Articulation of Scenario Construction of Lessons based on Ontological Engineering

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Abstract. A requirement to support teachers' professional vision for high-performance classrooms is to clarify criteria for analyze data collected from classroom. Plans of lessons can be a criterion for it because teachers can figure out and compare what are the plans for and what is happening in the lessons. This paper discusses the contribution of modeling plans of lessons based on ontological engineering.

1 Introduction

Teaching is an act of thoughtfulness and thoughtful teachers engage in reflective practice as a way to think about their teaching and about ways to continually develop and implement curriculum [2]. In such practice teachers need to carry out reflective inquiry about lessons: what are the plans for and what is happening in the lessons [1]. Figuring out both of them and finding the gap between them facilitate improvement of lessons and development of teaching skills. Nowadays, we can get a lot more data tracking teaching and learning activities than before, and technologies such as educational data mining and visual analytics make a contribution to analyzing what is happening in the activities. Teaching analytics by such technologies enhances teacher's reflective inquiry about lessons.

This study focuses on making plans of lessons, which are expected to be an important resource for teaching analytics. The plan of a lesson represents the design rationale of teaching and learning activities. If a teacher can make a clear plan that reflects the teacher's idea, it provides the semantics of events logged while the teachers and learners were enacting the plan. However, there are some difficulties in making clear plans. A difficulty in arranging plans is insufficiency of guidelines. Although learning and instructional theories may be guidelines on scenario construction of lessons, the abstractness of them makes it difficult to apply them to a particular lesson [10]. Usually, teachers describe a plan as a *lesson plan* [11] that is a description of the result of design. However, it is difficult for teachers to look back on decision-making and to examining the consistency of scenario construction.

The authors have developed OMNIBUS ontology and SMARTIES authoring system [3]. OMNIBUS is the ontology [9, 12] that aims to describe learning and instruction processes and to organize learning and instructional theories. It consists of the concepts for describing a process as decomposition of learning goals. SMARTIES is an authoring system based on OMNIBUS. The characteristics of SMARTIES are theory-awareness and standard-compliance. Theory-awareness means that SMARTIES knows a variety of learning and instructional theories and helps to apply to them to particular learning and instructional scenarios. SMARTIES can output such scenario designed based on theories in IMS Learning Design (LD) format [5, 6, 7, 8]. This output can be executed on any tools compliant with IMS LD. To verify practical effectiveness of them, the authors designed some lessons with an official research group of schoolteachers of Tokyo prefecture, named "ToChuSha".

Although this is not a thorough study and this paper can presents only the early result, with the results this paper aims to present an endeavor that is expected to make a contribution to the advancement of teaching analytics. The structure of the rest of this paper is as follows. The second section gives an overview of OMNIBUS, and then the third section explains the functions of SMARTIES. The fourth section presents the authors' practical study to verify the effectiveness of them. Finally, the last section concludes this paper.

2 OMNIBUS ontology

OMNIBUS is the ontology that aims to organize learning and instructional knowledge including learning and instructional theories as well as empirical knowledge of schoolteachers. It consists of the concepts for describing a process of learning and instruction as decomposition of learning goals.

OMNIBUS defines a framework for modeling learning and instructional process as learning and instructional (I_L) scenario model.

The basic policies of the definition of I_L scenario model are following [6]:

- Learning is modeled as state change of a learner,
- Learning and instructional process is organized with separation at "what to achieve" and "how to achieve", and
- The principles of learning and instruction are organized with relation to "how to achieve" as the design rationale.

Based on these policies, OMNIBUS ontology allows us to describe learning and instructional process as hierarchical part-whole structure of learning goals with the design rationale as shown in Fig. 1. I_L scenario model consists of the concepts of I_L event and WAY defined by OMNIBUS ontology.

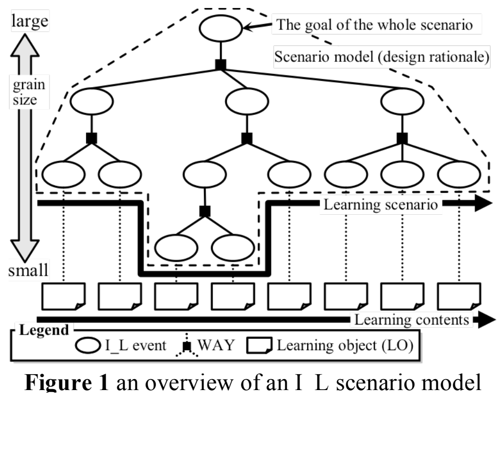

Figure 1 an overview of an I_L scenario model

An I_L event consists of state change of a learner (learning goal), a learner's action that cause the change (learning action) and an action facilitate the learning action (instructional action) as shown in Fig. 2. It is possible to describe learning and instructional process of varied grain sizes. I_L event of the largest grain size represents the learning goal of the whole scenario. I_L events of the smallest grain size represent concrete interaction between teachers and students to achieve the learning goal. There can be a variety of sizes of I_L events in a scenario and WAYs links I_L events as decomposition and achievement relation. Such links between the root and the leaf I_L events represent the design rationale of each concrete interaction to achieve the goal for the whole lesson.

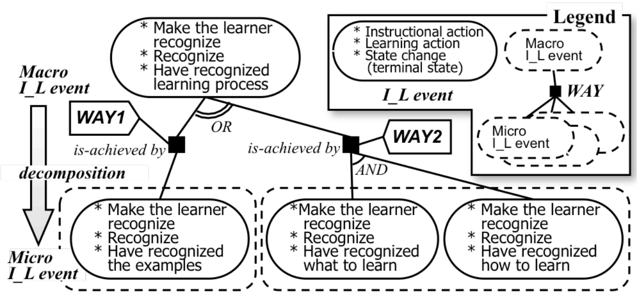

Figure 2 Examples of I_L events and WAYs

The essential of the modeling based on OMNIBUS is a distinction between learning goals and ways to achieve them. This distinction enables to manage a diversity of learning and instructional methods. There can be many methods to achieve a learning goal, and there is a method that can achieve some different learning goals. This approach can organize relationship between a variety of learning goals and methods to achieve them.

3 A Theory-aware and Standard-compliant Authoring System: SMARITES

SMARTIES is an authoring system based on OMNIBUS. The characteristics of SMARTIES are theory-awareness and standard-compliance. Theory-awareness means that SMARTIES knows a variety of learning and instructional theories and apply them to a learning and instructional scenario. SMARTIES can output such scenario designed based on theories in IMS Learning Design (LD) format. This output can be executed on any tools compliant with IMS LD.

Figure 1 shows a screenshot of SMARTIES. The Scenario editor (Fig. 1 (1)) is the main window on which the author makes a scenario model (Fig. 1 (a)) graphically. In principle, an author can describe a I_L scenario model freely according to the framework of I_L event decomposition. The model can be described by the author in his/her own terms as well as in terms of the concepts defined by the OMNIBUS (Fig. 1 (2)). If a user uses the concepts defined by the ontology, SMARTIES interprets the scenario model and offers intelligent supports including explanations of and suggestions on the model based on the educational theories. For example, the WAY-knowledge proposal window (Fig. 1 (5)) displays the applicable learning and instructional strategies based on theories (Fig. 1 (d)) for the scenario model with its explanation (Fig. 1 (f)). SMARTIES generates all of these contents dynamically based on the OMNIBUS.

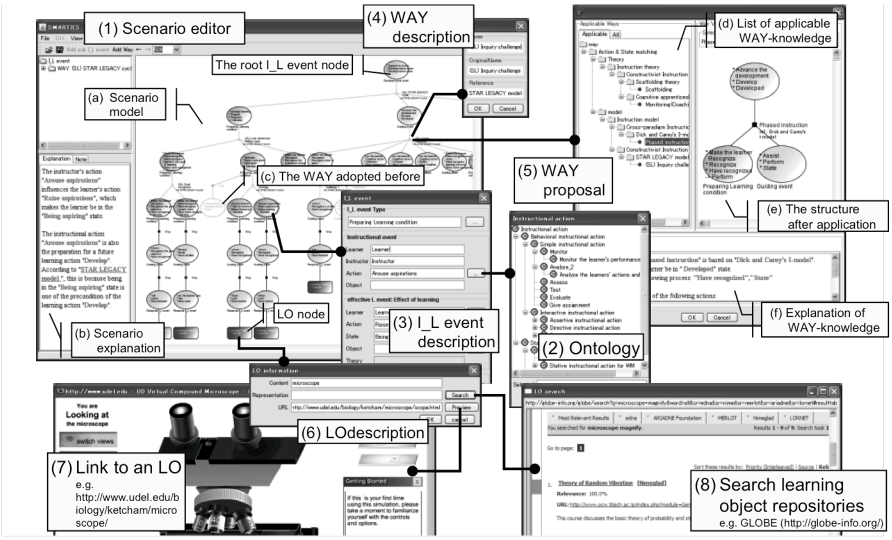

Figure 3 Screenshot of SMARTIES

Through these operations, a user can build the scenario model hierarchically from the abstract level to concrete level as shown in fig. 1(a). This tree structure indicates the design rationale of the scenario (a sequence of the leaves of the scenario model), and pieces of WAY-knowledge used there present the theoretical validity of it.

SMARTIES can convert the resultant I_L scenario model into the IMS LD format. In order to make an IMS LD description compatible with the I_L scenario model, WAYs in an I_L scenario model is separately described as structures of learners and instructors based on the fact that the structure of I_L scenario model corresponds to the structure to describe learning and instructional activities in IMS LD. With this correspondence, an individual learning described as a scenario model based on OMNIBUS can be compatible with IMS LD specifications. The scenario model content is correctly converted into the IMS LD description by feeding the IMS LD player with the scenario output in the IMS LD format from SMARTIES.

4 Designing Lessons with SMARTIES in Practice

The authors made some field trials to use OMNIBUS and SMARTIES in designing lessons in ToChuSha [4]. The goal of these trials is to confirm the following hypotheses formed in this study;

1. Making I_L scenario models enables teachers to make lesson design clearer.
2. I_L scenario models help teachers to consider alternative learning and instructional methods.

In the field trials, SMARTIES mainly played a role of a tool to describe design rationale of lessons made by teachers of ToChuSha. The major goal of the activity of ToChuSha is to make use of the results achieved up to now by them. Therefore, the priority is, rather than to make use of learning and instructional theories, to improve instructional methods they have used after clarifying the design intention of lessons.

We officially summarized findings from the field trials as follows:

A) **Clarification of the design rationale of lessons:** the design rationale that has not been described or described implicitly in the lesson plan but planed in the teacher's mind is described more explicitly in the I_L scenario model.

B) **Improvement of lesson design:** lesson designs are improved through discussions between the teacher and the author based on both of the I_L scenario models and past achievements of ToChuSha.

In the field trials, not the teachers but the author made I_L scenario models as stated in the previous section. The teachers checked whether the author translated the original lesson plans into the models faithfully. Then, the teachers and the authors made discussion for improving the lesson design. Through this process, the teachers and the authors clarified lesson design in the teachers' mind and then improved it.

Table 1 shows improvement process of the lesson plan in terms of the number of items and concordance between items of a lesson plan and the I_L scenario model made from it. This indicates that, in essence, both of the number of items in the lesson plan and the concordance rate are increasing step by step. This can be considered that the teacher updated the lesson plan in a reflection of improvement of the lesson design described as the I_L scenario model. In fact, the teacher commented that he could update the description of the lesson plan by reconfirming the lesson design with the scenario model. Thus, this suggests that the increase of the number of the I_L events means the progression of externalization and improvement of lesson design in his mind. In addition to that, this also suggests that the increase of the number of items in the lesson plan means the result of reflection of changes of lesson design on the lesson plan. That is to say, repeating update of models and the lesson plan helped him to clarify and externalize the design rationale of the lesson. Furthermore, the repetition also helped him reflect the change of lesson design on the lesson plan. Consequently, this can be a case supporting both hypotheses of this study as previously mentioned.

Some subject matter expert evaluated the resultant lesson plan. Firstly, ToChuSha authorized it. Members of ToChuSha accepted the lesson plan supported by OMNIBUS and SMARTIES, and then published it. Secondly, the teacher that has made the lesson plan demonstrated a lesson according to the plan at an annual domestic conference on educational research of social studies in Japanese junior high schools. At the conference, there was a reviewer for the lesson demonstrated. He highly appreciated it as well-designed one with a clearly defined position in the curriculum. Consequently, although the quality of the resultant lesson design did not undergo quantitative evaluation, the quality is ensured to a certain extent because some subject matter experts

Table 1 Improvement process of a lesson plan and an I_L scenario model

Update cycle of the lesson plan	1	2	3	4	5
# of items in the lesson plan	17	21	22	25	31
# of I_L events in the model	73	82	94	91	91
# of concordance of the items and the I_L events	56	57	77	78	88
The concordance rate (%)	76.7	69.5	81.9	85.7	96.7

properly assessed it.

5 Conclusion

This paper discusses an ontological engineering approach to articulate scenario construction of lessons. Realization of high-performance classrooms requires processing of data collected from classrooms and analyses of them. In the analyses, the plan of a lesson can be a criterion for analyzing the lesson implemented based on it.

OMNIBUS provides a conceptual framework to describe both of plans of lessons and learning and instructional knowledge from learning and instructional theories and empirical one accumulated by schoolteachers. SMARTIES provides an environment that teachers can describe their plans of lessons with reference to learning and instructional knowledge and convert it into the IMS LD format. In the field trials, OMNIBUS worked as the basis for describing design rationale of lessons and SMARTIES worked as a tool for describing them as I_L scenario model.

The ontological engineering approach discussed in this paper is complementary to technologies for teaching analytics. Modeling of plans of lessons can be a criterion for analyzing the lesson and contributes to support teachers' professional vision required to high-performance classrooms.

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