

A Semantic Web System for Helping Teachers Plan Lessons Using Ontology Alignment

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Abstract. In Japan, there are very few specialist teachers of IT education, though interest in IT education has continued to grow. And, it is difficult for them to gain the necessary knowledge and skills, since the educational goals and techniques of IT instruction are not yet clearly defined. So, we built ontology of the goal of IT education and its applications based on Semantic Web technology. This application was based on the alignment of ontologies to reuse the result of other research, and we have already described the outline of this application in the different paper. In this paper, we focus on technical details based on Semantic Web technology to realize this application.

Introduction

As a result of the widespread use of the Internet and the development of numerous large information systems, the necessity and importance of IT education have increased. However, there are very few specialist teachers who have the specific skills for teaching IT. Further, it is difficult for them to gain the necessary knowledge and skills, since the educational goals and techniques of IT instruction are not yet clearly defined. For example, most of the teachers who are not specialists mistakenly believe that the use of the technology itself is the main goal of IT education, though the ability to use information systems is a more complex and indispensable aspect of IT education.

Many instructors and researchers have published their opinions on various concepts of IT education and the relationships between these concepts [4]. However, it is difficult for teachers who are not specialists to understand and apply them. And, many organizations provide web pages that show teachers of IT education various useful resources--e.g., digital content, lesson plans, and Q & A [2], [3]. However, it is very difficult to collect the necessary resources for teachers because the relevant web pages are too numerous, and their formats and viewpoints are not unified even when the resources have the same purpose.

One of the causes of these problems is that various concepts related to IT education and practical skills are not yet clearly defined. Because most of the guidelines and commentaries about IT education present the concepts in a disorganized fashion, we believe that these concepts are not conveyed to teachers effectively. So, we built ontology which defines the concepts related to the goal of IT education. This ontology consists solely of concepts of the goal of IT education, and ensures that no confusion of various concepts occurs. However, because the ontology is quite abstract, we think that it is not effective to directly provide teachers with it. To solve this problem, we proposed a framework that can reuse results of

other research [4]. That research clarified concepts of goals of IT education and provided teachers with them. The characteristic of this classification is that it is easy for teachers to understand, though from an ontological engineering viewpoint that may need modification. So, by aligning our ontology and this classification, it is possible to provide teachers with the integrated benefits of both classifications. Moreover, we built a Semantic Web application based on this framework to provide teachers of IT education with useful resources from the various viewpoints they require.

We have already described our ontology and its application in other papers [1], [6]. However, in these papers, we focused on only the contents and functions of this application and did not focus on technical viewpoints. So, in this paper, we focused on technical details based on Semantic Web technology for realization of our application.

1. An Outline of Our Approach

In this section, we describe the outline of our system developed using Semantic Web technology.

1.1 Outline of the system architecture

The purpose of our project is to provide teachers of IT education with useful resources in accordance with the various viewpoints that they might have. The architecture of our system is shown in Figure 1. This framework includes two metadata: one is based on our ontologies, which are described in another paper in detail [1]. We authored metadata of various resources about IT education in RDF using the ontology of the goal of IT education and the ontology of the fundamental academic ability as the tag. The other is based on the Goal List of IT education [4], which was taken from other research which has been conducted by one of the authors for years.

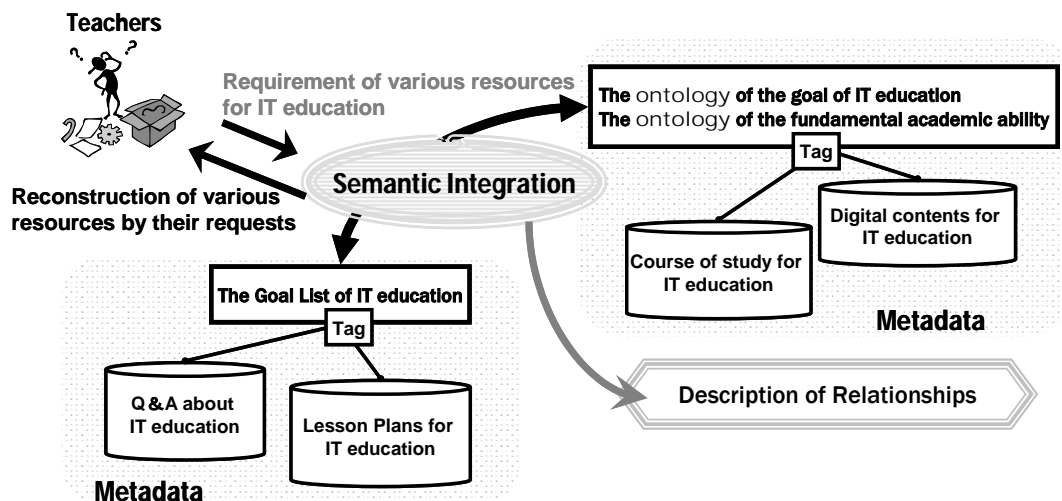


Figure 1. The outline of our approach that is compliant with the *openness* of the Semantic Web

The purpose of this Goal List is to provide teachers with viewpoints from which to evaluate the learner's activity during instruction in IT education. Because this Goal List was not generated based on the ontology theory, its quality is not as high as that of an ontology [1]. However, this Goal List already has been so widely used with the same purpose as an ontology

that many information resources that support teachers for IT education in Japan are annotated using it. Therefore, in this paper, we regard this Goal List as an ontology.

In this study, we realize semantic integration between the metadata based on separate ontologies by describing relations between our ontologies and the Goal List clearly. For example, in this framework, the system can reconstruct lesson plans tagged based on the Goal List from the viewpoint of our ontologies and provide with them. In addition, the system can integrate lesson plans based on the Goal List with digital contents based on our ontologies which are able to be used in each step in them. With this framework, it becomes possible for teachers to use many useful resources more effectively for a wider range of purposes.

In this paper, we describe the alignment of our ontologies and the Goal List which is the base of this framework and an example of application services based on it from the technical viewpoint.

1.2 The Layered Structure of Our Semantic Web Application

In this section, we describe the outline of the alignment of ontologies of our Semantic Web Application. The layered structure of this part is shown in Figure 2.

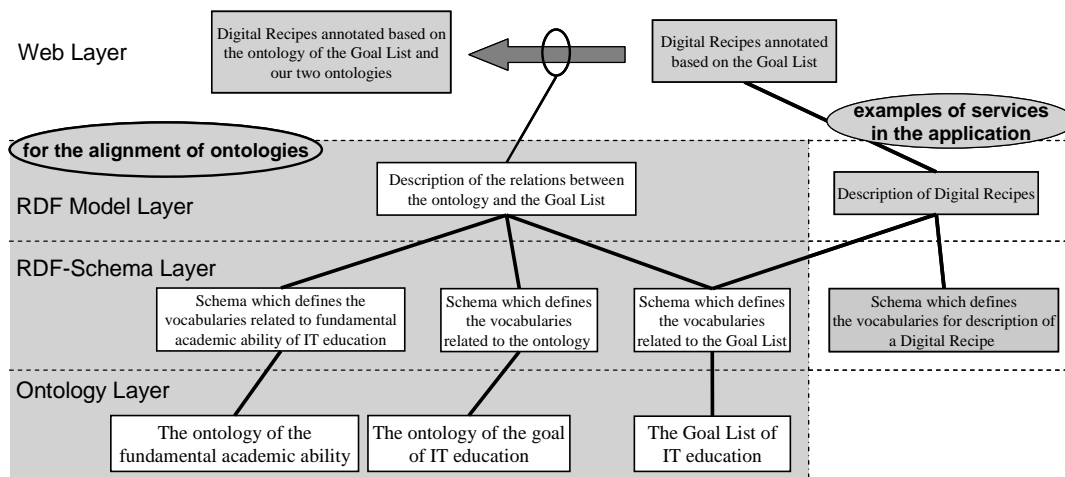


Figure 2. The Layered structure of part concerned with the alignment of ontologies of the Application

This application is constructed in four layers. The bottom layer is the ontology layer in which we define all of the concepts related to our two ontologies and the Goal List of IT education. The second layer is the RDF-Schema Layer in which the vocabularies of classes and properties used in the third layer, the RDF Model Layer, are defined. In the part for the alignment of ontologies, there are three schemata in this layer. As these schemata, the vocabularies of classes and properties related to our ontologies and the Goal List defined in the bottom layer are defined. The third layer is the RDF Model Layer in which, for the alignment of ontologies, we authored metadata of a resource that shows the relations between our two ontologies and the Goal List of IT education by using the vocabularies defined in the RDF-Schema Layer.

Thanks to this framework, we can reuse resources which were annotated based on the Goal List in our application. And, the application can provide teachers with the integrated benefits of both ontologies. As an example of resources, in this paper, we take up simple lesson plans on the Web (called Digital Recipes) provided by Okayama Prefecture Information Education Center [2]. These Digital Recipes are open to the public as resources

related to concepts of the Goal List. In this example, by this application, for each step in a flow of the instruction, the viewpoints of evaluation are provided with expression that is easy for teachers to understand these meaning as the benefit of the Goal List, and the goals of IT education, which is easy to be hidden in its shadow as the benefit of the ontology, are provided.

2. Details of Each Layer for Realization of Our Semantic Web Application

In this section, we describe the detail of each layer which was shown in the above section for realization of the alignment of ontologies.

2.1 Three Ontologies in the Ontology Layer

In this section, we describe the outline of these ontologies which are used in our Semantic Web application briefly, because we have already described them in other contributions [1], [6]. And, we show the advantages of our ontologies by comparison with the other classification from the viewpoint of the ontology theory.

A portion of the *is-a* hierarchy as the ontology of the goal of IT education is shown in Figure 3. This ontology was built on the editor "Hozo" [7], which is an environment for building ontologies. The ontology of the goal of IT education consists solely of the concepts of the goal of IT education. Stratification based on *is-a* relation is the essential property of these concepts, and ensures that no confusion of various concepts occurs; such confusion can obstruct teachers' understanding of concepts of IT education. To build this ontology, we first extracted three concepts that can be the goal of IT education. These are "Knowledge about information", "Skills to utilize information in the information society", and "Independent attitude toward participating in the information society". This classification is compliant with Bloom's taxonomy of instructional objectives [5]. Furthermore, we classified these three concepts into more specific ones.

We extracted and classified the goal of the "Period of Integrated Study" as the ontology of the fundamental academic ability [6]. The "Period of Integrated Study" was created to cultivate ways of learning and thinking and an attitude of trying to solve or pursue problems independently and creatively. The purpose of describing this ability is to show more clearly the essence of the concepts of the goal of IT education by identifying its differences from the academic ability, which is attained in other subjects. For this ontology, we classified three concepts; "Knowledge to live in the society", "Skills to utilize information in the society" and "Independent attitude toward participating in the society", as well as the goal of IT education.

The Goal List has three top-level categories, "Practical Ability of using information", "Scientific understanding of information", and "Awareness toward participating in the information society", which the Ministry of Education prepares in more detail in the same way as our *part-of* hierarchy. For this purpose, examples of more concrete learning activities that are easy for teachers to understand are provided with a level that shows when learners should attain this goal. We think that it is more suitable for teachers' understanding to provide them with information on activities related to concepts of learning. We think that it is easier for teachers to grasp each description when concepts of learning activities are included in the information provided. Further, it is difficult to set a level of difficulty for a goal of IT education without presenting concepts of learning activities. Consequently, the Goal List has many advantages as information that is provided to teachers directly.

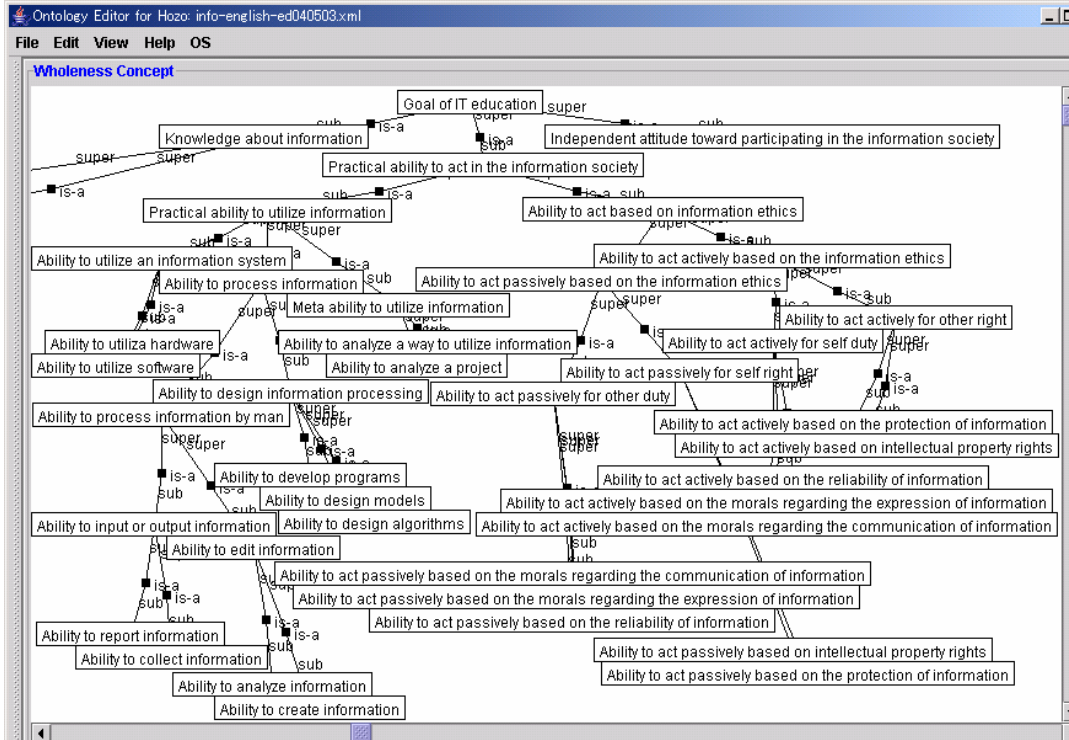


Figure 3. A part of the ontology of the goal of IT education (*is-a* hierarchy)

However, the Goal List has some faults from the viewpoint of classification of the goal of IT education. Although, essentially, the classification of educational goals should be performed by extracting the intrinsic goals that should be attained in education and systematizing them, in many of the current classifications, we find concepts other than goals; for example, learning activity and learning environment related to goals are incorrectly mixed up. Moreover, systematization like that in this example, in which other concepts are mixed, sometimes causes another problem: the extracted concepts are not completely independent of each other.

Given these considerations, to the best of our knowledge, there is no goal classification that properly captures the intrinsic educational goals of IT education without any confusion regarding learning activity, standard of evaluation for education, etc. It is difficult to separate various concepts related to IT education, because most goals of IT education are meta-abilities that are attained in the process of problem solving. Considering the fact that the purpose of the classification of the goal of IT education is to give teachers a clear understanding of the educational goals, our goal ontology is more suitable, based on the fact that it reveals the inherent conceptual structure of educational goals and thereby facilitates a teacher's understanding of those goals.

2.2 Definition of Vocabularies of Classes and Properties in RDF-Schema Layer

In this section, we describe the vocabularies defined in the RDF-Schema Layer for tags that are used in the RDF Model Layer. In this study, we define the vocabularies used to realize the alignment of ontologies in three namespaces.

The vocabularies defined in these three namespaces are shown in Table 1. The first schema which is referred to by the prefix "it_goal" in this study, defines the vocabularies of

classes and properties related to the goal of IT education. The second schema which is referred to by the prefix "pre_goal" in this study, defines the vocabularies of classes and properties related to the fundamental academic ability. The third schema which is referred to by the prefix "goal_list" in this study, defines the vocabularies of classes and properties related to the Goal List of IT education. In Table 1, we omit a description of the classes defined in these namespaces, because all classes show concepts of three ontologies which we explained in the above section.

Table 1. Vocabularies defined in the RDF-Schema Layer

prefix	type	vocabulary	explanation
it_goal	Property	target_it_goal	Target goal as IT education
pre_goal	Property	target_pre_goal	Target fundamental academic ability as goal
goal_list	Property	target_example	Target learning activity that includes same goal
goal_list	Property	example_activity	Example learning activity in the category of the Goal List
goal_list	Property	level of difficulty	Level of difficulty
sch_ed	Class	Subject	Subject in school
sch_ed	Class	Unit	Unit for learning content of education
sch_ed	Class	Activity	Learning activity by students
sch_ed	Class	Grade	Grade in school
sch_ed	Property	realization	Educational goal of an ideal to expect realization
sch_ed	Property	goal_Description	Description about target educational goal
sch_ed	Property	grade	Target grade of Subject or Sub-subject in school

In the RDF-Schema Layer, we also define other vocabularies to use in RDF Model Layer for description of other metadata which are used in our application. Here, in Table 1, we show parts of vocabularies which are used for examples of services which are shown in Figure 2. These vocabularies are defined in a namespace which are referred by the prefix "sch_ed". This schema defines the vocabularies of classes and properties related to the school education.

2.3 Description of relationships between our ontologies and the Goal List of IT education in the RDF Model Layer

In this section, we explain the RDF Model for the description of resources which show the relationships between our ontologies and the Goal List of IT education. In this study, we describe the relationships of these by giving meaning to concrete learning activities which are provided in the classification of the Goal List based on our ontologies.

In the Goal List of IT education, for this purpose, examples of concrete learning activities that are easy for teachers to understand are provided with a level that shows when learners should attain this goal. Each example of these learning activities is practical activity and contains educational goals that the concepts of our two ontologies explain. We authored metadata of these learning activities in RDF, which belong to the respective concepts of the Goal List, by using the vocabularies defined in the RDF-Schema about the concepts of the ontology of the goal of IT education and the fundamental academic ability. A part of the RDF Model for description of the metadata is shown in Figure 4.

As shown in this model, all learning activities which are provided in the classification of the Goal List are tagged based on the ontology of the goal of IT education and the ontology of the fundamental academic ability. So, the relationships between our two ontologies and the Goal List can be described around these learning activities in this model. Thanks to description of this model, the alignment of our ontologies and the Goal List can be realized, because the metadata which have already been open to the public are authored based on these learning activities in the Goal List by teachers.

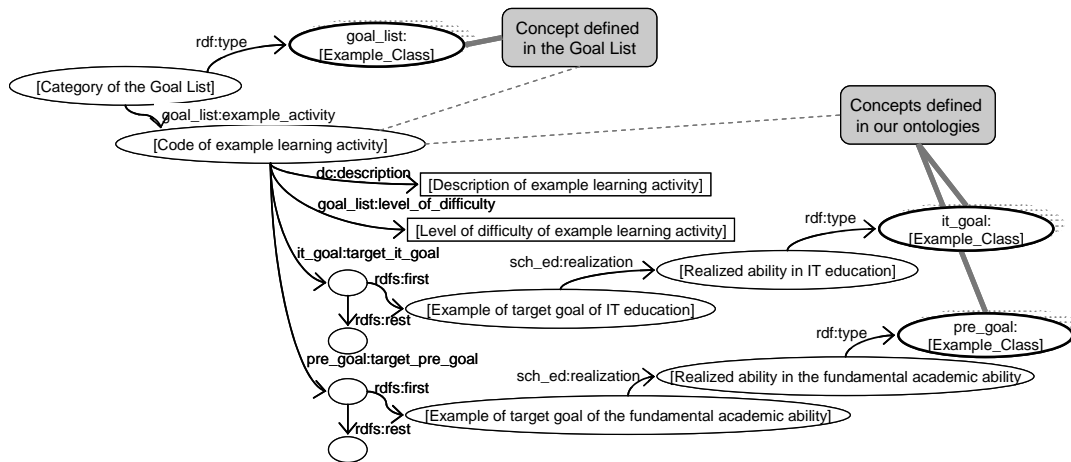


Figure 4. A part of an RDF Model for the description of the relationships between ontologies

3. Details of an Example of the Services of the Application by the alignment of ontologies

In this section, we describe details of an example of the services of the Semantic Web application by the alignment of ontologies. This example is a function which uses the Digital Recipes explained in Section 1. These Digital Recipes show the lesson plans of several classes for a unit. Each plan includes not only the basic information (such as target grade, target subject, aim in the whole classes and so on) but also the flow of concrete learning activities. In the metadata of the Digital Recipes, each learning activity is tagged based on the Goal List. We show an example of web pages of Digital Recipes which are tagged with the Goal List on the left in Figure 5. The services of the application explained in detail in this section is a system that converts the contents of the screen shot on the left in Figure 5 to the contents of the screen shot on the right. Next, we explain the details of processing to realize this service.

A part of description of the metadata of Digital Recipes based on the Goal List which are authored by teachers is shown on the left at the bottom in Figure 5. These metadata are output in RDF automatically from the contents which teachers input on the spread sheet software in the form specified by the macro function. The system analyzes the metadata of a Digital Recipe and extracts concepts of the Goal List tagged in this resource, then the system extracts the concepts of the ontology of the goal of IT education related to those concepts of the Goal List from the other resource (Description of the relations between the ontology and the Goal List) in the RDF Model Layer. The system integrates the original resources with extracted concepts of the ontology and outputs it as an HTML file.

This system can provide teachers with the integrated benefits of both ontologies. In this example, for each step in a flow of the instruction, the viewpoints of evaluation are provided with expression that is easy for teachers to understand these meaning as the benefit of the Goal List, and the goals of IT education, which is easy to be hidden in shadow of it as the benefit of the ontology, are provided.

4. Related Work

Many organizations and researchers have been trying to enhance shareability and reusability of various educational resources. Here, we introduce some of these efforts that are related to our approach briefly.

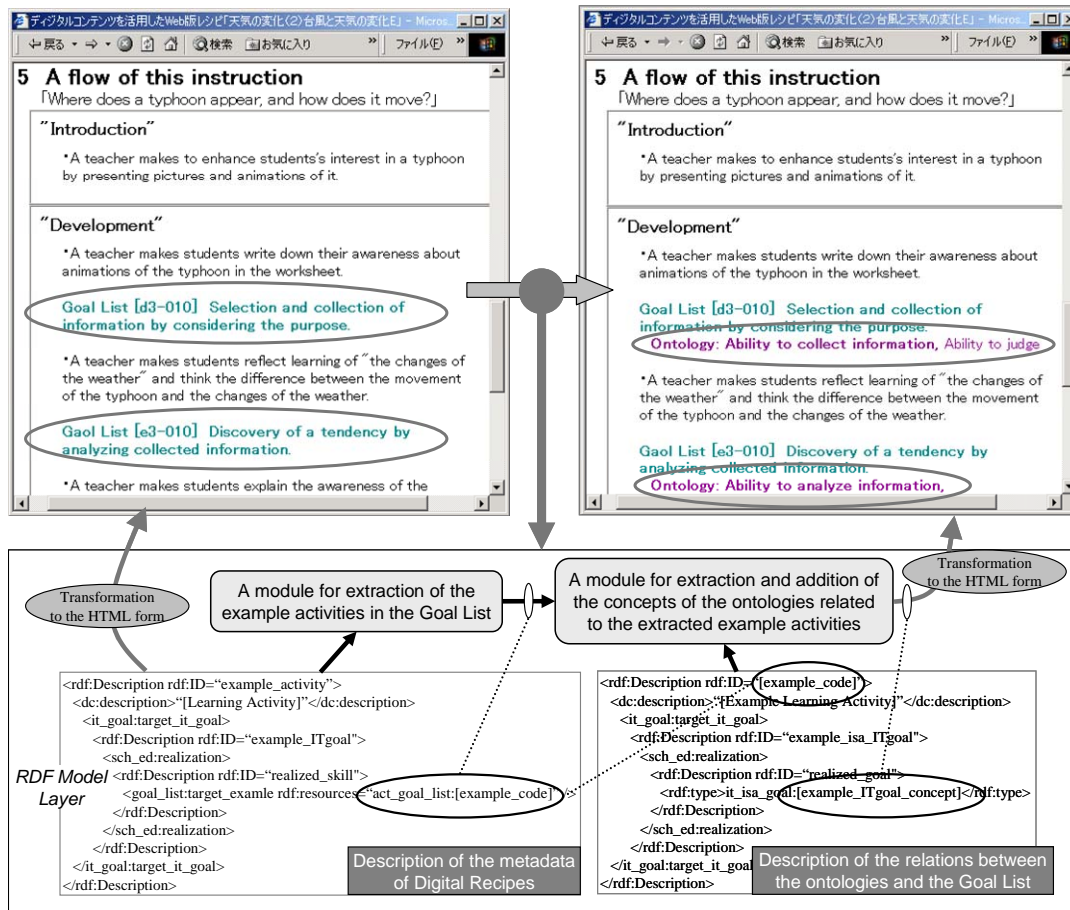


Figure 5. Details of an example of the services of the application by the alignment of ontologies

The Learning Object Metadata (LOM) was provided by The IEEE Learning Technology Standards Committee (LTSC) [8]. The LOM specifies the syntax and semantics of Learning Object Metadata, defined as the attributes required to full/adequate description of a learning object. We cannot describe the contents of the Learning Objects in compliance with the LOM standards because they focus on the minimal set of attributes to allow these LOs to be managed, located, and evaluated in total independence of their contents. Our approach aims at describing the detailed contents by limiting objects concretely such as lesson plans.

There is the IMS Learning Design project which aims at making the standard to describe the instruction/learning activities, the learning environment, and the learning objectives that can be expressed in lesson plan [9]. In compliance with this standard, we can express the contents of lesson plan in detail. However, we think that this expression is too complex for teachers who do not understand the contents and goal of education enough yet. Our approach aims at expressing them with solely educational goal for the teachers who do not understand them.

There are some researches based on these standards and various ontologies [10], [11]. The goal of [10] is to specify an evolutionary perspective on the Intelligent Educational Systems (IES) authoring and in this context to define the authoring framework EASE: powerful in its functionality, generic in its support of instructional strategies and user-friendly in its interaction with authors. And, the study [11] proposes a theory-aware ITS authoring system based on the domain and task ontologies of instructional design.

And, there is a research (TM4L) [12] which describes the metadata of digital learning resources based on ontologies as well as us. TM4L describes the metadata of digital course

libraries based on the ISO XTM standard (XML Topic Maps) to organize and retrieve information in a more efficient and meaningful way. The difference between our approach and TM4L's approach is that we realize the alignment with other ontology.

We intend to build a support system for designing an instructional system for cultivating practical skills to solve various problems based on the framework which is proposed in this paper with referring to the results of these related works.

5. Summary

We described the Semantic Web system which provides teachers of IT education with useful web resources. This system is based on the alignment of our ontologies and other ontology to reuse the results of other research. In this paper, we focused on the technical details based on Semantic Web technology to realize this system.

In future work, we intend to build the system which supports teachers of IT education dynamically to plan a lesson by describing relations between the concepts of our ontologies systematically.

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