Mohd Ayub A. F. et al. (Eds.) (2011). Workshop Proceedings of the 19th International Conference on Computers in Education. ChiangMai, Thailand: Asia-Pacific Society for Computers in Education.

The Effect of Ontological Modeling of Lesson Design: A Case Study in a Community of Teachers

Yusuke HAYASHI[a*], Toshinobu KASAI[b] & Riichiro MIZOGUCHI[c]
[a]*Information Technology Center, Nagoya University, Japan*
[b]*Graduate School of Education Master's Program, Okayama University, Japan*
[c]*The Institute of Scientific and Industrial Research, Osaka University, Japan*
*hay@icts.nagoya-u.ac.jp

Abstract: This paper discusses computer support for sharing empirical instructional design knowledge among active teachers in schools. The authors have developed an ontology called OMNIBUS and a theory-aware authoring system called SMARTIES. This study prompts their adoption by a community of social studies schoolteachers in Tokyo. This paper presents the advantages of OMNIBUS and SMARTIES and considers problems faced in widening their adoption in schools.

Keywords: ontological engineering, authoring system, lesson plan

Introduction

In the field of education, people have accumulated knowledge theoretically as well as practically. A representative theoretical approach is to build theories of learning or instructional. A typical practical approach involves a "lesson study" [5], in which schoolteachers observe and review each other. This interactive approach does not always work as well as in other areas. Schoolteachers tend to educate students using their own experiences [7].

A big goal of this study is to build an information system that support both for putting theoretical knowledge to practical use and for sharing the empirical knowledge of schoolteachers. In other words, this study aims at promoting exchanges of knowledge between researchers and schoolteachers. Hayashi et al. propose an ontology and an authoring system for utilizing theoretical knowledge of teaching; OMNIBUS ontology is a basis for organizing learning and instructional theories and SMARTEIS is a theory-aware and standards-compliant authoring system [1]. As the first step to achieve the latter goal, support for sharing the empirical knowledge of schoolteachers, this paper reports attempts to deploy them in practice with a lesson study group of teachers.

Deploying them in practice requires analyzing the needs of actual schoolteachers and developing support functions to meet these needs. The authors conducted a needs analysis with a lesson study group of teachers in Tokyo. This group is consisted of active teachers and former teachers. The active teachers are highly interested in lesson study and have experience of it. The former teachers are working in school committees to coach active teachers. In this study, we examined the practical aspects of OMNIBUS and SMARTIES with this group and considered improvements that can be made to the technology based on insights gained in its practical use.

	Items to be learned	Point of instruction	Evaluation (■), Methods (○)
Introduction(a)	" Check the location of Fuchu City in the Kanto region "(b) • Students look(b') for Fuchu city in the Kanto region and express(c) it in their exercise books.	• The teacher calls students attention to the positional relation of Fuchu City in Kanto region with comparative expression.	■ Students can look for Fuchu city in Kanto region with atlas ○ statements, exercise book

Fig. 1Part of a lesson plan modeled in this study.

This paper discusses the effect of modeling of design of lessons based on OMNIBUS. Schoolteachers describe a design of lesson in a document called lesson plan. The authors were given lesson plans that the group had prepared for their lesson study and modeled them based on OMNIBUS. The authors discussed the models with the active teachers in the group. What is discussed are the analysis results, proposals for alternative instructional strategies, and the usefulness of OMNIBUS and SMARTIES. The authors received six lesson plans from the group and modeled four of them. This paper reports the findings of the practical efforts in using the models.

The rest of this paper is structured as follows. The next section explains a proposed modeling framework and how a lesson plan is described in the framework. Section 3 reports the results of the practical efforts and considers the effectiveness of the framework, based on comments received from active teachers. Finally, the last section concludes this paper and presents some future plans for this study.

1. Modeling Lesson Design based on OMNIBUS

1.1 Learning and Instructional Scenario Model

OMNIBUS proposes a framework for modeling the learning and instructional process, called the *learning and instructional scenario model (I_L scenario model)*. This will not be taken up in detail here. This section concentrate on the basic features of it. Further details are given in [1].

The I_L scenario model is composed of the concepts *I_L event* and *WAY* that are defined in OMNIBUS. The definitions of them are explained later with examples. The basic features in the definition of the I_L scenario model are the following [6]:

- learning is modeled as a state change of a learner[1];
- learning and instructional process are organized separately as "what to achieve" and "how to achieve"; and
- the principles of learning and instruction are organized in relation to "how to achieve" as the design rationale.

Based on these features, OMNIBUS allows us to describe the design rationale of the learning and instructional process as a hierarchical part–whole structure of learning goals. Although OMNIBUS is firstly proposed as a basis for organizing theoretical knowledge in a cross-paradigm manner [1], this paper discusses another use of it. It is to extract and organize empirical knowledge from the practical efforts of active teachers.

[1] This includes change of cognitive, physical and affective state.

1.2 Modeling Lesson Designs as I_L scenario models

The aim of this study was to allow us to make computer-understandable *lesson design*. By lesson design, we mean a plan of a lesson in a teacher's mind. This study proposes describing lesson design as an I_L scenario model.

As mentioned above, a lesson design is often described in a document called a lesson plan. A lesson plan is composed of a plan of lessons for a course unit. A teacher describes the overall plan of the lessons and the detailed plan of one of them with learning goals, points of instruction and so on. Figure 1 shows an example of part of a detailed plan. The average length of a lesson plan is four A4 pages. Broadly speaking, half of them are for the overall plan, and the others are for the detailed one. This document functions as a medium for sharing lesson design among teachers. However, it is difficult for teachers to represent lesson design in a document of lesson plan because of the length limitation mentioned above and the difficulty in externalization of thoughts in one's mind. The I_L scenario model is expected to work as a means for bridging the gap between a lesson design and a lesson plan.

Figure 2 shows an example of an I_L scenario model made from the lesson plan shown in Fig. 1. This tree structure represents not the *is-a* structure of I_L event but the *part-whole* structure of it. Each node represents I_L event. This is composed of instructional action, learning action and state change of learner. The state change is the core of the I_L event as mentioned above. Each line linking nodes above and below it represents WAY. It means that the upper I_L event can be decomposed into the lower ones. On the contrary, this also means that the lower I_L events can achieve the upper one.

This model represents the design rationale behind the lesson plan. The part of the lesson plan shown in Fig. 1 describes the introduction part of the lesson. This description is shown as the nodes surrounded by a dotted line in Fig. 2. The authors inferred the rest from the description in the lesson plan and observations made in a lesson given by the teacher who created the lesson plan. In the lesson plan, the teacher asks students a question (Fig. 1(b, b')) and then lets them write down the answer (Fig. 1(c)) in the introduction part (Fig. 1(a)). Two nodes surrounded by a dotted line (Fig. 2(b) and (c)) represent the intention of these concrete actions. These nodes are I_L events representing that students recognize a topic (Fig. 2(b)) and externalize the cognition (Fig. 2(c)). The links between these events and the event representing the whole of the introduction part (Fig. 2(a)) composes the design rationale of this lesson plan.

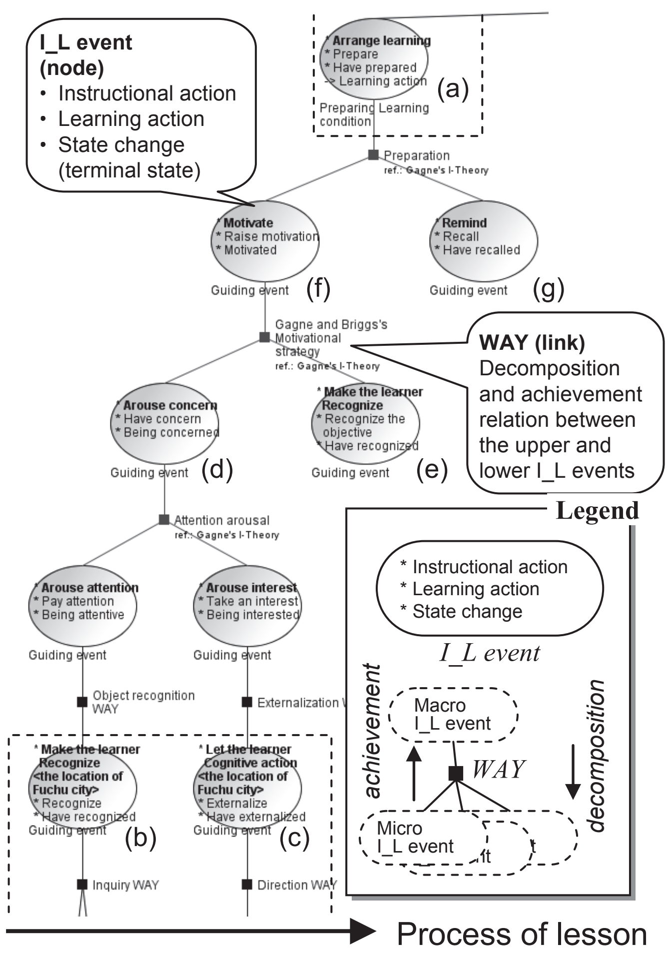

Fig. 2 Part of an I_L scenario model.

The events in Fig. 2(b) and (c) are for achieving the goal to get motivated to learn, which is represented in the event shown in Fig. 2(d). The event is paired with the event shown in Fig. 2(e) for making the learner recognize the goal of learning. This pair of events is for motivating the learner (Fig. 2(f)). Finally, this event for motivation is paired with the event for recalling prior learning (Fig. 2(g)), together composing the introduction of this lesson (Fig. 2(a)). Like this, an I_L scenario model allows us to describe the design rationale included the lesson design as a hierarchical structure of I_L events.

The lesson plans the authors examined are simple, like the one shown in Fig. 1, and do not have a detailed description of the design rationale. Of course, due to the length limitation, it is difficult for schoolteachers to write a lesson design in detail. However, reflection of the lesson design by the creator and sharing of it with others requires such an implicit design rationale included the lesson design. This study positions making I_L scenario model based on OMNIBUS as a tool to extract an implicit design rationale from a lesson design.

Note that the authors do not insist that the I_L scenario model should replace a lesson plan. The I_L scenario model complements a lesson plan, making the relation between the lesson design in the teachers mind and lesson plan as the resulting document clear by externalization of the implicit design rationale that is not described in the lesson plan clearly. Furthermore, making lesson design computer-understandable, the authors also aim to facilitate sharing of lesson designs and empirical knowledge among teachers. One of the causes of difficulty in sharing lesson designs is the differences in backgrounds among teachers or communities of teachers. OMNIBUS and the I_L scenario model help to expose such diverse backgrounds, allowing us to describe the lesson design behind the lesson plan. They also enable us to analyze lesson design, such as the characteristics of each lesson design, comparisons between them, and the tendencies of teachers and teacher communities.

2. An Analysis of Lesson Design with I_L Scenario Models

In this section, we discuss analysis of lesson design with an I_L scenario model and teachers' responses to it. The origins of the models illustrated in this section are lesson plans made by the group of teachers cooperating with the authors. The authors modeled the lesson plans with a presumption of the design rationale and then analyzed them and alternatives to some part of the design. We showed the teachers the models, analysis results, and alternatives in order to discuss their validity and the usefulness of the I_L scenario model for them. The authors made only four models and this section discusses the extraction and management of empirical knowledge of active teachers via these models.

In the practical efforts, the authors made the I_L scenario models on SMARTIES and the teachers did not operate it. This is because the purpose of this work was to assess not the utility of SMARTIES as an authoring tool but the usefulness of making I_L scenario models based on OMNIBUS. Although the preliminary study [3] suggests the usefulness of OMNIBUS, it also suggests some difficulty in the use of SMARTIES by active teachers. Therefore, in order to focus on assessing the usefulness of the model, active teachers were not assigned the task of making the I_L scenario models on SMARTIES in the current study.

2.1 A Structural Analysis of Lesson Design

An advantage of making an I_L scenario model is that we can compare lesson designs on a common foundation. OMNIBUS works as the common foundation that converges varying terms and represents the design rationales behind lesson plans.

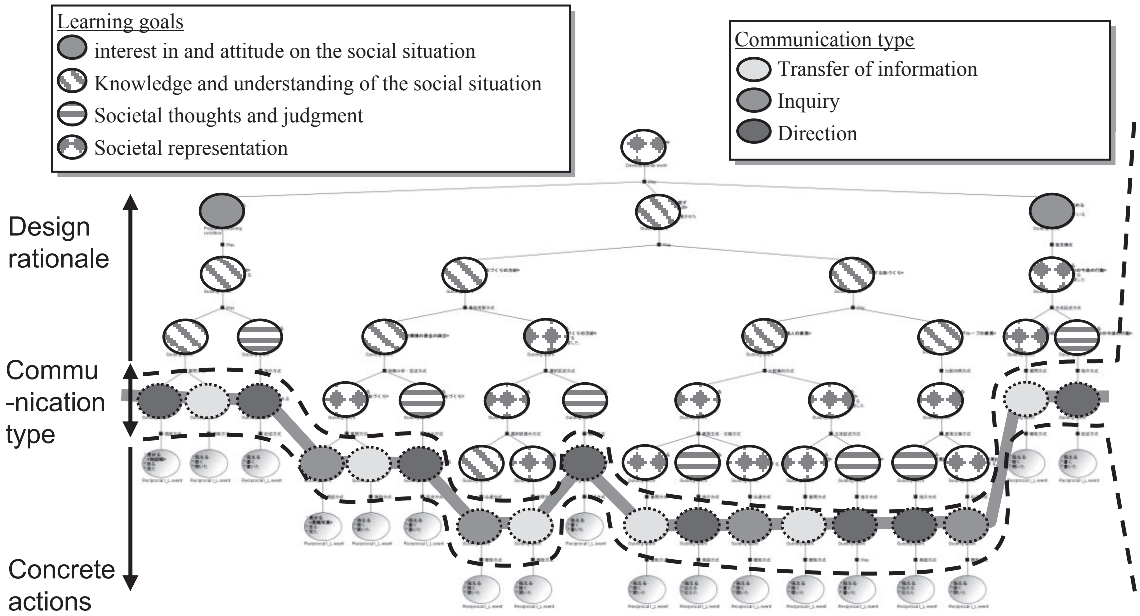

Fig. 3 An overview of an I_L scenario model.

Figure 3 illustrates an overview of the I_L scenario model made from a lesson plan provided by an active teacher and the structural analysis result obtained from it. This figure represents the model of the whole of a lesson. The nodes and links in the figure represent I_L events and WAYs, respectively. The flow of the lesson is represented from left to right in the figure. The bottom nodes represent the time-line of concrete actions to be performed teachers and students from left to right. For example, concrete actions include teachers talking or showing materials to students, and students verbalizing their opinions, so on. The hierarchical structure represents the design rationale behind the process of such concrete actions at multiple levels. For example, the second level from the root coarsely represents the lesson process, composed of “introduction”, “development” and “summary”.

Analysis shown here can be carried out from two standpoints according to the types of layers of the I_L scenario model [2]. One is the standpoint of interaction between teachers and learners, and the other is the standpoint of learners’ internal states that express learning goals. In particular, in the latter, the states defined by OMNIBUS are related to the goals defined in the curriculum guidelines set by the Ministry of Education in Japan, which are familiar to active teachers.

Fig. 3 also shows the I_L scenario model with state types. Nodes are overlaid with patterns correspond to types of learning goals and communication. This distribution of types represents tendency of this lesson. Fig. 4 shows quantitative analysis that is the proportion of types of communication between teachers and students in the model. These results tell that us this scenario is well-balanced in terms of both learning goals and communication styles with students because the types of them are not weighted in a type.

The teachers gave positive comments in the practical analysis of lesson design with OMNIBUS. Their comments showed that this analysis is useful to bring to light the problems involved in lesson design, such as inconsistency in lesson design and the gap between lesson design and the lesson plan.

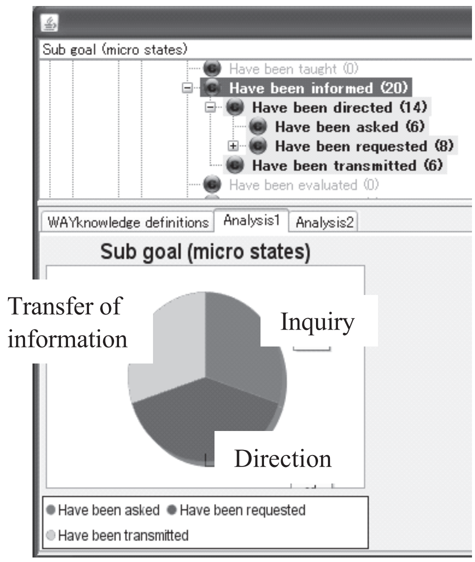

Fig. 4 Lesson design analysis result.

This will allow them to get an overview of a lesson design and then to refine it.

2.2 A Comparative Analysis of Instructional Strategies in Lesson Design

Another advantage of making an I_L scenario model is to record the design rationale included a lesson design. As stated above, an I_L scenario model can separately deal with a learning goal and ways to achieve it because of the separation of the concepts of I_L event and WAY. For example, in order to make a learner recognize his/her error, a teacher can directly inform him/her or can make him/her aware of it indirectly. The former is a kind of cognitivist way to achieve the goal. The latter is a kind of constructivist way. There are pros and cons to both: whereas the former is effective in achieving the goal itself, the latter is effective in generating self-reflection. In this manner, there are alternative ways to achieve a learning goal, depending on the educational policy. Organizing learning goals and ways to achieve them separately and combining them for a lesson allows us to record not only the final decision but also alternatives. This helps to clarify the reason for the decision making.

Figure 5 shows an example of such a record that includes a teacher's final decision and the alternatives. The combination of WAYs (a) and (b) is the final decision described in the source lesson plan. WAYs (a') and (b') are alternatives to (a) and (b), respectively. The final decision, the combination of WAYs (a) and (b), means that a teacher presents multiple choices of typical thoughts on the topic in order to help learners make their own thoughts and then let the learners choose one as their own thought. Modeling the process as multistage decomposition by WAYs (a) and (b) is helpful in considering alternatives. In this case, the main focus of decomposition is multiple choices to be presented to students. The difference between WAYs (a) and (a') is whether or not a teacher lets the students consider multiple choices. The difference between WAYs (b) and (b') is whether or not the teacher gives choices to the students when the teacher lets the students consider multiple choices.

It is noteworthy that, in this study, the WAY describes these differences in the abstraction level. Making each instructional or learning strategy reusable in the other lesson designs requires abstraction and modularization of the strategy instead of embedding it in a lesson design. Furthermore, its background is valuable information for principled reuse of strategies. For example, WAY (b') is closer to a constructivist approach than WAY (b) is and requires a heavy cognitive load of learners. Therefore, we could consider that WAY (b) is suitable for the primary stage of learning and WAY (b') is suitable for the advanced stage.

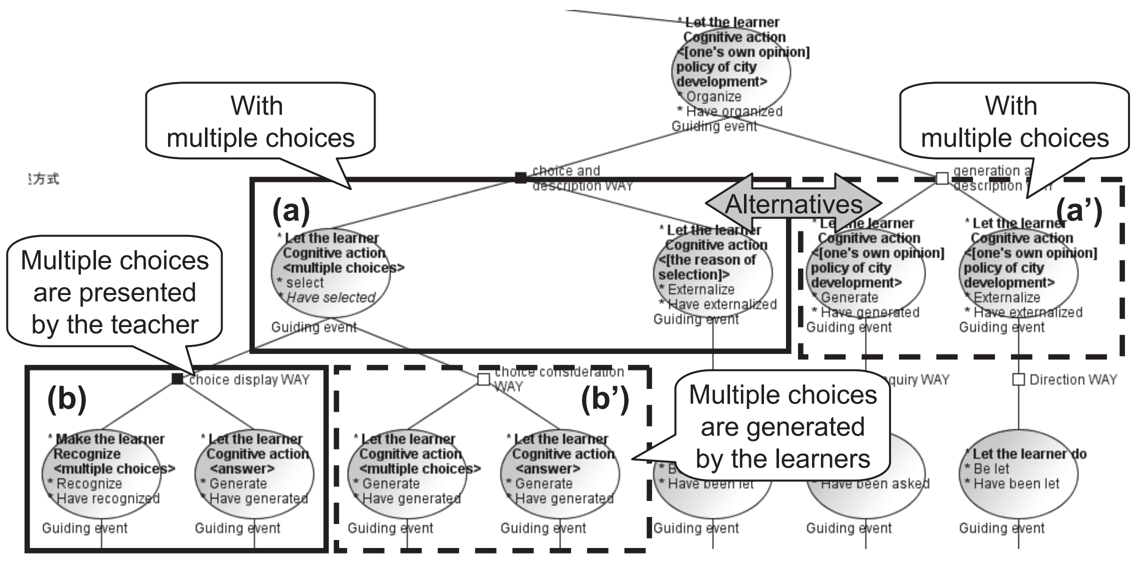

Fig. 5 Alternatives in an I_L scenario model.

Abstraction of strategies and information about them will allow us to reuse lesson designs and strategies included in them effectively.

In fact, when the authors showed an I_L scenario model with alternative strategies to an active teacher, he explained the difference between his own educational policy and that of the teacher who made the source lesson plan. He noted that the teacher who made the lesson plan often used the strategies of WAYs (a) and (b), whereas he often used the strategies of WAYs (a) and (b') not like this lesson design. He also said that, although he had been aware of the difference between him and other teacher, he had never fully verbalized the difference. Based on these impressions, he commented that describing a lesson design as an I_L scenario model helps to understand the difference between not only lessons but also teaching styles. He also suggested that this method may be helpful for disseminating instructional strategies in a community of teachers. He expected that such dissemination facilitates awareness of the differences between teachers' own strategies and those of others.

3. Conclusion

This paper reports the findings of practical efforts for the development of a technology for extracting and organizing empirical knowledge of active teachers. Although we do not insist on the generality of the results because of the paucity of available data, the teachers who joined in the practical efforts gave positive comments on the effectiveness of OMNIBUS in describing lesson design. Their comments suggested that modeling strategies in a lesson design as WAYs allows us to organize empirical knowledge in a reusable manner.

Our practical efforts revealed that what active teachers require is a system for organizing the instructional strategies of excellent teachers or strategies that have been refined in a community, rather than mere theoretical knowledge that the authors have accumulated so far by themselves. In response to these findings, we also aim to make OMNIBUS a common foundation for sharing the empirical knowledge that active teachers have accumulated. This foundation may be a circular system of theory and practice in which we can put theories into practice effectively and build theories from findings gained in practice.

Of course, it is difficult for active teachers to describe lesson design and extract empirical knowledge to be shared in a community of teachers with their current forms of OMNIBUS and SMARTIES. In the earlier preliminary study and the practical efforts reported in this paper, it took time for teachers to understand OMNIBUS and SMARTIES. It is difficult for them to describe the lesson designs behind lesson plans because they tend to make lesson designs with habitual ways of thinking. They are usually not aware of the design rationale. Therefore, the authors are planning to improve OMNIBUS and SMARTIES in terms of usability. This includes not only refining the user interface of SMARTIES but also developing a way of managing OMNIBUS and SMARTIES in a community of teachers. In addition to that, the authors also planning to add functions for reducing the cognitive load on teachers in terms of meta-cognition [4]. It is necessary to consider support functions for helping externalization and self-reflection of the lesson designs in their mind.

An even broader goal of this study is to strengthen the solidarity of communities of teachers in terms of knowledge sharing. Currently communities of teachers are mainly organized by subject. For example, the community that we have collaborated with is social studies. In social studies, there are the three areas of civics, geography, and history, and each area tends to develop its own instructional methods. Of course, each area needs its own methods that depend on the subject. However, through our practical efforts, we consider that there are two types of instructional method that can be shared beyond subject boundaries. We are planning to conduct a survey of pilot schools with regard to such cross-subject instructional methods. In pilot schools, teachers conduct cross-curricular discussions with each other, and this appears to be a suitable scenario for considering the generality of instructional methods.

Acknowledgements

The authors are deeply grateful to Tochusya, the community of social studies teachers in Tokyo. In particular, the authors would like to thank Mr. Makoto Ikeshita at the Kaishin first junior high school and Mr. Hidemi Nakano at the Fuchu fifth junior high school, whose comments and suggestions were immensely valuable throughout the course of this study.

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