Goal Transition Model and Its Application for Supporting Teachers based on Ontologies

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Abstract. In Japan, the "Period of Integrated Study" program to enhance practical skills began in elementary and secondary education in 2002. Most goals of this program involve meta-ability, which cannot be fully learned by traditional Japanese instructional methods. For this reason, it is necessary and important to provide instructors with a powerful help system that can locate and provide access to a variety of useful information resources. To this end, we built a system that reconstructs the resources according to various viewpoints based on Semantic Web technology. Further, we propose Goal Transition Model to show a skeleton of the transition of instructional goals based on ontologies. And we propose support functions that are used in the model.

Introduction

In Japanese elementary and secondary education, the acquisition academic knowledge had been regarded as important rather than the enhancement of practical skills. In April 2002, however, the Ministry of Education started the "Period of Integrated Study" program in the elementary and secondary education system. The objective of this program is to cultivate learners' ways of learning and thinking and an attitude of trying to creatively solve problems by themselves. However, because Japanese teachers have little experiences with instruction in practical skills, they lack the specific skills for instructional design. In particular, teachers do not have skills in information technology (IT) education.

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 organizations provide web pages that provide various useful resources for teachers--e.g., digital content, lesson plans, and Q&A [1], [2]. 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 cause 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 the "Period of Integrated Study" present the concepts in a disorganized fashion, we believe that these concepts are not conveyed to teachers effectively. To solve this problem, it is necessary to clarify and articulate the fundamental concepts of practical skills. We believe that ontological engineering can assist in meeting this goal. The ontology provides a common vocabulary/concepts and fundamental conceptual structure of IT education and can promote the reuse and sharing of these concepts among teachers. However, because the ontology is quite abstract, we think that it is not effective to directly provide teachers with it. So, in this study, we use the ontology as a basis and introduce educational goals for practical skills to define other useful information. If useful web resources for the "Period of Integrated Study" are tagged on the basis of ontology, they can be accessed according to the various viewpoints they might have. This framework is realized based on Semantic Web technology.

One of the authors reports on [4] a classification of the goal of IT education in the "Period of Integrated Study" in terms of those which are familiar to the teachers and explains the resource. Although the terms have been well accepted by teachers, they need quite a few modifications from the ontological engineering viewpoint. We make use of the results of this research by identifying the relations between this ontology and our ontologies. Our method is compliant with the openness of the Semantic Web in that it allows the alignment of separate ontologies. Further, we propose Goal Transition Model that shows an skeleton of the transition of the instructional goals based on ontologies. If the skeleton of each provided lesson plan are expressed based on this model, teachers can judge whether or not the plan is appropriate for their instructional objectives without reading it in detail. In this paper, we propose support functions for them which are used in the model.

1. An Outline of Our Approach That Complies with the Openness of the Semantic Web

In this section, we describe the framework for realizing a system that provides teachers in elementary and secondary education with useful resources in accordance with the various viewpoints that they might have. This framework is an example of the Semantic Web application system that is open to the decentralized world. An outline of this framework is shown in Figure 1.

This framework includes two instances of Semantic Web components: one is based on our ontologies, which is described later in detail. We authored metadata of various resources about IT education and the "Period of Integrated Study" in RDF using the ontology of the goal of IT education and the ontology of the fundamental academic ability as the tag; the other Semantic Web component is based on the Goal List of IT education, which was taken from the other research result [4].

The purpose of the Goal List is to provide teachers with teacher-friendly terms by which they can easily express and evaluate the learner's activity during IT instruction in the "Period of Integrated Study" program. Because the Goal List was not generated based on the ontology theory, its quality is not as high as that of an ontology [5]. However, the Goal List already has been so widely used for annotation of large number of information resources of IT education in Japan with the same purpose as an ontology. 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 the relations between our ontologies and the Goal List clearly. For example, in this framework, the system can reconstruct lesson plans tagged on the basis of the Goal List from the viewpoint of our ontologies and provide them with it. In addition, the system can integrate lesson plans based on the Goal List with digital contents based on our

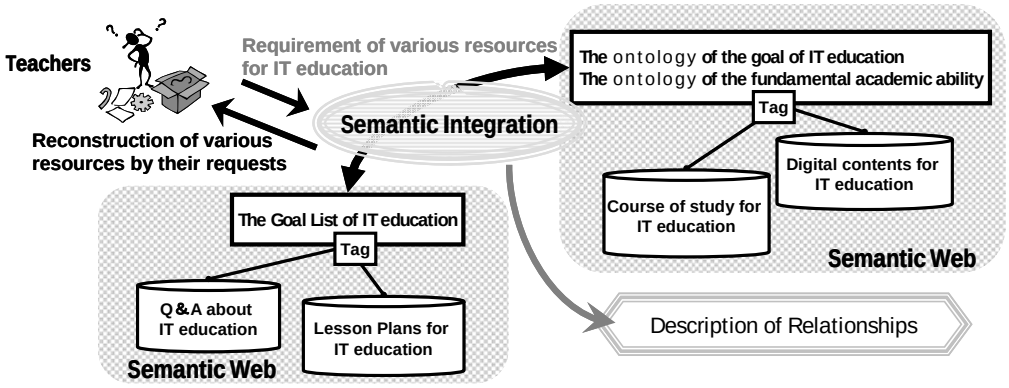

Figure 1. The outline of our approach that is compliant with the *openness* of the Semantic Web

ontologies which can be used in each step in the lesson plans. This framework enables teachers to use many useful resources more effectively for a wider range of purposes.

2. Our Two Ontologies and Relationships Between These And the Goal List

2.1 The Ontology of the Goal of IT Education

We have built the ontology of the goal of IT education [5]. In this paper, we do not explain this ontology in detail due to space limitation, but we explain only the outline of this.

The ontology of the goal of IT education should consist solely of the goal concepts. Stratification based on an *is-a* relation has to reflect the essential property of these concepts, and ensures that no confusion of various concepts occurs; such confusion can obstruct teachers' understanding of the concepts of IT education. For this ontology, we extracted three concepts that can be the goal of IT education. These are "Knowledge about information/IT", "Skills to use it in the information society", and "Independent attitude in the information society". This classification is compliant with Bloom's taxonomy of instructional objectives [6]. Furthermore, we classified these three concepts into finer classes (subgoals).

2.2 The Ontology of Fundamental Academic Ability

For elementary and secondary education, the Ministry of Education determined a Courses of Study that cultivates a "zest for living," i.e. the ability to learn and think independently, as well as the acquisition of rudiments and basics. For that purpose, the "Period of Integrated Study" was created to cultivate learners' ways of learning and thinking and an attitude of trying to creatively solve or pursue problems by themselves. We extracted and classified goals of the "Period of Integrated Study" as ontology of the fundamental academic ability. This ontology is shown in Figure 2. For this ontology, we classified three concepts, namely "Knowledge to live in the society", "Skills to live in the society" and "Independent attitude in the society", similar to the goal of IT education.

We can regard the "Ability to utilize information," which is the whole of goal of IT education, as a specialized area of fundamental academic ability that is necessary in the information society. Here, we clarify the boundary between the goal of IT education and fundamental academic ability. We define all of the concepts involved in the ontology of the goal of IT education as "academic ability," which is necessary to utilize digital information under an environment based on the information system and the information and telecommunications network. For example, "Skill to investigate," which is one of the concepts of the ontology of fundamental academic ability, means a skill to get necessary information (including non-digital information). On the other hand, a skill to get necessary digital information using IT is "Skill to collect information through IT," which is one of the concepts of the ontology of the goal of IT education. Some pairs, as in this example, exist in two ontologies. A relation of these pairs is that the specialized concept of the ontology of the

fundamental academic ability is the concept of the ontology of the goal of IT education. And, this specialization means that an object of a concept of the ontology of the fundamental

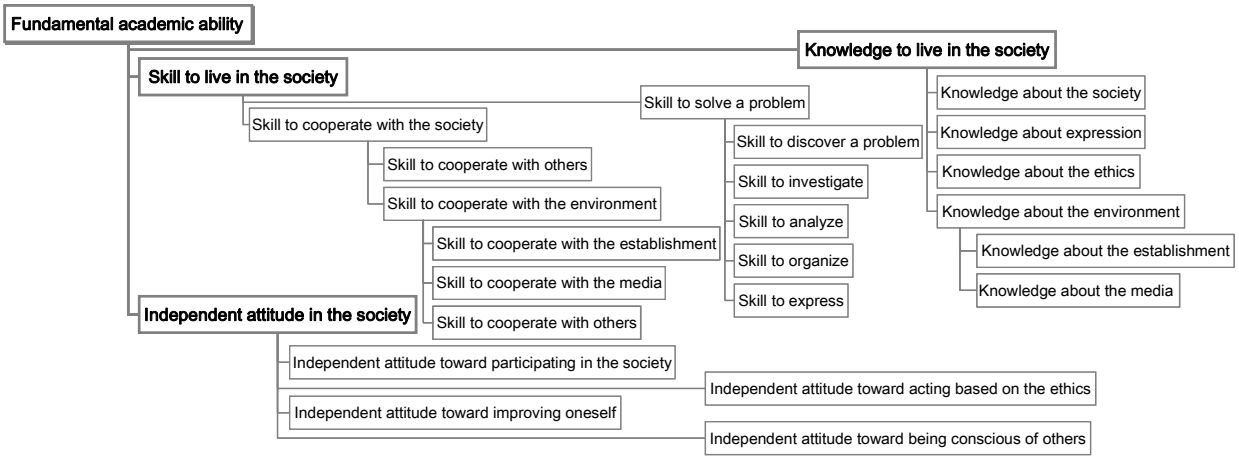

Figure 2. The ontology of the fundamental academic ability

academic ability is specialized into digital information.

2.3 Description of Relationships between Our Ontologies and the Goal List of IT Education

The concepts in the two ontologies that we built do not show practical skills but rather necessary fundamental skills in practice. In other words, they are concepts of high generality which can be applied in various situations. However, it is difficult for teachers to make sense of such concepts of high generality and to make use of these in instructional design. It is therefore necessary to describe the relationships between these concepts and practical activities that cultivate practical skills.

In the Goal List of IT education, for this purpose, examples of concrete learning activities that are easy for teachers to understand are provided together with information that shows when learners should attain this goal. Each example of these learning activities is practical and contains educational goals. We authored metadata related to these learning activities which belong to the respective concepts of the Goal List in RDF. We authored them using the vocabularies defined in the RDF-Schema related to the concepts of the ontology of the goal of IT education and fundamental academic ability. Thanks to this description, the system, which is the Semantic Web application, can reconstruct lesson plans tagged based on the Goal List from the viewpoint of our two ontologies.

3. The Problem-Solving Process and the Goal Transition Model

As mentioned in the above, the concepts in our two ontologies are those of high generality which can be applied in various situations. If more concrete situation of activity is fixed, these concepts of educational goal are set with a role in the situation in detail according to at the concreteness level of abstraction. The most concrete activities are actual learning activities in an actual class. Though there are various ways to make situations more concrete, in this paper, we mainly investigate the situation where a purpose of learning activities is problem-solving (parts of the problem-solving process), since the "Period of Integrated Study" program makes much of cultivating the ability to solve various problems in society. Next, we explain a general process for problem-solving and describe the fundamental academic ability that is necessary in each step of this process as educational goal.

3.1 The Problem-Solving Process and the Educational Goals That are Necessary at Each Step

In this study, we defined the Problem-Solving Process which is more general as a cycle shown in the left figure in Figure 3 with referring to National Geography Standards [11]. The educational goals at each step of this process are extracted from our two ontologies. These are shown in the right figure in Figure 3.

Each concept of these educational goals has a role in this process. For example, although "Skill to analyze" appears in two different steps, the roles in the problem-solving process are different from each other. Its role in the step of "Classification, analysis and judgment" involves the analysis of various kinds of information (including non-digital information) collected to solve the problem. Its role in the step of "Self-evaluation" involves the analysis to evaluate the process of problem-solving by oneself. The concepts of academic ability are necessary in steps of the problem-solving process, and these concepts have a leading role in the process. In this paper, we call these concepts "leading skills" in the problem-solving process. And in this process, if a more concrete activity is given in each step, other concepts of academic ability are set with more detailed roles.

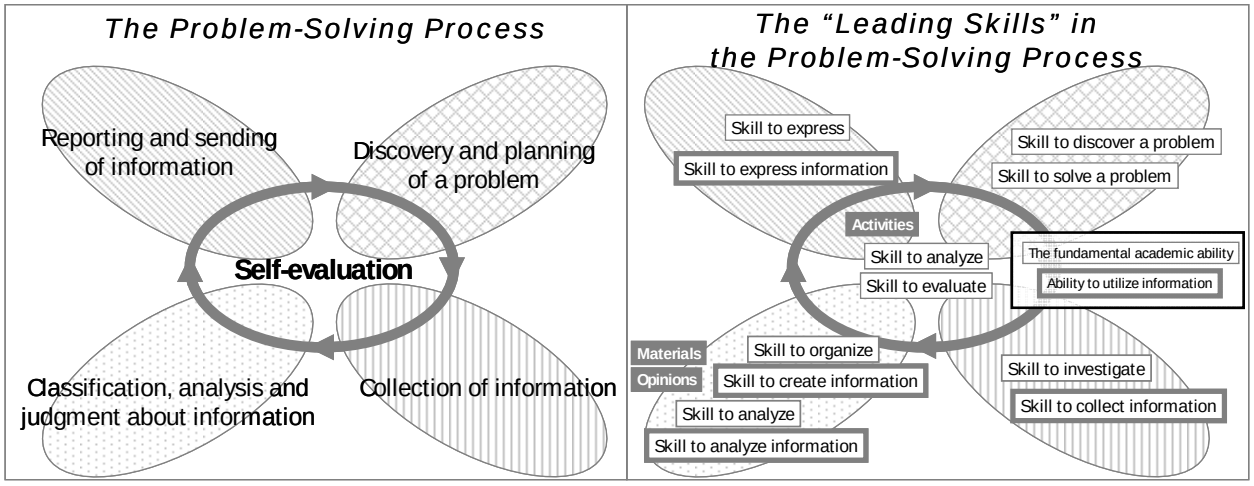

Figure 3. The problem-solving process and the leading skills in this process

3.2 The Goal Transition Model

Most lesson plans of the "Period of Integrated Study" program which are provided via the internet aim to cultivate practical skills to be used in the problem-solving process. If all of the leading skills of the problem-solving process are extracted in order from each lesson plan, it is possible to express a skeleton of the instruction from the perspective of the problem-solving process. In this study, we call this skeleton "the Goal Transition Model". All concepts which can be used in this model are defined in our two ontologies. An example of a Goal Transition Model extracted from an actual lesson plan is shown on the right at the center in Figure 4.

Here, "Skill to analyze," which exists in different steps of the problem-solving process, can be distinguished by considering its role. In this study, we classify and describe objects of analysis clearly to judge which step it is. The object of "Skill to analyze" in the step of "Classification, analysis and judgment" is "materials" or "opinions" because its role is the analysis of various kinds of information collected to solve the problem. The object of "Skill to analyze" in the step of "Self-evaluation" is "activities" because its role is the analysis to evaluate the process of problem-solving performed by learner's self. In this study, we use "problems", "learner's self", "others" and "situation" as objects of analysis in addition to the three objects mentioned above, "materials", "opinions" and "activities". However, "Skill to analyze" is regarded as a leading skill in the problem-solving process only when its object is one of these latter three objects. Otherwise, this concept is regarded as simply another goal concept. In the Goal Transition Model, the other concepts are connecting to the side of the

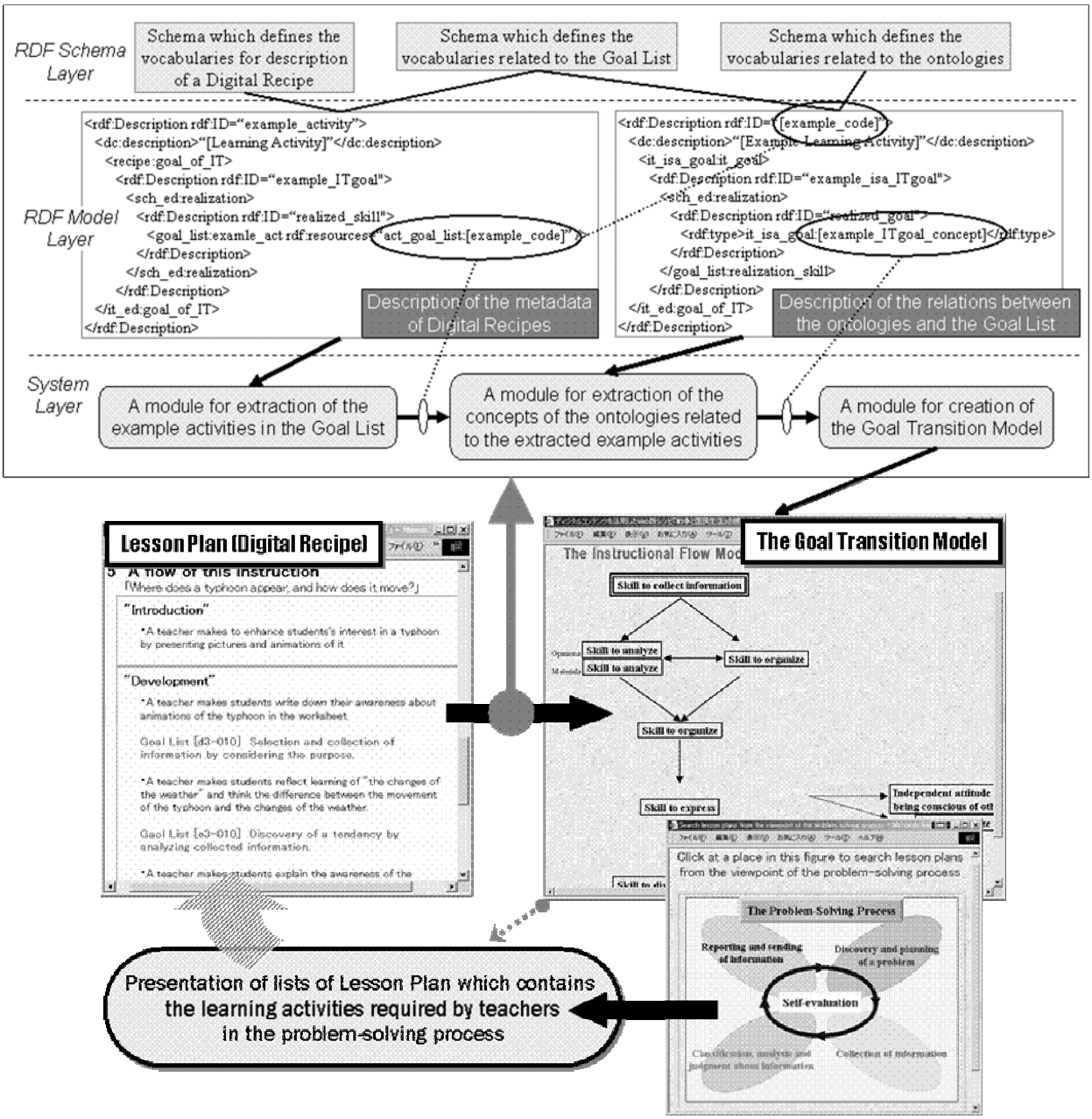

Figure 4. Two functions which support teachers by using the Goal Transition Model

"leading skill," which is contained in the same learning activities as shown on the right at the center in Figure 4.

4. Building of a Support System for Teachers by Using the Goal Transition Model

We have built the support system including functions that are realized by using the Goal Transition Model based on the framework which explained in Section 1. In this section, we describe how to create this model from lesson plans and these two implemented functions.

4.1 How to Create the Goal Transition Model from a Lesson Plan

The resources used by this system are simple lesson plans on the Web (called Digital Recipes) [2] provided by Okayama Prefecture Information Education Center. These Digital Recipes are open to the public as resources related to concepts of the Goal List. However, they were not described as metadata in the Semantic web sense. So we authored the metadata of these resources from the viewpoint of the Goal List. A procedural flow to create the Goal Transition Model from the metadata of a Digital Recipe by the system is shown at the top in Figure 4.

The system analyzes the metadata of a Digital Recipe we produced and extracts concepts of the Goal List tagged in this resource, and then the system extracts the concepts of the ontology of the goal of IT education and the ontology of the fundamental academic ability related to those concepts of the Goal List from the other resource (this describes the relations between our two ontologies and the Goal List). Next, the system connects and outputs the leading skills in the order of the problem-solving process. Further, the system outputs each other concept at the right side of the leading skill contained in the same learning activity that contains it. Here, when the different concepts which are in the same step of the problem-solving process and are repeated, the system outputs these concepts in parallel from the previous leading skill. This is because these concepts which are in the same step cannot be arranged.

4.2 Details of Implemented Functions by Using the Goal Transition Model

One function builds the Goal Transition Model of a lesson plan (Digital Recipe) automatically and provides teachers with it as shown at the top in Figure 4. For this function, teachers can get the skeleton of this lesson from the viewpoint of educational goals without going through the lesson plan in detail. This skeleton provides teachers with the true nature of the lesson, which can be difficult to uncover among superficial information such as learning activities, information systems, digital contents and so on. Therefore, we think that this function is useful for teachers who are not accustomed to the cultivation of practical skills.

The other function searches necessary lesson plans from the viewpoint of the problem-solving process according to requirement of teachers. By clicking on the place which shows each step in the problem-solving process, teachers can get lists of lesson plans which contain the learning activities required as shown at the bottom in Figure 4. In Japan, although IT education and the "Period of Integrated Study" program attach importance to the cultivation of an ability to solve problems, the function which can search the necessary lesson plans which are open to the public from the viewpoint of a step in the problem-solving process is nearly nonexistent. In this study, this function is realized by using the framework of the Semantic Web based on ontologies and the Goal Transition Model that we proposed.

4.3 Evaluation of Our Approach

We have evaluated the effectiveness of the ontology of the goal of IT education by an experiments with 21 high school teachers [3]. In this evaluation, it was shown both qualitatively and quantitatively that our ontology is effective on deepening teachers' understanding of the goal of IT education. And, it was shown that teachers had two kinds of opinions about the use of the ontology: One is that the presentation of the ontology itself is not very helpful for teachers to design better instruction of IT education and the other is that the addition of the ontology to the other support resources enhances the utility of its resources for teachers. But, we have not evaluated the proposed Goal Transition Model and its application function yet. In the near future, we intend to evaluate them.

5. 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.

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 of this paper aims at describing the contents by limiting objects to lesson plan.

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 [7]. 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.

And, there are some researches based on these standards and various ontologies [9], [10]. The goal of [9] is to specify an evolutional 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 [10] proposes a theory-aware ITS authoring system based on the domain and task ontologies of instructional design. 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.

6. Summary

In this paper, we described two ontologies; the ontology of the goal of IT education and the ontology of the fundamental academic ability. And, we proposed a framework to make use of the results of another research [4] by alignment of these ontologies based on Semantic Web technology. Further, we proposed a Goal Transition Model that shows a skeleton of the transition instructional goals from a lesson plan, and a support system that has functions realized by this model.

References

[1] The Meeting of Tuesday (2002), The curriculum lists of information education in the "Period of Integrated Study", HomePage of the Meeting of Tuesday, http://www.kayoo.org/sozai/.

[2] Okayama Prefectural Information Center (2002), Okayama Prefectural Information Education Center, Digital Contents Recipes and Worksheets, http://www2.jyose.pref.okayama.jp/cec/webresipi/index.htm.

[3] T. Kasai, H. Yamaguchi, K. Nagano, R. Mizoguchi (2005), Systematic Description of the Goal of IT Education Based on Ontology Theory, IEICE Trans. on Information and Systems, J88-D-I, No.1, pp.3-15.

[4] The Meeting of Tuesday (2001), The Meeting of Tuesday, The Goal List of Information Education, Mail-Magazine of the Meeting of Tuesday, http://kayoo.org/home /project/list.html.

[5] T. Kasai, H. Yamaguchi, K. Nagano, R. Mizoguchi (2004), Building of an Ontology of the Goal of IT Education and Its Applications, In Proceedings of the 3rd International Workshops of Applications of Semantic Web Technologies for E-Learning (SW-EL'04), pp.55-65.

[6] B.S. Bloom, J. T. Hastings, G. F. Madaus (1971), Handbook on formative and summative evaluation of student learning, McGraw-Hill.

[7] IMS (2002), IMS Learning Design Specification ver.1.0, http://www.imsglobal.org/learningdesign/.

[8] IEEE LTSC (2002), IEEE Standard for Learning Object Metadata, http://ltsc.ieee.org/wg12/.

[9] L. Aroyo, A. Inaba, L. Soldatova, R. Mizoguchi (2004), EASE: Evolutional Authoring Support Environment, Proc. of the seventh International Conference on Intelligent Tutoring Systems (ITS2004).

[10] J. Bourdeau, R. Mizoguchi (2000), Collaborative Ontological Engineering of Instructional Design Knowledge for an ITS Authoring Environment, Proc. of the 6th International Conference on Intelligent Tutoring Systems (ITS2002), pp.399-409.

[11] Geography Education Standards Project (1994), Geography for Life: National Geography Standards, National Geographic Research and Exploration.