IMS specifications. In this way, the proposed solution provides a complete solution for the design and development of efficient e-learning systems.

Keywords: LTSA, ontology, intelligent e-learning, LTSA with contextual knowledge, an ontology-based e-learning, an ontology-based learning content, an ontology of the Korean cultural heritages, KEM (Korea Educational Metadata)

1. INTRODUCTION

Learning objects provide efficient support for e-learning systems. Recently, a global effort has been underway, aimed at developing technologies that would enable efficient e-learning; technologies based on learning objects and their description methods, i.e., metadata, as well as on processes for their management and structuring as educational entities. However, despite their potential of advancing e-learning technology, their contribution to the educational process is still limited. Thus, many researchers are trying to find intelligent ways to apply them from the pedagogical or technical point of view.

Learning objects are reusable learning materials, and the object-oriented paradigm makes them reusable objects like LEGO blocks [1]. This paradigm may solve the problem of costly reproduction of learning materials for e-learning systems. The problem

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arising here is related to the size and extent of complexity (granularity) of methods used to achieve the appropriate composition of learning objects in order to (automatically or not) generate courses with pedagogic efficiency and value [2]. The most important point here is the appropriate composition of learning objects. We will concentrate our attention on this subject.

The composition of learning objects is a concern in learning design, i.e., instructional design. Some learning theories or teaching strategies can help researchers design the structures of learning objects from the pedagogical point of view. For example, cognitive psychology suggests that a mental model consists of two major components: *knowledge structures* and *processes* for using this knowledge. Thus, a major concern in instructional design is the representation and organization of subject contents to facilitate learning [3].

Several studies have focused on the pedagogical aspect of e-learning systems over the past few years, but they have provided insufficient guidelines for e-learning designers. The primary purpose of this study is to model the subject contents structure, i.e., the structural knowledge in a mental model, for intelligent e-learning systems because we are of the opinion that the structure of the subject contents can help an instructional designer to design and implement an intelligent sequence of learning. In order to illustrate the context of our work, this paper starts with a brief introduction to related works. After introducing our learning contents structure model, we will present our case study.

2. RELATED WORKS

F. P. Rokou *et al*. distinguished three basic levels in every Web-based application: the Web character of the program, the pedagogical background, and the personalized management of the learning material [4]. They defined a Web-based program as an information system that contains a Web server, a network, HTTP, and a browser in which data supplied by users act on the system's status and cause changes. The pedagogical background means the educational model that is used in combination with pedagogical goals set by the instructor. The personalized management of the learning materials means the set of rules and mechanisms that are used to select learning materials based on the student's characteristics, the educational objectives, the teaching model, and the available media.

Many works have combined and integrated these three factors in e-learning systems, leading to several standardization projects. Some projects have focused on determining the standard architecture and format for learning environments, such as IEEE Learning Technology Systems Architecture (LTSC), Instructional Management Systems (IMS), and Sharable Content Object Reference Model (SCORM). IMS and SCORM define and deliver XML-based interoperable specifications for exchanging and sequencing learning contents, i.e., learning objects, among many heterogeneous e-learning systems. They mainly focus on the standardization of learning and teaching methods as well as on the modeling of how the systems manage interoperating educational data relevant to the educational process [5].

IMS and SCORM have announced their content packaging model and sequencing model, respectively. The key technologies behind these models are the content package, activity tree, learning activities, sequencing rules, and navigation model. Their sequencing models define a method for representing the intended behavior of an authored learning experience, and their navigation models describe how the learner- and system-initiated navigation events can be triggered and processed.

Juan Quemada and Bernd Simon have also presented a model for educational activities and educational materials [6]. Their model for educational activities denotes educational events that identify the instructor(s) involved and take place in a virtual meeting according to a specific schedule. F. P. Rokou *et al*. described the introduction of stereotypes to the pedagogical design of educational systems and appropriate modifications of the existing package diagrams of UML (Unified Modeling Language) [3].

The IMS and SCORM models describe well the educational activities and system implementation, but not the educational contents knowledge in educational activities. Juan Quemada's and F. P. Rokou's models add more pedagogical background by emphasizing educational contents and sequences using the taxonomy of learning resources and stereotypes of teaching models. But the educational contents and their sequencing in these models are dependent on the system and lack standardization and reusability. Thus, we believe that if an educational contents frame of learning resources can be introduced into an e-learning system, including ontology-based properties and hierarchical semantic associations, then this e-learning system will have the capabilities of providing adaptable and intelligent learning to learners.

The hierarchical contents structure is able to show the entire educational contents, the available sequence of learning, and the structure of the educational concepts, such as the related super- or sub- concepts in the learning contents. Furthermore, some of semantic relationships among the educational contents, such as 'equivalent', 'inverse', 'similar', 'aggregate' and 'classified', can provide important and useful information for the intelligent e-learning system.

For this purpose, an ontology is introduced in our model. It can play a crucial role in enabling the representation, processing, sharing and reuse of knowledge among applications in modern Web-based e-learning systems because it specifies the conceptualization of a specific domain in terms of concepts, attributes, and relationships. Moreover, the number of ontology-centered researches has increased dramatically because popular ontological languages are based on Web technology standards, such as XML and RDF(S), so as to share and reuse it in any Web-based knowledge system [7, 8]. Thus, we have devised a model that provides the contents structure using an ontology for an adaptive and intelligent e-learning system.

3. AN ONTOLOGY-BASED LEARNING CONTENTS MODEL

Before describing our ontology-based model, we will discuss learning environments. We will concentrate on the IEEE Learning Technology Systems Architecture (LTSA) because this model is generic enough to represent a variety of learning systems from different domains [9]. Fig. 1 shows the model used by IEEE LTSA along with our ontology-based learning contents.

Course sequencing generally starts with the learner entity component that receives the learning contents (Multimedia in Fig. 1) while the learner's behavior is being

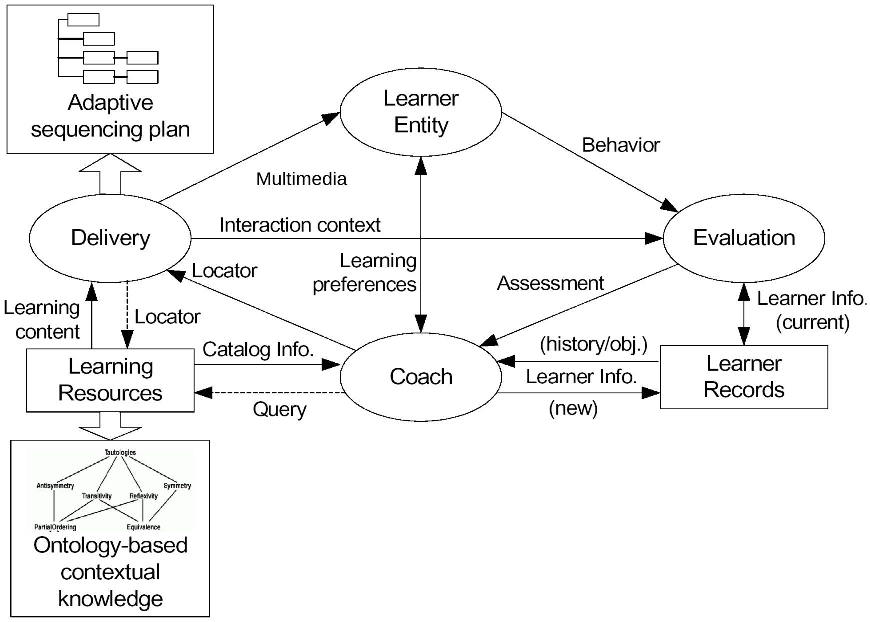

Fig. 1. LTSA with the ontology-based contextual knowledge.

observed. The instructor (the coach component in Fig. 1) sends queries to the learning resources to search for learning content that is appropriate for the learner entity component. The ontological knowledge is added to the learning resources as a resource for contextual learning, and it may be searched by means of queries. The learner's performance is measured by the evaluation component, and the result is stored in the learner records database. The data in it can be used by the coach component to locate a new content. In Fig. 1, the two squares with dotted lines are added for our proposed enhanced ontology-based model; they represent the adaptive sequencing plan and the ontology-based contextual knowledge.

Searching learning resources and sequencing a course can be done using a knowledge base of learning resources and a delivery component. To implement the knowledge base, first of all, the leaning resources have to be described by means of metadata. (In this case, two different kinds of metadata can be distinguished; the first type describes knowledge and knowledge networks; the second type describes modularized content resources, as in [10].)

The first kind of metadata consists of the contextual knowledge of the learning resources, i.e., an ontology in our model. It contains the general representation of the structural knowledge on specific domains, such as biology, history, mathematics, and so on. The ontology can be used for adaptive learning to retrieve the context of a course and to structure the contents. The second kind of metadata actually consists of the framing description of each learning object of a subject, i.e., the modularized content, which is linked to the concept of the ontology. For instructors to be able to sequence courses and create exercises adaptively, the suitability of different approaches has to be analyzed based on the relationships between the resources and their descriptions.

Fig. 2 shows a data structure diagram of our proposed model that is deduced by the above approach in the general form of UML. The learning activity class is the main class in our model, and the subject content class is the ontology of the subject knowledge. With this ontology, an instructional designer or a system developer can design an adaptive sequencing plan consisting of a learning structure, link, and sequence of specific resources in the learning activity. Other classes, such as the learner record class, are based on the IMS specifications.

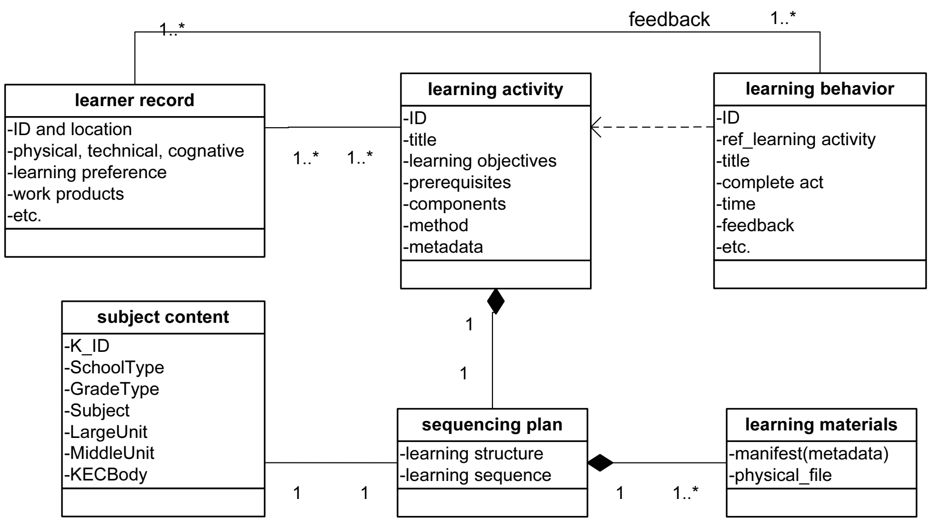

Fig. 2. A data structure diagram of our proposed model.

```
<KEC> ::= '<' KEC '>' <KECHeader><KECBody> '<' /KEC '>'
<KECHeader> ::= <K_ID><SchoolType><GradeType><Subject><LargeUnit>[<MiddleUnitName>]
<K_ID> ::= '<' K_ID '>' <identifier> '<' /K_ID '>'
<SchoolType> ::= '<'schoolType '>'(Primary | Middle | High | University | Lifelong) '<'/schoolType '>'
<GradeType> ::= '<'gradeType '>' (1 | 2 | 3 | 4 | 5 | 6)    '<' /gradeType '>'
<Subject> ::= <SubjectByKEM>
<LargeUnit> ::= <LargeUnitByKEM>
<MiddleUnit> ::= <MiddleUnitByKEM>
```

Fig. 3. EBNF for describing the header of the subject content model.

Fig. 3 shows the header of the ontology model for a specific subject's content based on KEM (Korea Educational Metadata), using EBNF. KEM consists of both core elements extracted from global metadata standards, such as DC, GEM, and LOM, and new elements representing curricula used in Korea. Two simple taxonomies for 'SchoolType' and 'GradeType' are introduced because of the need to render these taxonomies explicit. Other taxonomies are not further defined because they are dependent on the specific subject.

Based on our design described above, we designed UML collaboration. Fig. 4 shows the message flow between service providers. This figure also shows two examples. One is a situation in which a coach uses the learning resource library to search for some learning resources using the ontology-based search service, which can get concepts similar to typed keywords and provide the coach with relevant search results. The other is a situation in which the delivery service makes a sequence plan by using concept search to get similar, sub-, and super-concepts in the domain ontology. These hierarchically designed concepts help the coach design an adaptive sequence of learning activity.

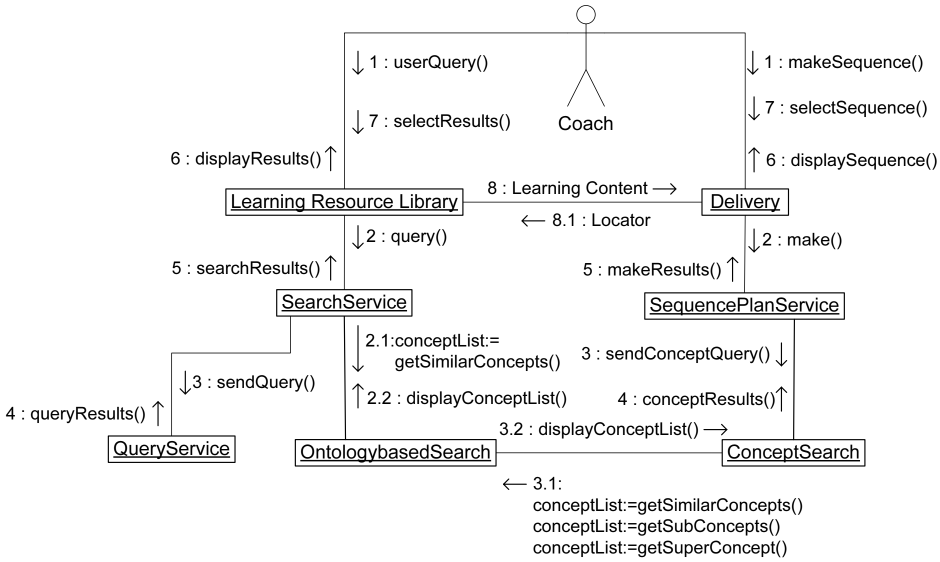

Fig. 4. Collaboration in our proposed model.

4. CASE STUDY

In the following case study, we present an example of the adaptive design of content management and a learning activity for a subject. The specific domain is cultural heritage for primary school students. The general educational goal is the comprehension of cultural heritage and relics in Korea. An ontology of Korean cultural heritage must contain some useful information about Korean history, including the ‘classification type’, ‘year or period’, ‘location’, and so on. These historical properties need to be added to the main frame of KEM for the classification of many kinds of relics. Fig. 5 shows a snapshot of the Korean history ontology for cultural heritage with the classes and properties in the Protégé 2000 ontology editor, and Fig. 6 shows a portion of the Korean history ontology source in the OWL Web ontology language.

‘Changdeokgung’ in Fig. 5 was found by using the ontology. Its current information is shown in the middle window, including that ‘Changdeokgung’ is a ‘Historic_site’ that was built in the ‘Joseon’ period and belongs to ‘World_cultural_properties’. A learner or a teacher can organize his/her learning activity adaptively by sequencing learning

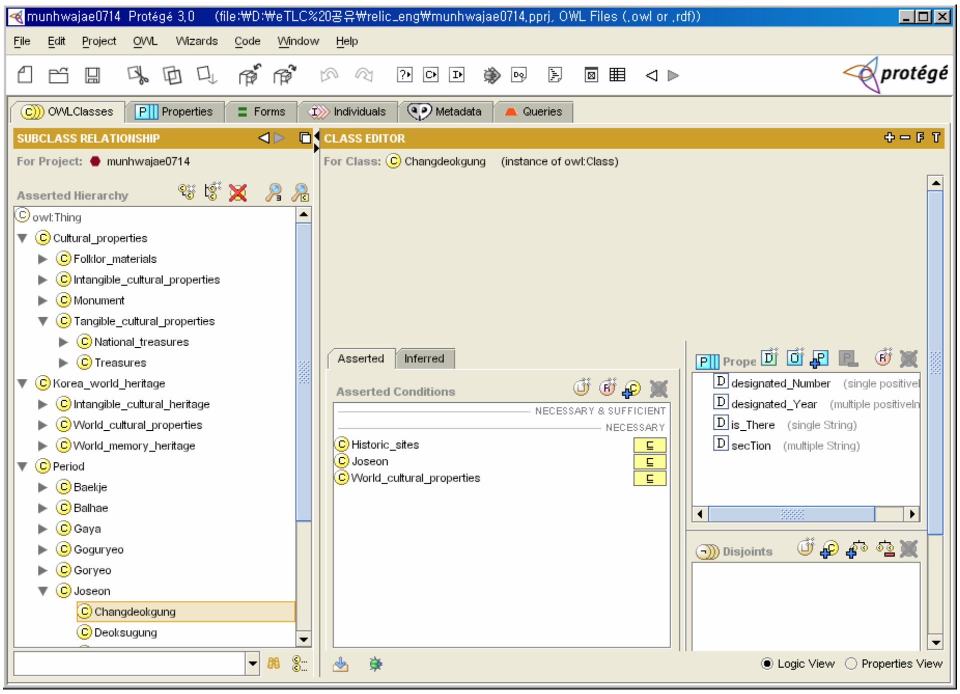

Fig. 5. A snapshot of the Korean history ontology in Protégé 2000.

```
</owl:Class>
   <owl:Class rdf:ID = "Changdeokgung">
      <rdfs:subClassOf>
         <owl:Class rdf:about = "#World_cultural_properties"/>
      </rdfs:subClassOf>
      <rdfs:subClassOf>
         <owl:Class rdf:about = "#Joseon"/>
      </rdfs:subClassOf>
      <rdfs:comment rdf:datatype = "http://www.w3.org/2001/XMLSchema#string">
        Changdeokgung Palace
      </rdfs:comment>
      <rdfs:subClassOf rdf:resource = "#Historic_sites"/>
</owl:Class>
<Changdeokgung rdf:ID = "In_Changdeokgung">
      <secTion rdf:datatype = "http://www.w3.org/2001/XMLSchema#string">royal_palace</secTion>
      <is_There rdf:datatype = "http://www.w3.org/2001/XMLSchema#string">
        Seoul Jongro_gu</is_There>
      <designated_Year rdf:datatype = "http://www.w3.org/2001/XMLSchema#positiveInteger">
        1997</designated_Year>
      <designated_Number rdf:datatype = "http://www.w3.org/2001/XMLSchema#positiveInteger">
        122</designated_Number>
</Changdeokgung>
```

Fig. 6. A portion of the Korean history ontology in OWL.

contents using an ontology in the left window that shows contextual knowledge about Korean cultural heritage. For example, one course can further explore the cultural heritage of the 'Joseon' period; another course can investigate other 'Historic_sites' or 'World_cultural_properties' in Korea. Some relevant properties related to current heritage are shown in the right window.

Fig. 7 shows a diagram of collaboration for our case study based the diagram shown in Fig. 2. Among several classes, the ontology of heritage is located in the manifest (KECBody) of the subject content class.

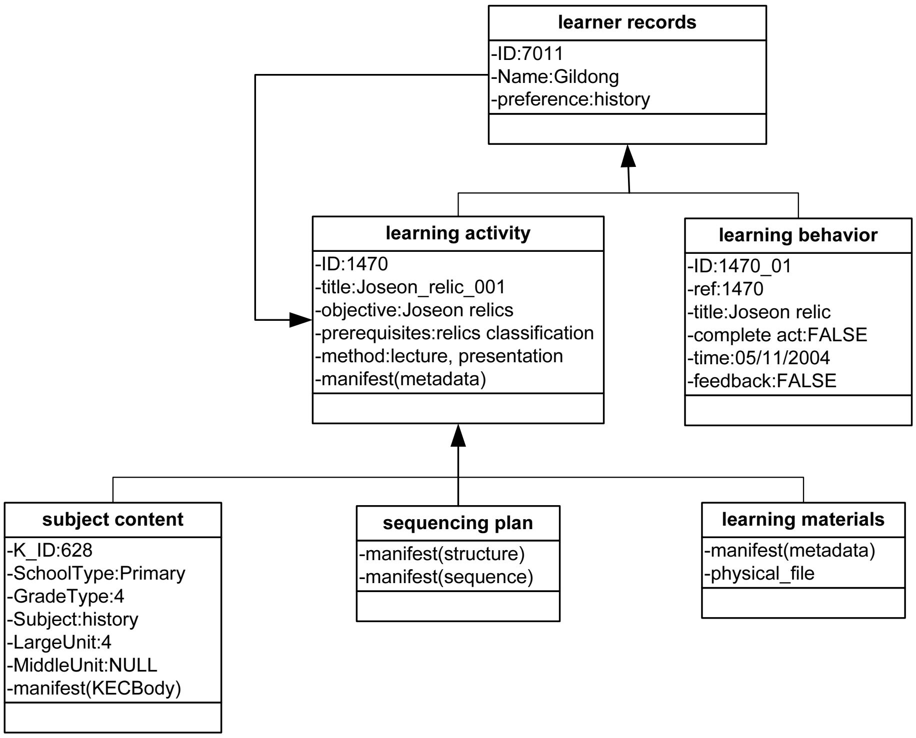

Fig. 7. Collaboration in the case study.

5. CONCLUSIONS AND FUTURE WORKS

The enhanced model proposed in this paper identifies the problem of currently deployed Web learning architecture models and intends to explore an efficient and practical solution. A metadata-based ontology is introduced for this purpose and added to the IEEE LTSA model. UML is used for the design of an ontology-based educational contents model based on the IMS specifications. In this way, the proposed solution can help instructional designers design and develop efficient e-learning systems. To evaluate our model, we plan to develop a prototypical Learning Content Management System (LCMS), i.e., a learning resource library, with an ontology and a Learning Management

System (LMS). After developing the prototype system, we will apply it to a history class in a primary school for evaluation in a real learning situation.

We believe that there are two primary advantages of the ontology-based contents model in this paper. One is that the proposed model, which contains a hierarchical contents structure and semantic relationships between concepts, can provide related useful information for searching and sequencing learning resources in e-learning systems. The other is that it can help a developer or an instructor develop a learning sequence plan by helping the instructor understand the why and how of the learning process.

REFERENCES

1. D. A. Wiley, "Connecting learning objects to instructional design theory: a definition, a metaphor, and taxonomy," http://reusability.org/read/chapters/wiley.doc, 2002.
2. F. P. Rokou *et al.*, "InfoLab: a web learning pedagogical based content repurposing approach," in *The 3rd IEEE International Conference on Advanced Learning Technologies*, 2003, pp. 150-154.
3. M. D. Merrill, "Knowledge objects and mental-models," http://reusability.org/read, 2003.
4. F. P. Rokou *et al*., "Modeling web-based educational systems: process design teaching model," *Educational Technology and Society*, Vol. 7, 2004, pp. 42-50.
5. H. Adelsberger *et al.*, "The Essen model: a step towards a standard learning process," http://citeseer.ist.psu.edu/515384.html, 2003.
6. J. Quemanda and B. Simon, "A use-case based model for learning resources in educational mediators," *Educational Technology and Society*, Vol. 6, 2003, pp. 149-163.
7. Y. Sure *et al.*, "Methodology for development and employment of ontology based knowledge management applications," *ACM SIGMOD Record*, Vol. 31, 2002, pp. 18-23.
8. C. Brewster *et al.*, "Knowledge representation with ontologies: the present and future," *IEEE Intelligent Systems*, Vol. 19, 2004, pp. 72-81.
9. IEEE LTSA, IEEE P1484.1/D9 Draft Standard for Learning Technology – Learning Technology Systems Architecture (LTSA), 2001, pp. 17-43.
10. S. Fischer, "Course and exercise sequencing using metadata in adaptive hypermedia learning systems," *Journal of Educational Resources in Computing*, Vol. 1, 2001, pp. 21-42.

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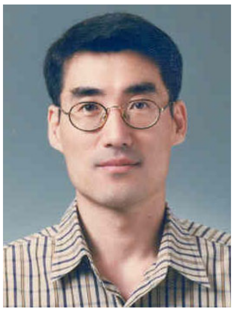

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