Building an ontology of IT education goals

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Abstract: In Japan, the interest in IT education is continuously growing. Most goals of the IT education involve metaability, which cannot be learned by the traditional Japanese instructional methods. It is difficult to design effective IT education material. Moreover, there are only a few specialists in IT education. For this reason, it is necessary and important to provide IT instructors with a powerful help system that can locate and provide access to a variety of useful information resources. We present a system that reconstructs the resources according to the various viewpoints expressed in the ontology of IT education goals. Further, we propose an ontology alignment framework.

Keywords: IT education; ontology; Semantic Web; education support.

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1 Introduction

As a result of the widespread use of the internet and the development of numerous large information systems, the necessity and importance of Information Technology (IT) education have increased. In Japan, high school instruction in IT began in April 2003. However, most of the IT teachers are incumbent teachers in general subjects; as of April 2004, there were very few specialist teachers of IT. As a result, it is likely that most of the teachers of IT courses lack the specific skills for teaching this topic. Further, it is difficult for them to gain the necessary knowledge and skills because the educational goals and techniques for IT instruction are not yet clearly defined. For example, most of the teachers who are not specialists by mistake 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 (Ministry of Education, 2000; Ohiwa et al., 2001; The Meeting of Tuesday, 2001). Most of them take into account the factors that are useful during the usual instructional design process, such as situations and areas of content, to meet the educational goals. But it is also necessary, given that the main goal of IT education is to enhance the metaability to make use of information in various situations, to add educational goals that are related to the main

goal of an instructional 'unit', keeping in mind the content and situations addressed in this particular unit. This problem can be solved by teachers who have technical knowledge as a result of their prior learning experiences. For teachers who are not specialists in information technology, it is difficult to comprehend this problem. Consequently, a framework is necessary that reconstructs these useful resources from various viewpoints and in response to teachers' requests.

Many organisations provide web pages that show teachers of IT education and its various useful resources – for example, digital content, lesson plans and Q&A (NICER, 2003; Okayama Prefectural Information Education Center, 2004; The Meeting of Tuesday, 2003). However, it will be very difficult to collect the necessary resources for teachers because 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 of IT education are to be yet clearly defined. Because most of the guidelines and commentaries about the subject present the concepts in a disorganised fashion, we believe that these concepts are not conveyed to the teachers effectively. To solve this problem, it is necessary to clarify and to articulate the fundamental concepts of IT education. We consider that ontology engineering can assist in meeting this goal. The ontology provides a common vocabulary and a set of concepts about IT education and can promote the reuse and sharing of these concepts among teachers. However, because the ontology is too abstract for teachers to understand, we think that it is not effective to directly provide teachers with the ontology. Therefore, in this study, we use the ontology as a basis and introduce IT education goals, which are more familiar with teachers than ontology, to define other support information for IT education. If useful web resources for IT education are tagged on the basis of ontology, they can be accessed according to the various viewpoints they represent. This framework is realised based on the Semantic Web technology.

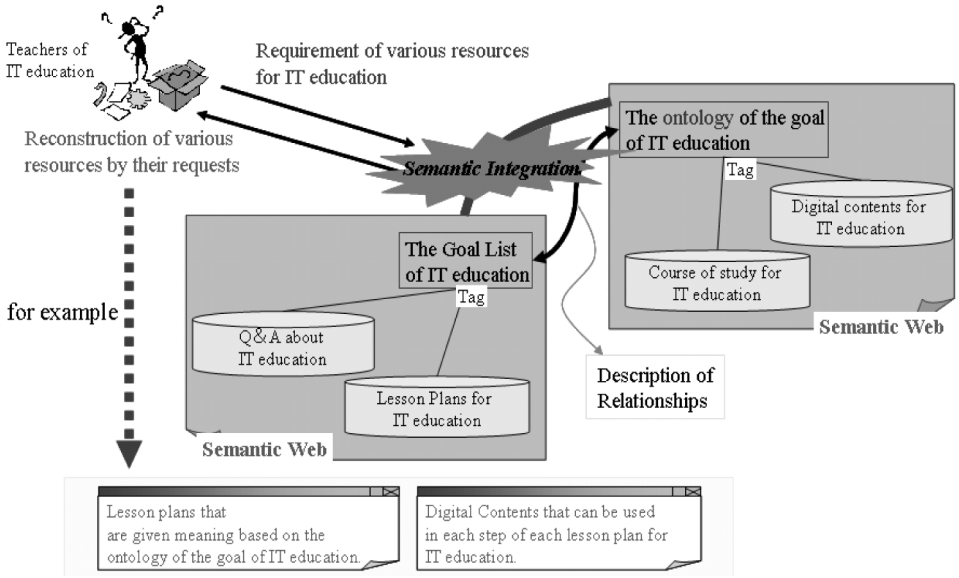
In The Meeting of Tuesday (2001) the goal of IT education has been classified and gives a meaning to resources about IT education, though from an ontology engineering viewpoint the classification may need modification and the method of giving meaning to resources does not allow authoring of metadata. We propose to make use of the results of this research by identifying relations between this ontology and our ontology. This framework is compliant with the *openness* of the Semantic Web in which it allows alignment of different ontologies. In this framework many information resources on IT education can be used more effectively because each system can reconstruct information resources annotated using its ontology.

The outline of our approach is described in the next section. Next, the characteristics and benefits of our ontology are provided in detail. In addition, we show a prototype system based on the Semantic Web technology, which provide teachers with various information resources.

2 An outline of our approach that is compliant with the *openness* of the Semantic Web

In this section, we describe the framework for realising a system that provides teachers of IT 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 decentralised world. An outline of this framework is shown in Figure 1.

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



This framework includes two instances of Semantic Web components: one is based on our ontology, which is described later in detail. We authored metadata of various resources about IT education in RDF using the ontology of IT education as the tag; the other is based on the Goal List of IT education (The Meeting of Tuesday, 2001), which was taken from other research.

The purpose of this Goal List is to provide teachers with viewpoints to evaluate the learner's activity during instruction in IT education. Because this Goal List is not generated based on the ontology theory, its quality is not as high as that of an ontology (we explain this problem in detail later). However, this Goal List already has been 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.

The Goal List was created by one of the authors of this paper. Although this fact seems to suggest that these two ontologies are built by the same organisation and that this framework is closed or centralised, that is not the case; in this paper, we consider the Goal List as a result of other organisation's research, because this classification was established before the author began to contribute to the current joint research.

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

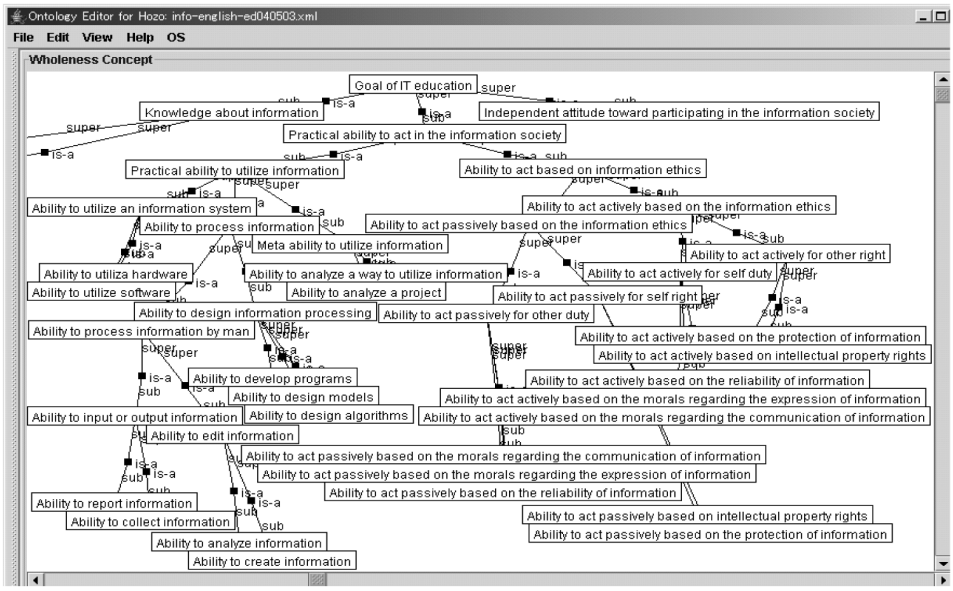
3 An ontology of the goal of IT education

In this section, we describe the ontology of the goal of IT education. Firstly, we show a hierarchy in which the classification is based on *is-a* relation, and we show another hierarchy in which it is based on *part-of* relation. Next, we explain why both *is-a* relation and *part-of* relation are necessary and describe the difference between these two relations. Further, we show the benefits of our ontology in detail by comparing it with other classifications.

3.1 The is-a hierarchy of the goal of IT education

In this section, we show the *is-a* hierarchy of the goal of IT education. A part of the *is-a* hierarchy as the ontology of the goal of IT education is shown in Figure 2. This ontology is built on the editor 'Hozo' (Kozaki et al., 2000), which is an environment for building ontologies.

Figure 2 A part of the ontology of the goal of IT education (*is-a* hierarchy)



The ontology of the goal of IT education consists solely of 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. This stratification is one of the characteristics of the ontology and is one of the important reasons why we have applied the ontology theory.

In this study, for this ontology, we extracted three concepts that can be the goal of IT education. These are 'Knowledge about information', 'Practical ability to act in the information society' and 'Independent attitude toward participating in the information society'.[1] This classification is compliant with Bloom's taxonomy of instructional objectives (Bloom et al., 1971). Furthermore, we have classified these three concepts.

Bloom's taxonomy of instructional objectives classifies the whole of the goal to be attained in instruction into three domains. The first domain is a cognitive domain, which consists of various goals regarding the comprehension of knowledge and enhancement of intellectual ability. The second domain is an affective domain, which consists of various goals regarding the formation of interest, attitude and value, and is related to enhancement of ability to judge properly and to adapt. The last domain is a psychomotor domain, which consists of various goals regarding acquirement of skills of manipulation and execution. It is clear that the three concepts extracted as goal of IT education correspond to Bloom's taxonomy of instructional objectives as follows: 'Knowledge about information' and the cognitive domain, 'Independent attitude towards participation in the information society' and the affective domain, 'Practical ability to act in the information society' and the psychomotor domain.

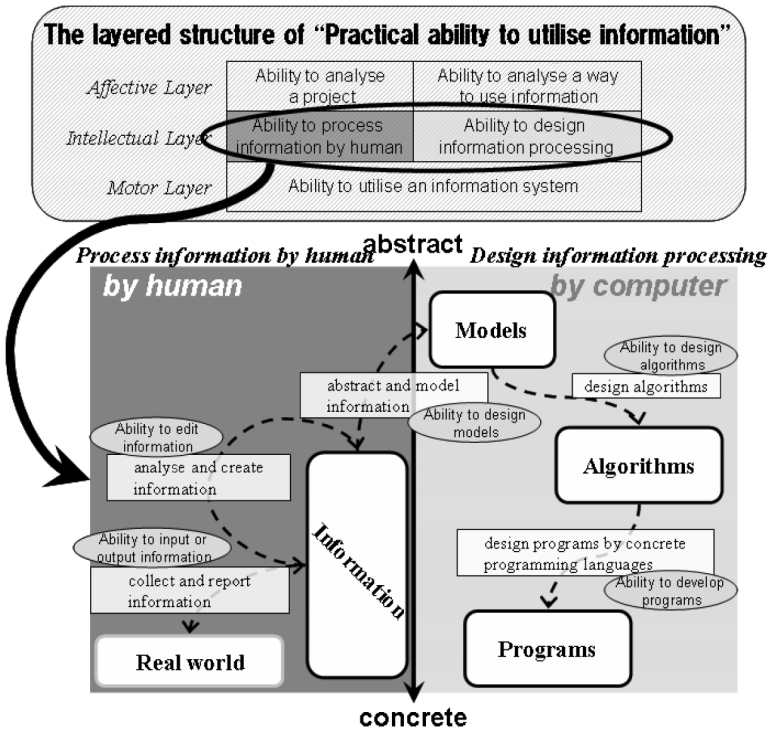
'Practical ability to act in the information society' can be specialised in 'Practical ability to utilise information' and 'Ability to act based on the information ethics'. The former is further specialised in 'Meta ability to utilise information', 'Ability to process information' and 'Ability to utilise an information system'. This classification is based on Bloom's taxonomy of instructional objectives as shown in the upper part of Figure 3. The Motor Layer corresponds to the psychomotor domain, which is based also on Bloom's taxonomy. In this layer, the ability to manipulate the information system is the concept of the goal of IT education. The Intellectual Layer corresponds to the cognitive domain, and the ability to process information is comprised of concepts in this layer. Further, we can classify this concept under an ability to process information by human ('Ability to process information by human') and an ability to process information by computer ('Ability to process information by computer'). The Affective Layer corresponds to the affective domain, which is based on Bloom's taxonomy, and the ability to analyse a project and to practice utilisation of information from the metalevel ('Ability to analyse a project' and 'Ability to analyse a way to utilise information') are concepts represented in this layer.

As stated above, 'Ability to process information' is specialised into 'Ability to process information by human' and 'Ability to process information by computer'. This classification is based on a viewpoint that is whether man is conscious of information processing by a computer or not.[2] Furthermore, these two concepts are classified into five concepts as shown in the lower portion of Figure 3. We can specialise 'Ability to process information by human' into input or output of information, into or from human as a medium ('Ability to input or output information') and processing and creation of information, which have been input into human as a medium ('Ability to edit information'). 'Ability to input or output information' is specialised in extraction and collection of information from the real world ('Ability to collect information') and reporting and sending of information to the real world ('Ability to report information'). 'Ability to edit information' is specialised into 'Ability to analyse information' and 'Ability to create information'.

We can divide 'Ability to process information using a computer' into the following three subabilities: abstraction of information with consciousness of processing by a computer ('Ability to design model'), design of structures of data and steps to process information ('Ability to design algorithms') and description of steps for information processing by using concrete programming languages ('Ability to develop programs'). Note here that the abstraction of information without taking computer processing into account belongs to 'Ability to edit information'. This distinction is usually difficult

to make. In this study, we decide that one aspect of abstraction is whether it is done for processing using a computer. Even if a modelling process about computer processing is performed unconsciously, such an ability is classified with 'Ability to process information using a computer' if it is a procedure, formulation or theory on computer processing.

Figure 3 The layered structure of the practical ability to utilise information

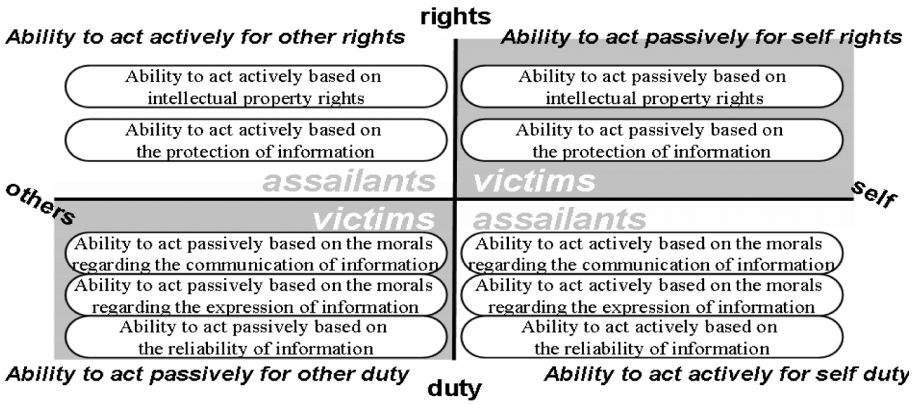


'Ability to act based on the information ethics', which is another specialisation concept of 'Practical ability to act in the information society', is classified as shown in Figure 4. The ability to act based on the information ethics for taking part in the information society can be classified into an ability to act by a subject person so as not to become an assailant ('Ability to act actively based on the information ethics') and an ability to act so as to avoid being a victim ('Ability to act passively based on the information ethics'). Further, the ability to act based on the information ethics can be classified in a two-dimensional space spanned by an axis that represents the owner of information that is a behavioural object into self or others and an axis that represents a target to take into consideration ethically into owner's right or duty. The ability to act based on the information ethics can thus be classified into four areas as shown in Figure 4.

When 'Ability to act actively based on the information ethics' and 'Ability to act passively based on the information ethics' are interpreted in this point, the former is in areas of the second and the fourth quadrants, the latter in areas of the first and the third quadrants. 'Ability to act actively based on the information ethics' is specialised in 'Ability to act actively for others' rights' and 'Ability to act actively for self duties',

and ‘Ability to act passively based on the information ethics’ is specialised in ‘Ability to act passively for self rights’ and ‘Ability to act passively for others’ duties’. We can divide these concepts further into specialised concepts related to intellectual property rights such as information protection, information communication morals, information expression morals and information reliability.

Figure 4 A structure of the ability to act based on the information ethics



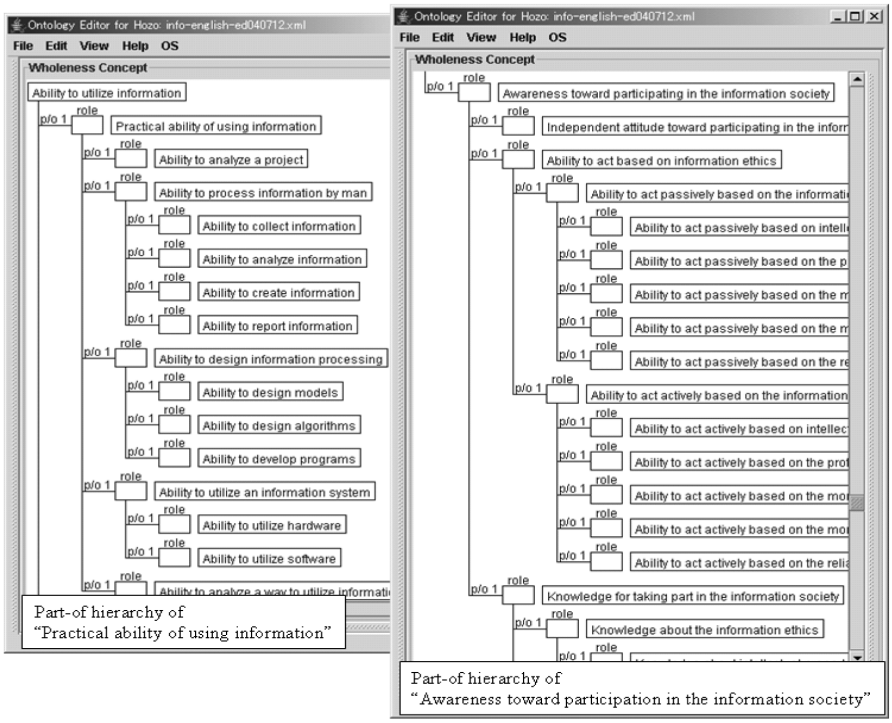
Finally, we briefly describe the *is-a* hierarchy under the concept of ‘Knowledge about information’. Firstly, ‘Knowledge about information’ is specialised in ‘Knowledge about the information science’ and ‘Knowledge for taking part in the information society’. ‘Knowledge about information science’ is specialised in ‘Knowledge about an information system’, ‘Knowledge about the expression of information’, ‘Knowledge about the design of information processing’ and ‘Knowledge about the communication of information’ from contents of knowledge. ‘Knowledge for taking part in the information society’ is specialised in ‘Knowledge about the information society’ and ‘Knowledge about the information ethics’. Note that these concepts of goal of IT education can be classified in the same way from contents of knowledge.

‘Knowledge about an information system’ is specialised in ‘Knowledge about hardware’ and ‘Knowledge about software’. ‘Knowledge about the design of information processing’ is specialised in ‘Knowledge about designing models’, ‘Knowledge about designing algorithms’ and ‘Knowledge about developing programs’. ‘Knowledge about the communication of information’ is specialised in ‘Knowledge about networks’ and ‘Knowledge about the information communication technology’. ‘Knowledge about the information society’ is specialised in ‘Knowledge about the influence of information’ and ‘Knowledge about the value of information’. ‘Knowledge about the information ethics’ is specialised in ‘Knowledge about intellectual property rights’, ‘Knowledge about the protection of information’, ‘Knowledge about morals regarding the expression of information’, ‘Knowledge about the morals regarding the communication of information’ and ‘Knowledge about the reliability of information’.

3.2 A part-of hierarchy of the goal of IT education

In this paper, we also describe a *part-of* hierarchy for the goals of IT education. A part of the *part-of* hierarchy is shown in Figure 5.

Figure 5 A part of the *part-of* hierarchy of the goal of IT education



A concept that shows the whole of the goal of IT education as 'Ability to utilise information' provided by the Ministry of Education in Japan. The Ministry of Education has prepared three viewpoints of this concept. These are 'Practical ability of using information', 'Scientific understanding of information' and 'Awareness towards participation in the information society'; this relation can be interpreted with *part-of* relation. In this study, we have classified these three viewpoints in more detail.

The structure of the *part-of* hierarchy is almost the same as that of the *is-a* hierarchy for these concepts. For example, the lower hierarchy of 'Practical ability of using information' is almost the same as the lower hierarchy of 'Practical ability to utilise information' in the *is-a* hierarchy and the lower hierarchy of 'Scientific understanding of information' has almost the same structure as the lower hierarchy of 'Knowledge about the information science' in the *is-a* hierarchy. This correlative relationship is typical between *part-of* relations and *is-a* relations. Here, we discuss a common problem that is caused by *is-a* relation and *part-of* relation.

It is known that there are some kinds of *part-of* relations that use different semantics (Mizoguchi et al., 1999). The classification into three viewpoints prepared by the Ministry of Education is a *part-of* relation called *Function-part-of* (Mizoguchi et al., 1999). This relation is one of *part-of* relations that each makes a 'functional' contribution on the whole. In this case, the structure of the *part-of* hierarchy does not become the same as that of the *is-a* hierarchy. However, where concepts such as knowledge and ability, which are included in our *part-of* hierarchy, are concerned, such a problem occurs, because *part-of* relation needs the *Operation-part-of*, which requires careful attention for differentiation between the *is-a* and *part-of* relations.

One of the examples of the *operation-part-of* is found in the case of plant operation. Consider a normal operation (operation in a normal situation) and a restoration operation (one in a situation where recovery is implemented from above). Both operations are apparently subclasses of the operation class. At the same time, however, if the operation is regarded as a working process, this relation can be interpreted as also a *part-of* relation, given that the whole operation process is composed of normal operations and restoration operations. The nature of this relation is that a class to which a whole concept belongs is a super class of a class to which all partial concepts belong. When we consider these from a viewpoint of time or space, we can interpret these as *part-of* relations.

For example, when we regard knowledge as a field of study, we find that *is-a* relation is suitable, but when we regard knowledge as what a learner should learn and use, we find that *part-of* relation is more suitable. In other words, it means that to learn knowledge it is necessary to learn all more detailed knowledge. In the same manner, when we regard an ability as simply an ability, we find that *is-a* relation is suitable, but when we regard ability, which a learner possesses and performs, we find that *part-of* relation is more suitable.

For example, when we regard 'Ability to process information by human' as an ability, each of the concepts ('Ability to collect information', 'Ability to analyse information', 'Ability to create information', and 'Ability to report information'), which are subordinate concepts is the ability to process information by human and we can find that these relations are *is-a* relations. However, when we regard 'Ability to process information by human' from the viewpoint of a process of processing, the ability to process information by human is realised by all concepts ('Ability to collect information', 'Ability to analyse information', 'Ability to create information' and 'Ability to report information') and we can find that these relations are *part-of* relations. In the case of knowledge and capability, as in this example, the structure of the *part-of* hierarchy and the structure of the *is-a* hierarchy are almost the same, though their meanings are quite different. The other classification of the goal of IT education mentioned above does not make a clear distinction between *is-a* relation and *part-of* relation. Such confusion obstructs the understanding of teachers of the goal of IT education. One of the advantages of our research is that it separates the hierarchy of *is-a* relation and that of *part-of* relation completely.

The necessity of having a *part-of* hierarchy that has almost the same structure as an *is-a* hierarchy occurs when an instance of a class of a middle concept[3] is made. When an instance of a class of a middle concept in an *is-a* hierarchy is made, we can obtain an instance of a goal of IT education that belongs to one of the subclasses of its middle concepts. In other words, we cannot obtain an instance of a goal of IT education from each of those subclasses that belongs to the class of the middle concept in an *is-a* hierarchy. In a *part-of* hierarchy, on the other hand, we can obtain an instance of a goal of IT education from each of those subclasses that belongs to the class of the middle concepts. Therefore, we described not only an *is-a* hierarchy but also a *part-of* hierarchy of goal concepts in our research.

In the target world in which the structure of an *is-a* hierarchy is almost the same as that of a *part-of* hierarchy, the confusion of *is-a* relation with *part-of* relation can obstruct a user's understanding of the distinction. In the usual classification of the goal of IT education, *is-a* relation and *part-of* relation were also confused. This is also one of potential obstructions to teachers' understanding of IT education. Thus, it is necessary to

distinguish hierarchies based on *is-a* relation and *part-of* relation clearly as we have done here. The concrete obstruction of the confusion of *is-a* relation and *part-of* relation is described in Section 3.3.2.

3.3 A benefit of the ontology of the goal of IT education

In this section, we show the advantages of the ontology of the goal of IT education over other classifications from two viewpoints. Firstly, we describe how confusion among goal concepts is obstructive, referring to the Goal List (The Meeting of Tuesday, 2001) introduced in Section 2. Next, we explain another ontology, which a student in our laboratory built, then we describe the obstructive confusion of *is-a* relation and *part-of* relation by comparison of our ontology with this ontology.

3.3.1 There is no confusion with other concepts

In this paragraph, as an example of the current standard classification of goal of IT education, we take up the Goal List (The Meeting of Tuesday, 2001), which is well known in Japan. Though this Goal List was not generated based on the ontology theory, this Goal List already has been widely used with the same purpose as an ontology in Japan. Therefore, it is necessary for this Goal List to have the same natures as the ontology. For this reason, we compare this Goal List and our ontology from the viewpoint of the ontology theory. The classification of the Goal List of IT education is shown in Figure 6.

Figure 6 The classification of the Goal List of IT education

A : Practical Ability of using information
- (1) Expression and communicating information
  - a: Expression of information
  - b: Communication by a media
- (2) Using information in problem solving
  - c: Discovery and planning of a problem
  - d: Collection of information
  - e: Classification, analysis and judgment about information
  - f : Reporting and sending of information
- (3) Selecting the means of information (information media, computer, network)
  - g: Selecting the means of information

B: Scientific understanding of information
- (4) Understanding various means of information and its advantages and disadvantages
- (5) Basic theories and methods of information processing, information technology, and human's information recognition

C : Awareness towards participating in the information society
- (6) Awareness towards information
  - m: Awareness towards information
- (7) Information ethics and responsibility in sending out information
  - n: Information ethics

The Goal List has three top-level categories, 'Practical Ability of using information', 'Scientific understanding of information' and 'Awareness towards 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, though these levels are not shown in this figure. 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. 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 systematising 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. For example, in the case of the Goal List, the concept of the goal 'Selecting the means of information' contains not only the goal of IT education but also that of a learning environment in which learning occurs. This is influenced by the purpose of the Goal List, which is to provide teachers with viewpoints of evaluation of learners of IT education. Moreover, systematisation like this example, in which other concepts are mixed, sometimes causes another problem: the extracted concepts are not completely independent of each other. For example, in the case of the Goal List, both 'Expression of information' and 'Reporting and sending of information' are subordinate concepts of 'Practical ability of using information' and have the same goal as 'Ability to report information'. When teachers use such a classification, their awareness to this goal may be obstructed by superficial differences among learning activities.

Given the above 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 metaabilities 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 these goals.

3.3.2 No confusion between is-a relation and part-of relation

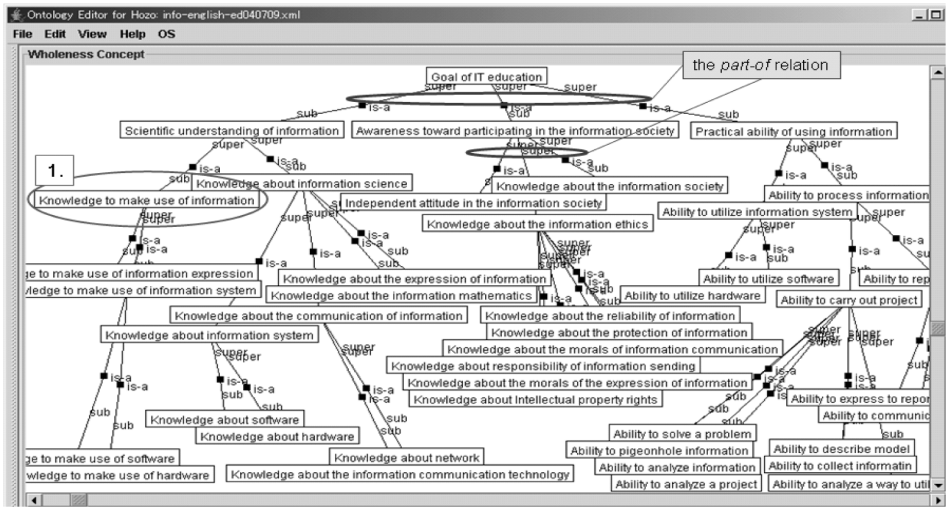
An ontology of the goal of IT education that was built by a student in our laboratory whose understanding about the ontology theory was insufficient is shown in Figure 7. In this paragraph, we show obstruction caused by confusion between the *is-a* and *part-of* relations through a comparison of this ontology and our ontology.

The student described all relations as *is-a* relations without considering the meaning of classification. As a result, the viewpoint of the classification is not unified and a distinct *part-of* relation exists. The first obstruction related to this confusion is that the inheritance of attributes, which is one of the biggest advantages of the *is-a* hierarchy, is not realised in this hierarchy. And also, it can confuse teachers by classifying a concept based on an *is-a* relation in spite of having classified it originally based on *part-of* relation.

For example, the topmost classification in Figure 6 is originally based on *part-of* relation, but it is classified based on *is-a* relation. This can promote misunderstanding by teachers that the educational goal of three subordinate concepts can be attained independently to attain the educational goal of the super no space ordinate concept,

when, because this hierarchy is *part-of* relation (*function-part-of*), the goal of the superordinate concept cannot be actually attained unless all goals of subordinate concepts are attained with each role on the whole. This can also obstruct teachers' understanding of each specific goal of IT education. For example, in the *part-of* hierarchy, teachers can easily understand that 'Ability to analyse a project' is an ability to analyse a project that can be solved by processing of information, which is done later on the whole process for solving it, because the definition of *part-of* relation shows that it is a part of the whole process of processing information directly. However, in an *is-a* hierarchy, teachers can easily misunderstand that this concept is an ability to consider a project with no relation to processing of information because subordinate concepts are independent in this hierarchy.

Figure 7 An ontology of the goal of IT education built by a student in our laboratory whose understanding of the ontology theory was insufficient



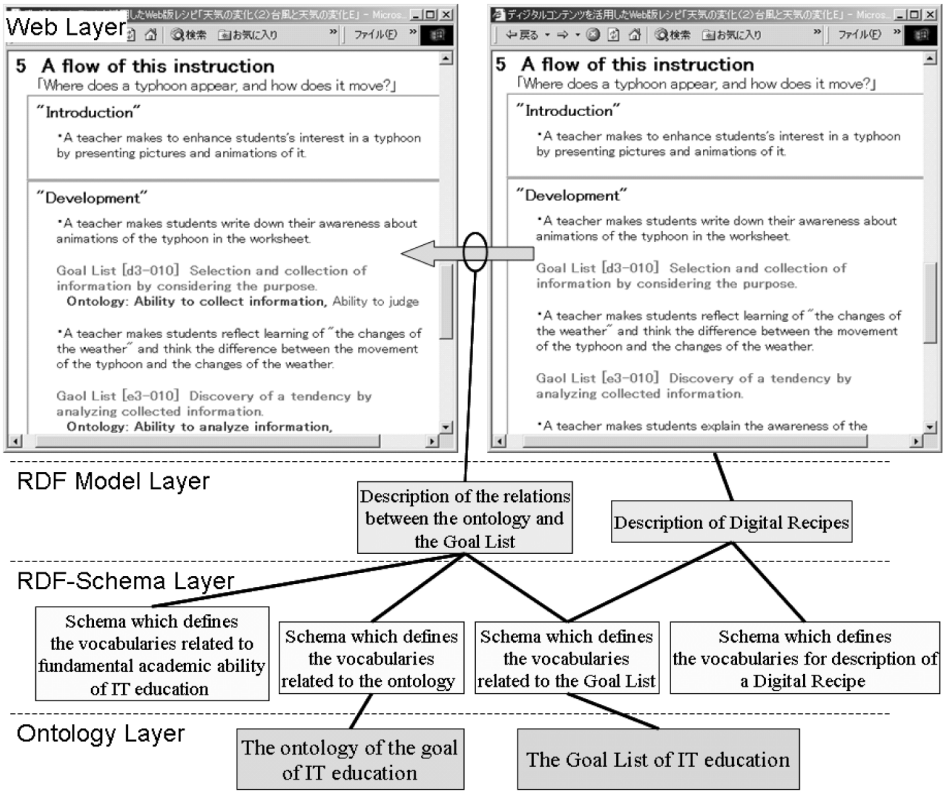
Further, the author of this ontology created concepts such as 'Knowledge to make use of information' to get rid of these contradiction as shown by '1' in Figure 6. This concept is inappropriate because both concepts of knowledge and ability of utilisation are confused in it. These examples illustrate how the mixture of *is-a* and *part-of* relations can confuse both users and authors. Therefore, our ontology of the goal of IT education, which incorporates the distinction between *is-a* relation and *part-of* relation and the exclusion of other concepts, is meaningful.

4 A prototype system based on semantic integration

In this section, we describe a prototype system for supporting teachers based on the above framework. Resources used by this system are simple lesson plans on the web (called Digital Recipes) 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; we authored the metadata of these resources from the viewpoint of the Goal List.

The layered structure of the prototype system we built is shown in Figure 8. This system is constructed in four layers. The bottom layer is the ontology layer. In this layer, we define all the concepts related to the above the ontology of the goal of IT education and the Goal List of IT education.

Figure 8 The layered structure of the prototype system based on semantic integration



The second layer is the RDF-Schema Layer. In this layer, the vocabularies of classes and properties used in the third layer, the RDF Model Layer, are defined. There are four schemata in this layer. As two schemata in them, the vocabularies of classes and properties related to the ontology and the Goal List defined in the bottom layer are defined. The third schema defines the vocabularies related to the fundamental academic ability of IT education. 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 example, there is an ability to express something, which is the fundamental academic ability of the ability to report information. The difference between them is 'Use of various ways to express information'. We do not describe this fundamental academic ability in this paper in detail. The fourth schema defines the vocabularies of classes and properties for description of resources of the Digital Recipes this prototype system processes.

The third layer is the RDF Model Layer. In this layer, we can author metadata of various resources by using the vocabularies defined in the RDF Schema Layer. For this prototype system, we authored metadata of two resources. One is a resource that shows

the relations between the Goal List, the ontology of the goal of IT education and the fundamental academic ability of IT education. The Goal List provides teachers with some examples of more concrete learning activities with a level that shows when learners should attain each goal classified. For this resource, we authored metadata of these learning activities, which belong to the respective concepts of the Goal List, by using the vocabularies defined in the RDF-Schema Layer related to the ontology of the goal of IT education and the fundamental academic ability of IT education. The other resource is the description of the metadata of the Digital Recipes. We described the same contents as the resources that are open to the public in RDF. Thus, this metadata is described based on the Goal List.

The topmost layer is the Web Layer. In this layer, the system analyses the metadata described in RDF and provides teachers with web pages that are reconstructed as HTML files. For example, the screen shot on the right in Figure 8 shows a web page that the system analyses the metadata of a Digital Recipe, which a teacher requests and provides him/her with it. These web pages are almost the same as the contents of the resources provided by Okayama Prefecture Information Education Center.

The prototype system explained in detail in this section is a system that converts the contents of the screen shot on the right in Figure 8 to the contents of the screen shot on the left. The system analyses 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. The example of integrated information that is an output by the system is the screen shot on the left in Figure 8.

This prototype 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 the shadow of it as the benefit of the ontology are provided. In this framework, the system can extract Digital Recipes, which contains a particular goal of IT education by using the relations between the Goal List and our ontology. Furthermore, the system can also extract Digital Recipes that teachers will be able to develop easily into the instruction, which contains a particular goal of IT education by using the description of the relations between our ontology and the fundamental academic ability. We have already finished the implementation of these functions. This example of processing by the prototype system is based on a very simple mechanism, though this system realises the fundamental function of semantic integration based on two ontologies. In this framework, the system will be able to integrate more complicatedly resources based on two ontologies according to the features and their manner of use.

5 Related work

Many organisations 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) (IEEE LTSC, 2002). The LOM specifies the syntax and semantics of LOM, defined as the attributes required to full/adequate description of a learning object. And the IMS Learning Design project (IMS, 2002) 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. In compliance with this standard, we can express the contents of lesson plan in detail. However, it is difficult to share the resources based on the nature of the contents, because these approaches focus on the minimal set of attributes to allow these LOs and Lessons to be managed, located and evaluated in total independence of their contents. Our approach aims at describing the metadata of the detailed contents based on the ontology to facilitate the sharing of information.

In the area of the Knowledge Management, there is OntoShare (Davies et al., 2003) that annotates documents in a collaborative manner using shared ontologies in a large organisation. This system facilitates and encourages the sharing of information between communities of practice within organisations based on Semantic Web technology. However, the share of ontologies in this approach is realised only in an organisation. It is difficult to share ontologies in the open environment. Our approach aims at realisation of the same effect as the time when ontologies can be shared in the open environment, using the other research result, which has been spreading to the public in about ten years.

There is a research using these standards and various ontologies (Aroyo et al., 2004; Bourdeau and Mizoguchi, 2000). The goal of Aroyo et al. (2004) 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. The study of Bourdeau and Mizoguchi (2000) 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 instruction for cultivating ability to utilise information 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 the ontology of the goal of IT education in detail. We proposed a framework to use the results of ontology alignment with other IT education goal ontologies. The ontology of the goal of IT education consists solely of concepts of the goal of IT education in a *is-a* hierarchy. We considered the difference between *is-a* relation and *part-of* relation and classified separately the *part-of* hierarchy. Then, we showed the advantages of our ontology over other classification from the above two viewpoints. We described a prototype system, which realises semantic integration by the alignment between our ontology and the Goal List.

As future work, we intend to build a more effective system based on this framework according to these features and the manner of use. We also intend to build another system to support dynamically the teachers when they design instruction. For realisation of this system, we plan to use not only the framework shown in Figure 8 but also the different types of '*part-of*' relations between the goals of IT education.

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Notes

[1]In Figure 2, a root concept of *is-a* hierarchy (Goal of IT education) and these three concepts are linked by an *is-a* relation. Strictly, these are not *is-a* relations but relation that these concepts can get value of a goal of IT education as a roll concept.

[2]'A learner processes information by using computer' is not contained in 'Ability to process information by human' or 'Ability to process information by computer' because the ontology of the goal of IT education discusses only concepts of goal of IT education, not other concepts such as learning activity. However, the goal of IT education contained in this activity belongs to 'Ability to process by human'.

[3]Here, 'middle concept' means a node, which is not a leaf node in the tree structure. In other words, it is a node, which has more than one child node.