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Ontological Modeling for Reflective Instructional Design: A Case Study on Modeling a Lesson Plan

Yusuke HAYASHI[a*], Toshinobu KASAI[b] & Riichiro MIZOGUCHI[a]
[a]*The Institute of Scientific and Industrial Research, Osaka University, Japan*
[b]*Graduate School of Education Master's Program, Okayama University, Japan*
*hayashi@ei.sanken.osaka-u.ac.jp

Abstract: This paper discusses computer-based support for self-reflection of teachers in a lesson design task. One of the keys to success in the design task is an alternating cycle of externalization of ideas and reflection resulting from those externalized ideas. However, it is difficult for teachers to externalize their ideas to generate effective reflection. This study aims at enhancing reflection by ontological modeling of the design rationale of a lesson plan. The result of a trial in which a teacher externalized the design rationale of her plan and investigated reflection generated in the trial is reported here.

Keywords: Ontology, Instructional design, lesson plan, self-reflection

Introduction

Teachers explicitly or implicitly make plans of their lessons before they deliver them, in a format called "a lesson plan." In this paper, in order to distinguish the content of a plan and its representation, we call the former a "lesson plan design" and the latter a "lesson plan script." Although a lesson plan design is not always fully described in a lesson plan script because of readability, length restrictions, and so on, the script plays an important role in clarifying the designs of the teacher who made it, as well as in sharing the design with other teachers in a peer-review meeting, which is called "lesson study" [8]. In particular, it is said that the discussions in lesson studies encourage improvements in teaching ability [1].

One of the difficulties in making a lesson plan is that a teacher typically designs and refines a plan in his/her mind through describing it in a certain format. In other words, this process is done with an alternating cycle of externalization of ideas and reflection resulting from those externalized ideas. A task like this is called an "ill-defined design task" [7][9]. Achieving such a task requires support not only for representing the product (a lesson plan script in the case of this study) but also for reflecting decision-making in the design process [4]. Reflection can be classified into two types: "reflection-in-action" and "reflection-on-action" [6]. The former is reflection that is carried out during a task and improves the task dynamically, whereas the latter is reflection that is carried out after a task and helps to evaluate the task and the product. It is considered that both types of reflection are helpful in designing and refining a lesson plan.

This study aims at building computer systems to support designing lesson plans in terms of reflection carried out during the process. In this paper, we report the results of a trial in which a junior-high school teacher modeled the design rationale of a lesson plan using the results obtained in the OMNIBUS project [2] with the help of the authors. We discuss the results in terms of the two types of reflection mentioned above.

This paper is organized as follows. The next section presents an overview of the OMNIBUS project conducted by the authors and the results expected to support lesson plan design in terms of reflection in the process. Section 2 reports the results of a trial carried out with a junior-high school teacher, and Section 3 discusses the results in terms of reflection in and after the design process. Finally, the last section concludes this paper and presents our future plans for this study.

1. OMNIBUS project

The OMNIBUS project is a research project aimed at building a learning/instructional-theory-related ontology named OMNIBUS and a theory-aware authoring system named SMARTIES. This section gives an overview of OMNIBUS and SMARTIES in terms of their expected roles in making lesson plans. The starting point of this project is to organize a variety of learning/instructional theories independently of the learning paradigms. The results are reported in [2]. Currently we aim to deploy OMNIBUS and SMARTIES in practical settings in order to investigate the capability of OMNIBUS to accumulate not only theoretical but also practical knowledge and to enhance SMARTIES for instructional design, including lesson planning. The main topic discussed in this paper is the latter.

The cores of OMNIBUS are the concept of an *I_L event* and its decomposition structure. An I_L event is a basic unit of learning and instruction from the standpoint of engineering approximation. Fig. 1 shows its basic construction. Note that, in OMNIBUS, leaning is defined as state changes of a learner. An I_L event is composed of the state change of a learner and the actions of the learner and an instructor, which are called learning and instructional actions. In the latter, the word “instructional” is used in a broad sense as to mean any actions facilitating learning in agreement with the definition of the word by Reigeluth and Carr-Chellman [5].

In OMNIBUS, a learning/instructional scenario is modeled as a tree structure of I_L events that is called an *I_L event decomposition tree*. Fig. 2 illustrates an example[1]. The flow of a scenario is represented as the sequence of leaf nodes taken from left to right. The root node represents the goal of the whole scenario. The bottom layer, called *learning/instructional scenario*, represents the sequence of actual learning and instructional actions with learning objects provided for the learners. The hierarchical structure of I_L events is called a *scenario model* and represents the design rationale of the learning/instructional scenario.

The key of this tree structure is the hierarchical relation between upper (macro) and lower (micro) I_L events, called a *WAY*. This is a relational concept that defines achievement and decomposition relation between I_L events. A WAY can be interpreted in bottom-up and top-down manners. In the case of bottom-up interpretation, it should be read as “performing the micro I_L events achieves the macro I_L event.” On the other hand, interpreted in a top-down manner, in order to achieve the macro I_L event, those micro I_L events are available as a method. With this modeling framework, we conducted a trial to reproduce an actual

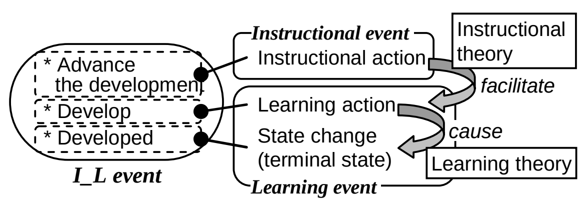

Fig. 1 I_L event.

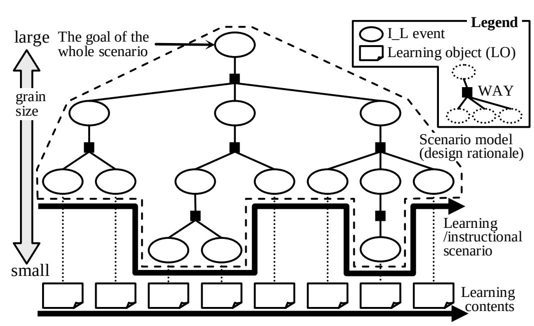

Fig. 2 I_L event decomposition tree.

[1] This is not an *is-a* structure but a kind of part-whole structure of a goal and sub-goals.

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lesson plan made by a teacher in the form of an I_L event decomposition tree.

SMARTIES is an authoring system that is aware of learning/instructional theories and compliant with the standard technology of IMS Learning Design. For further details of the functionalities of SMARTIES, see [2]. Although one of the characteristics of SMARTIES is the theory-awareness, in the trial reported in this paper, SMARTIES was used just as an environment for a teacher to externalize and model her lesson plan, as well as its design rationale, without theoretical support. As the basic functionality, SMARTIES allows users to make an I_L event decomposition tree in either a bottom-up or top-down manner. Therefore, SMARTIES can be used to externalize the design rationale of a lesson plan in the form of an I_L event decomposition tree. In addition, although this was not used in the trial, if I_L events are described in terms of the concepts defined by OMNIBUS, SMARTIES can provide applicable theory-based learning/instructional strategies modeled as an I_L event decomposition and can help authors analyze the I_L event decomposition tree.

2. A Trial of OMNIBUS and SMARTIES for Designing a Lesson Plan

2.1 Setting of the trial

A trial for modeling a lesson plan based on OMNIBUS and SMARTIES was carried out as design practice of a lesson plan in a course for teachers of technology in the graduate school of a university. Its purposes include examining:

- the capability of the OMNIBUS ontology for describing the content of a lesson plan made by actual teachers, and
- the effectiveness of SMARTIES for facilitating reflection-in/on-action in designing a lesson plan through building an I_L event decomposition tree.

The trial subject was a student in the graduate school of Okayama University, originally a Japanese junior-high school teacher of technology and home economics. She had 11 years teaching experience and had participated in lesson studies several times a year. Therefore she was familiar with making lesson plans.

Table 1 shows the course of the trial. Before this trial, the subject made a lesson plan script on sheets of paper. This lesson plan was made newly for the lecture in question and was refined through discussion with the second author, who was the teacher of the course. In this trial, the first and second authors asked the subject questions about her script and, together with her, modeled it as an I_L event decomposition tree in SMARTIES. The purposes of the questions asked in this trial were:

(1) to represent each step in the script as state changes of learners, and

(2) to clarify the design rationale of each step in the script.

Following these purposes, the questions are basically “what state do you want to make your students achieve?” and “what is the design rationale for an activity of learners or instruction by the teacher?” Such questions by the authors were used as a trigger to get implicit information that had not been described in the script but had been considered in the design process by the subject. The authors modeled what was elicited from her as an I_L event decomposition tree.

Note that, in the trial, the first author, not the subject, operated SMARTIES. This is because the purpose of this trial was not to evaluate the usability of SMARTIES but to examine the description capability of OMNIBUS. SMARTIES is still just a prototype system designed to verify the feasibility of ontology-aware functions,

Table 1 The course of the trial.

Pre-trial	Making a lesson plan script through discussion with the instructor (the second author) without SMARTIES
1	Explanation of SMARTIES (30 min.)
2	Modeling a lesson plan with SMARTIES (5 hours in total)
Post-trial	Modification of the lesson plan script by the subject alone without SMARTIES

and it usually takes time for teachers to become familiar with using it by themselves.
Finally, after the trial, the subject refined the paper-based lesson plan script based on the I_L event decomposition tree made in this trial. The refined lesson plan script was given to the authors together with the reasons for the refinements.

2.2 An overview of the I_L event decomposition tree made in the trial

The lesson plan script used in this trial was for a lecture on Technology and Home Economics for junior-high school students, aiming at developing their ability to select materials and processing methods appropriate to making required products.

Figure 3 shows an overall view of the I_L event decomposition tree made in this trial. Each node represents an I_L event, and each link between upper and lower nodes represents a WAY. This model was composed of 77 I_L events. As explained in Section 1.1, the bottom layer of the model represents the actual interaction between the teacher and the students, and the upper layers in the structure represent the design rationale of the interaction. The rightmost node is for wrapping up the lesson. Although only this node could not be further decomposed due to time limitations, the others were decomposed several times. The number of decompositions depended on the granularity of the design rationale that the subject explained in the trial.

The original lesson plan script was composed of 11 steps of instruction. Among them, we were not able to sufficiently model the last two steps, which involve the wrapping-up part of the lesson. Therefore, nine steps in the script were modeled in this trial. As is seen in Fig. 4, those nine steps were decomposed into 23 I_L events. The remaining 54 I_L events (higher than the leaf level) in the tree represent the design rationale of the sequence.

Although in SMARTIES users can use their own terms to describe the content of I_L events, the model made in this trial was described only in terms of the concepts defined in OMNIBUS. Note that this does not mean that all the terms appearing in the original script had already been defined in OMNIBUS as is. Although some terms were the same as some concepts in OMNIBUS, others were replaced with similar concepts in consultation with the trial subject, without losing the intended meaning. For example, “confirm” in the script was replaced with “recognize”, defined in OMNIBUS. “Exchange information” was replaced with a combination of “ask” and “inform.” Strictly speaking, the replacement is not always correct. However, at least in this trial, such replacement was done in mutual agreement with the subject and was acceptable to her. Of course, the ac-

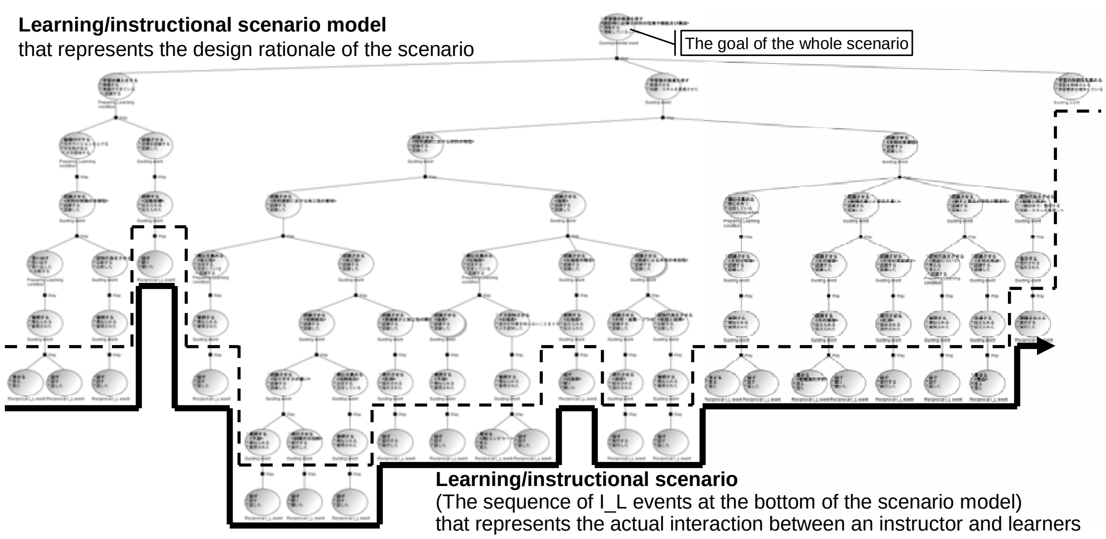

Fig. 3 Overall view of the I_L event decomposition tree made in this trial.

ceptable range will differ from one subject to another, and replacement of terms by concepts defined in OMNIBUS should be done carefully depending on the subject.

3. Discussion of the trial results

3.1 Reflection-in-Action

This subsection presents how the design rationale of the lesson plan was explained by the subject and modeled during the trial. The subject had already finished making her lesson plan script before the trial. In the trial, she recalled and explained its design rationale. This process done in the trial can be considered as equivalent to a partial process of *Reflection-in-action*. Reflection-in-action is what a person does to refine the product during its design process by reflecting on decision-making during the process. In terms of a timing for reflection, what the subject did in the trial was not reflection-in-action because it did not involve reflecting on it in the middle of the process of designing the original plan, but instead involved recalling and reflecting on it after the design process was completed. However, from the scope of reflection, the reflection done in this trial focused not on the whole product but on each decision-making step, and hence this can be interpreted as equivalent to the scope of reflection-in-action. Consequently, although what the subject did in the trial is not real reflection-in-action, not the same as in the timing, we can consider reflection-in-action in designing the lesson plan with the trial result from the scope.

Figure 4(A) shows a portion of the original script that the subject made before the trial. Although the script was composed of seven columns, only three columns are extracted here because these are important in making an I_L event decomposition tree. The leftmost column in the table represents the types of major processes, and Fig. 4(A) is a part of a “preparation” phase, one of the phases in this plan, which are named by the subject: “preparation”, “understanding/construction” and “conclusion.” Each row has subprocesses from the viewpoints of both learners and teachers. The second and third cells from the left represent sub-processes of learners and teachers, respectively. Each of them has two levels of actions. Items with simple numbers represent the first-level subprocesses, and items with bracketed numbers represent the second-level sub-processes, which are the most concrete actions in the script.

In this trial, the authors first focused on the actions in the second-level subprocesses and began making a part of the I_L event decomposition tree shown in Fig. 4(B) from the script. For example, from “*asking* the students a question to focus attention on material workability” shown in Fig. 4(a-1), we first made an I_L event having “ask” as the instructional action, shown in Fig. 4(b-1). Finally, however, two I_L events were made in the model in relation to this part in the script. The other one was added through dialogue between the subject and the authors. After we made one of the I_L events, the subject remembered two kinds of intentions of asking questions. One is to cause the learners to remember what they learned before this lesson, and the other is to let them compare what they recalled. Therefore, we made another I_L event, and these two intentions were separately described as two different macro I_L events (Fig 4(b-2)). Upon obtaining more information from the subject, these two I_L events were for making the learners recognize the variety of materials (Fig 4(b-3)) and for getting them motivated (Fig 4(b-4)).

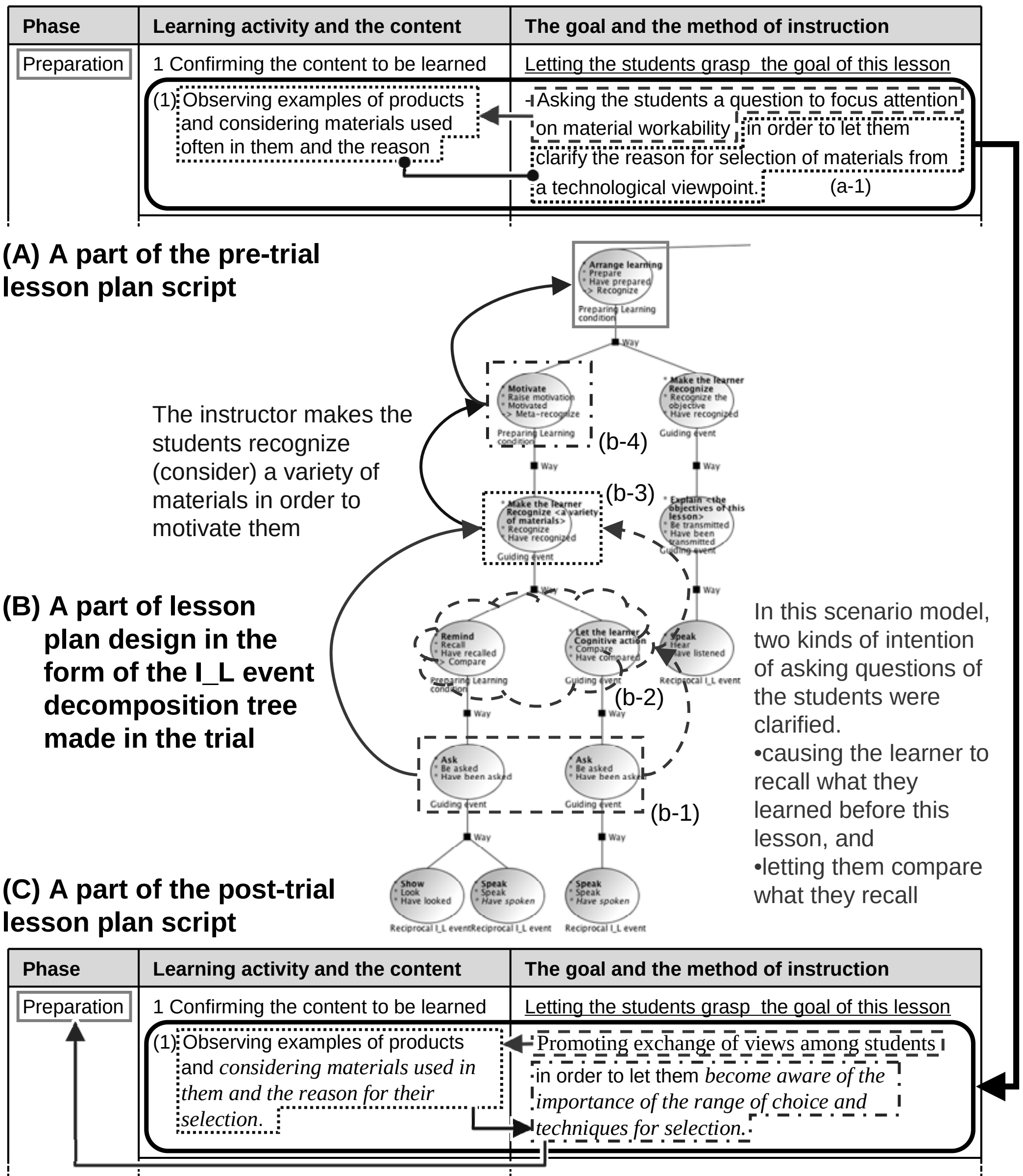

Fig. 4 The lesson plan and the I_L event decomposition tree made in the trial.

Through even more dialogue between the subject and the authors, the part of the I_L event decomposition tree shown in Fig. 4(B) was finally made from the script shown in Fig. 4(A). Only the part of it shown in Fig. 4(b-1) and (b-3) is described explicitly in the script; the other parts are not described in the script, although the subject thought about them. Such an implicit design rationale in the lesson plan design was extracted through modeling and dialogue about the script with SMARTIES.

3.2 Reflection-on-Action

This subsection discusses the effect of the scenario model made in the trial on the changes of the script before and after the trial. The changes can be considered as a result of reflection-on-action. As stated above, the model is the representation of the design rationale of the original script. That is to say, it offers the subject an overview of the design rationale that is in her mind. The subject surveyed it and modified the script after the trial. This is exactly reflection-on-action achieved with the help of SMARTIES.

Fig. 4(C) shows a part of the script that the subject modified from the part shown in Fig. 4(A) after the trial. The changes in the script from the pre-trial to the post-trial versions are italicized in Fig. 4(C). The major difference is that the meaning of this part in the lesson was clarified compared with the pre-trial script. In a broad sense, the goal of this part is the same as "getting learners motivated" in both scripts. However, the subject explained that the goal in the pre-trial script was for only part of the lesson, whereas the goal in the post-trial script was for the whole lesson. To put it more concretely, the former is for the motivation to use a machine tool in this lesson, and the latter is for the motivation to become aware of the importance of what they learn in this lesson.

The subject described the reasons for the changes as "thanks to the model made in SMARTIES" and "thanks to dialogue with the authors." This means that the use of SMARTIES and communication with the authors in the trial both had an influence on reflection after the trial, and it cannot be identified which one mainly affected reflection with the current data.

3.3 Correspondence between the scenario model and the lesson plan scripts before and after the trial

This subsection presents quantitative analyses of the influence of modeling the lesson plan on refinement of its script. Table 2 shows the correspondence relation between the scenario model made in the trial and the scripts before and after the trial. The scenario model was composed of 77 I_L events, as mentioned in Section 2.2.

Only 31 of them (40 % of the total) correspond to the pre-trial script. There are three possible interpretations for this low correspondence: (1) the subject did not describe them although she had thought about them, (2) she changed her thoughts through the trial, and (3) she newly thought about them in the trial. In the questionnaire after the trial, she explained that the reasons for this were mainly because she had not described everthing that she had explicitly thought about and what she had designed tacitly based on years of experience. Consequently, it can be considered that the reason is mainly (1), and that SMARTIES helped her to remember the design rationale. However, we cannot confirm this because we did not record the dialogue and cannot conduct a protocol analysis of it.

On the other hand, 52 of the I_L events in the scenario model (68 % of the total) correspond to the post-trial script. This percentage is larger than that in the pre-trial script. This is thought to be because what the subject did not describe in the pre-trial script was clarified during the trial and then described in the post-trial script in order to refine it. If all the things in a lesson plan design could be described in the script, the percentage of the correspondence might not be so high. However, a script is usually in the form of a summary because of readability, and it is difficult to describe all of the design in the script, as mentioned above. In this trial, according to the subject's custom, the script was limited to two pages of A4-size paper. In that respect, it can be considered that the increase of the correspondence rate shows the effect of OMNIBUS and SMARTIES on reflection in designing the lesson plan. Verification of this effect needs analysis of not only the percentage of the correspondence but also the quality of the script. This will be the topic of future work in this study.

Table 2 Correspondence between the model and the pre/post-trial scripts.

	Total number of I_L events in the model	Number of I_L events corresponding to the script	Correspondence rate
Pre-trial	77	31	40 %
Post-trial		52	68 %

4. Conclusion

This paper discusses the effectiveness of OMNIBUS and SMARTIES in designing lesson plans in terms of reflection. From the results of the trial, we consider that OMNIBUS and SMARTIES have a certain effect on reflection in designing lesson plans. The trial demonstrated that modeling a lesson plan as an I_L event decomposition tree aided reflection-in-action in which teachers can retrospectively review the decision-making, and that taking an overall look at the model helps reflection-on-action in which they can check the validity and consistency of the lesson plan design. Of course, this paper presents the results of only one trial. In order to verify the effectiveness of our proposal, even more trials and data are required.

In addition to the problem of the validity, the difficulty of use of OMNIBUS has significant scope for continued improvement. It is very difficult for teachers to use SMARTIES in its current state. One of the main reasons is the difficulty in expressing their ideas in terms of the controlled concepts and vocabulary defined in OMNIBUS. Although it is very difficult to organize the universal vocabulary, there is a fair possibility of success in building a shared vocabulary in a community of teachers. Actually, there is an example of ontology aligned with vocabulary in a teacher community [3]. In addition SMARTIES should have a new function for bridging the gap between detailed concepts defined in OMNIBUS and teachers' mind.

There is plenty of room for further research into practical deployment of OMNIBUS and SMARTIES. From this viewpoint, we might go on to an even more detailed examination of reflection in designing lesson plans and the functionality of authoring systems to support such reflection.

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