Theory-aware Explanation Support for Standard-compliant Scenario Building

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ABSTRACT
Nowadays standard technologies play important roles in enhancing sharability, reusability and interoperability of learning contents. However, there is a lack of pedagogical justification of the contents implemented with the standards. This paper discusses the standard-compliance of our ontology-based modeling framework and how the framework gives theoretical justification to standard-compliant learning/instructional scenarios in a theory-aware authoring tool.

Keywords
Ontology, Theory-awareness, Authoring tool, Standard-technologies

INTRODUCTION

Standard technologies play important roles in development and delivery of learning contents nowadays. Major contributions of such technologies include enhancing sharability, reusability and interoperability. Thanks to them, we can easily make a courseware through reconstructing existing courseware and learning objects, for example, finding reusable learning objects or courseware in learning object repositories with LOM [7] and describing a scenario as a sequence of them with IMS Learning Design (LD) [8].

Although standard technologies provide the stakeholders with such great benefits related to learning contents, there is a lack of pedagogical justification of the contents implemented with the standards. For example, one of the characteristics of IMS LD is pedagogically-neutral and hence it allows designers to describe any instructional and learning scenario but does not provide them with any pedagogical justification. Because it provides just a framework (at least as of Sep 9th, 2007) for scenario specification, making scenarios with IMS LD has difficulties in explicit integration of pedagogical knowledge (e.g. educational theories and best practices) even though it underlines their importance. Although pedagogical independence makes sense as specifications of a standard technology, in the practical use of the specifications, it is highly desirable to provide designers with guidelines for building learning contents and to enhance the pedagogical legitimacy of them.

Our study focuses on the educational theories and proposes an information system which helps users to utilize them. To put it more concretely, this means that such information systems can help users not only to find appropriate theories according to the goal and the situation but also to apply them to building a scenario based on the understanding of the theories. In this study such a capability of information system is called "Theory-awareness" [9]. In order to realize theory-awareness, it is necessary to organize pedagogical knowledge in a formal and computer-understandable way. Several studies have been made on organizing it only in a formal way. A representative example of such study is the pedagogical patterns project [11]. This project gives a coherent and accessible form. This form enables easy sharing of pedagogical knowledge as patterns within the community. There is also a study that takes an approach to detecting patterns in IMS LD compliant learning contents [3]. However, such patterns in these studies are written fully or partly in natural language and therefore the diversity of interpretation remains in the description of them.

In this study we take an ontological engineering approach to organizing the educational theories in a formal and computer-understandable way [1][2][9]. This approach focuses on grasping fundamental concepts of learning and instruction, and enabling information systems to be aware of the theories on the basis of such concepts. Through this approach we have proposed OMNIBUS ontology[1], which is a comprehensive ontology that covers different theories and paradigms [10], and a modeling framework of learning and instructional scenario based on it [5][6]. However, the purpose of this study is not to expose a scientifically valid basis for organizing educational theories nor to reconstruct them on this basis, but rather to find an engineering approximation that allows the building of an engineering infrastructure that enables practitioners to utilize educational theories.

At this moment, we have finished developing a prototype system of a theory-aware and standard-compliant authoring tool based on the proposed framework, which is called SMARTIES [10]. This prototype supports authors in building standard-compliant scenario with theoretical justification. Furthermore, we are currently developing an explanation function in our prototype. This function provides theory-based interpretation of scenarios as comprehensible explanation messages. This paper discusses such functionality of a theory-aware authoring tool.

This paper is organized as follows. Firstly we summarize our previous work [5][6]: our perspective on modeling of learning and instruction in section 1, and then

[1] This ontology is open to the public on our web site: `http://edont.qee.jp/omnibus/`.

our modeling framework for them and a relation between our framework and IMS LD in section 2. Section 3 discusses a generation mechanism of scenario explanation based on theory-awareness. The final section concludes this paper.

1. TOWARD EMBODYING THEORY-AWARENESS AND STANDARD-COMPLIANCE IN AUTHORING TOOLS

One of the objectives of this study is building a comprehensive ontology which covers different theories and paradigms as the basis of theory-aware and standard-compliant authoring tools. As the result, we have proposed OMNIBUS ontology. In this section we briefly discuss the problems and our approach for building the ontology. The details are given in our previous papers [5][6].

1.1 Consideration of a comprehensive ontology for educational theories

There is a big difficulty in building a comprehensive ontology of learning theories. It is considered that, in the first place, each paradigm or theory has its own definition of "Learning" and that we could not organize variety of theories on a common basis. However, for example, Reigeluth [13] and Ertmer [4] give some considerations for commonality and difference among paradigms and theories. We can summarize these statements as follows; every theory has some sort of common basis for explaining learning and instruction, and while the assumed mechanism of developing knowledge is different for each paradigm, the idea of states in the learning process is common. In a similar line of the thought, this study sets up the working hypothesis that there must be an engineering approximation of the states where we can conceptualize "Learning" in terms of state change of learners [5].

1.2 Toward the operational interpretation of educational theories

The difficulty in modeling instruction and learning might be that the change is achieved by two kinds of actions; instructional actions and learning actions. That is to say, instructional actions lead a learner to do some sorts of learning actions and learning actions cause the change of learner's state.

In order to model such relations appropriately, we have defined a concept that we call I_L event as shown in Fig. 1. I_L events link instructional events to learning events. In this study a learning event is composed of state-change and learning action. Learning actions cause the change of learner's state. On the other hand, an instructional event is composed of an instructional action. This affects learning events. The key points of our conceptualization are to emphasize the relations among these three and to model a contribution of instructional action on the change of learner's state.

What is important here is these relations can be explained by instructional and learning theories. The theories describe or prescribe appropriate relations among them. Based on the concept of I_L event, this study has a proposed modeling framework of learning and instructional scenario with theoretical justification.

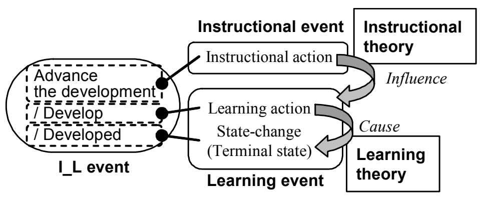

Fig. 1 The definition of an I_L event

2. MAKING SHARABLE SCENARIOS JUSTIFIED BY EDUCATIONAL THEORIES

We have discussed basic concepts for descriptive model of learning and instruction, and the relation of the concepts and theories in the previous section. Next, we discuss how to organize theoretical knowledge and to reflect theoretical knowledge to a scenario compliant with standard technologies.

2.1 Requirements for sharable and theory-justified scenario description

A learning/instructional scenario is composed of sequence of learning and instructional actions. Therefore it is considered that designing a scenario means structuring a sequence of learning and instructional actions to achieve a learning goal. Learning and instructional theories also prescribe how to organize the sequence as well as the relation between learning and instruction as discussed in the previous section. For this reason, firstly, we have set two requirements for theory-justified scenario descriptions: (1) to establish a framework for structuring learning and instructional actions in line with design intention and (2) to enable designers to apply theories to design of the structure.

In addition, the sharability of scenarios is also very important. Our approach to this problem is to establish standard-compliance of our ontological model with standard technologies and we have chosen IMS LD specifications. In order to make IMS LD work with educational theories, this study proposes relating the OMNBUS ontology to IMS LD [12]. The descriptive aspect of the theories helps keep the consistency of a model of a learning process influenced by an instructional process. We have defined this as the concept of I_L event. On the other hand, the prescriptive aspect of the theories will work as guidelines for making a model of instructional and learning processes. Therefore, it is also necessary to define prescriptive concepts for modeling learning and instructional strategies. Hereafter we discuss how to define such prescriptive concepts and to map both descriptive and prescriptive concepts to IMS LD descriptions.

2.2 I_L event decomposition tree

In our modeling approach, a sequence of instructional and learning actions is described in terms of state changes of a learner and how to achieve the changes. The former, which is a change caused by each action, can be described as an I_L event. What we focus on here is the latter, which is described as a sequence of changes to be achieved. Such sequence means a way to achieve the change caused by the entire sequence. Usually, a change can be achieved in several ways. That is, there may be different ways to achieve the same goal. Actually each theory is considered as composition of such ways which we call learning strategies.

In our framework, a scenario can be modeled as a hierarchical structure of I_L events for achieving a certain change of a learner state [5]. We call it an “I_L event decomposition tree”. The basic idea of an I_L event decomposition tree is to relate a macro-I_L event to the lower (micro) ones that collectively achieve the upper (macro) I_L event as a way of achievement of the change of a learner state (referred to just as “WAY” hereafter).

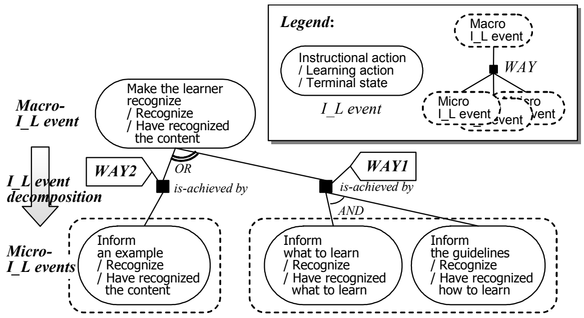

Fig. 2 An example of I_L event decomposition

Fig. 2 illustrates an example of an I_L event decomposition. This shows that there are two WAYs to achieve the macro-I_L event, which is to introduce content for making a learner recognize it. WAY1 is based on Gagne and Briggs’s theory. This firstly presents what to learn and then gives guidelines. The other is based on Collins’s. This gives only demonstrations and no explanations. In this case the macro-I_L event is not decomposed but concretized. These ways can be thought to have the same goal but achieve it by different strategies. Such relation between WAYs is described by OR relation like between WAY1 and WAY2.

A way has two sorts of interpretations. One, so-called bottom-up manner, is the sum of the changes of learner state in micro-I_L events realizes the change of learner state of the macro-I_L event. This manner, which concentrates on states, is descriptive. It describes which outcome is produced by a sequence of changes of learner state. The other, so-called top-down manner, is that an instructional action of a macro-I_L event is decomposed into detailed or concrete instructional actions of micro-I_L events. This manner, which concentrates on action, is prescriptive. It prescribes which sequence of instructional sub-actions is required for performing the intended instructional action.

Following the top-down interpretation, this study proposes a method to systematize theoretical knowledge. Theories prescribe strategies for planning instructional and learning process according to supposed situations. In our modeling framework, a learning and instructional strategy is modeled as a WAY in view of generality which can be adapted to the specialized concrete application situations. Such a generic WAY is called WAY-knowledge. Currently, we have organized 80 pieces of WAY-knowledge based on some theories[10]. Organizing WAY-knowledge is expected to contribute to clarification of the conceptual structure of each theory and to theory-eclectic design guidelines for modeling learning and instructional processes [5].

2.3 Mapping an I_L event decomposition tree onto IMS LD

In order to enhance the sharability and reusability of scenario descriptions we have mapped I_L event decomposition tree onto IMS LD. Briefly speaking, the major components of IMS LD are *role* (roles of participants), *activity* (tree structures of activities of each role) and *environment* (environment used for the activities). It is considered that an I_L event decomposition tree corresponds to activity-structures for learners and instructors, in IMS LD, instructors can be described as a kind of staff. Each unit of decomposition in an I_L event decomposition tree can be converted to two activity- structures for learner and instructor as shown in Fig. 3. An activity-structure is composed of the description of an (whole) activity and has references to sub-activities (activity or activity-structure). A macro-I_L event in a WAY is described as a whole activity and micro ones are referred to as sub-activities. Leaf nodes of an I_L event decomposition tree are

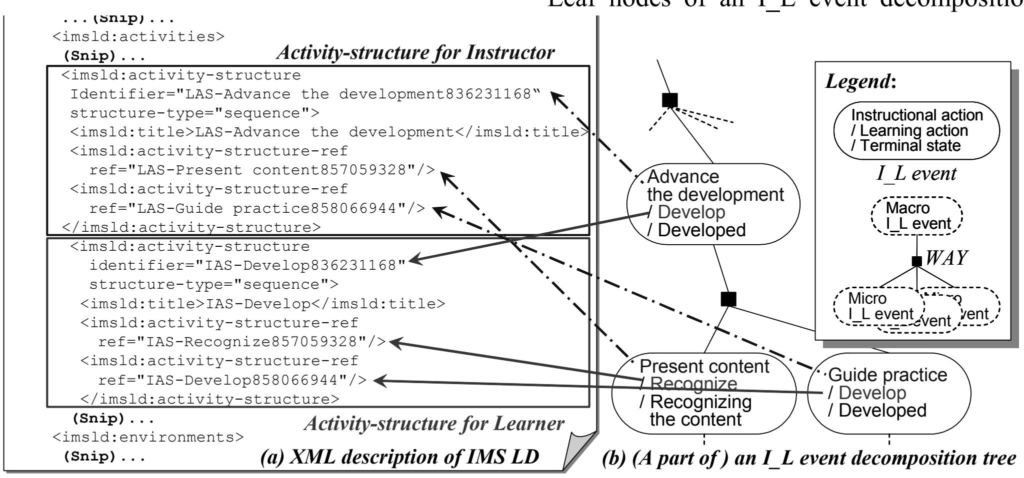

Fig. 3 Mapping an I_L event decomposition tree into IMS LD

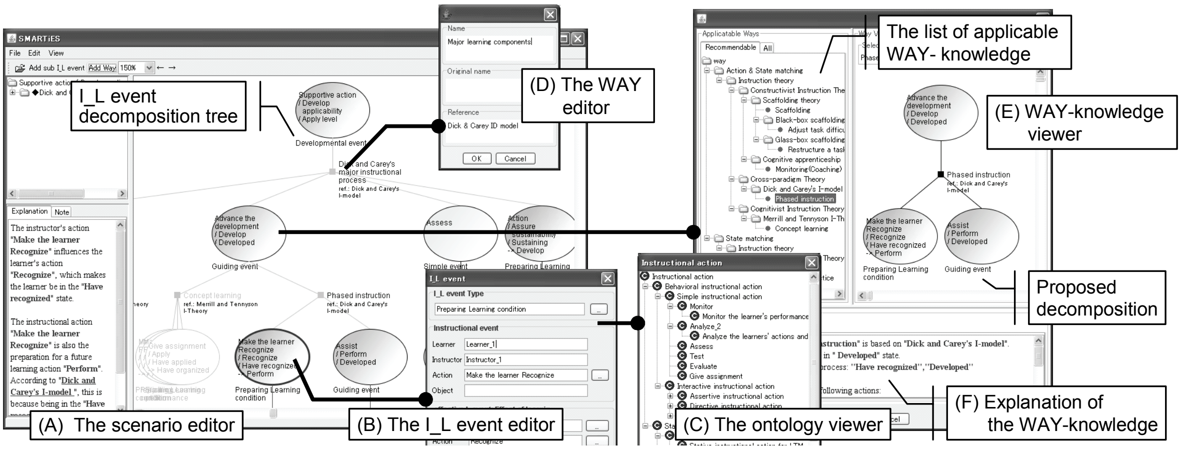

Fig. 4 User interfaces of SMARTIES

converted to learning-activity or support-activity.

In IMS LD, only the top and leaf activities have the description of the objective while the others do not have. Therefore only a part of the design intention is remained in the descriptions although IMS LD keeps the sharability and executability of learning/instructional scenarios. On the other hand, an I_L event decomposition tree keeps whole of the design intention together with theoretical justification of it. For these reasons, IMS LD and our modeling approach are complementary to each other.

In this manner our prototype of an authoring tool can export an I_L event decomposition tree into an IMS LD description. The executability of such exported descriptions was confirmed by experimentally use of IMS LD compliant tools, for example, Reload LD player and LD editor [14].

3. THEORY-AWARE SUPPORT FOR SCENARIO AUTHORING

This study focuses on the following two requirements for realization of theory-awareness in an instructional/learning design support system [6]: The system can (1) help designers to build a theoretically valid model of learning/instruction, and (2) explain its theoretical justification to designers.

3.1 Scenario description support

Figure 4 shows the user interfaces of SMARTIES that is a proto-type system of a theory-aware and standard-compliant authoring tool. This screen shot shows how an author makes an instructional and learning scenario model using "WAY-knowledge".

The scenario editor (fig. 4(A)) provides authors with an environment to describe an I_L event decomposition tree as an instructional and learning scenario model. An I_L event is represented as a node and the decomposition of each node is represented as a tree whose root is the macro-I_L event with a few nodes as micro-I_L events. In this window, an author decomposes the learning goals of the scenario step-by-step by choosing applicable "WAY-knowledge".

The Way-knowledge viewer (fig. 4(E)) provides authors with applicable "WAY-knowledge" candidates in order to help him/her decompose each I_L event. It displays applicable pieces of "WAY-knowledge" appropriate to the selected I_L event that he/she wants to decompose. This is done by I_L event pattern matching based on OMNIBUS ontology. When the author chooses one of them, a proposed decomposition is displayed on the viewer and the explanation is shown (fig. 4(F)). If the author decides to adopt the selected Way, the proposal is applied to the main window. By repetition of the process mentioned above, a scenario author makes instructional and learning process model, moving from abstract levels to concrete ones.

3.2 A classification of explanation types and cases

One of the characteristics of theory-aware systems is the ability to interpret learning/instructional scenarios in terms of theories and to explain its result.

In this study, we have classified types of explanation of a scenario. Table 1 summarizes the classification. Each type of explanation report interpretation result of a scenario model based on the OMNIBUS ontology. *Scenario comprehension* uses the scenario model and the descriptive concepts in the OMNIBUS ontology. Even if an author does not use any pieces of WAY-knowledge for scenario authoring, this interpretation can be done. *Theory exposition* uses only WAY-knowledge. This just tells what each theory proposes

Table 1. A classification of explanation messages (not exhaustive)

Type	Notes
Scenario comprehension	*Explanation of just an interpretation of the relation among events in a scenario. Without any theoretical justification. E.g. An event is preparation of another event.*
Theory exposition	*Explanation of the theory itself independently of a specific situation.*
Theoretical justification	*Explanation of an interpretation of the relation among events in a scenario with theoretical justification. E.g. An event is preparation of another event and the necessity is guaranteed by theory A.*

independently of a particular scenario. A *theoretical justification* of scenarios is a combination of them. This reports both interpretation of a particular scenario and justification of it based on pieces of WAY-knowledge. These kinds of explanation is expected to be useful for authors to review their own scenario or to know the deign intention of others'.

3.3 Generation mechanism of scenario explanation

In order to generate the scenario explanation, we made message templates whose vocabulary comes from the OMNIBUS ontology and whose structure is partly based on an I_L event decomposition tree. Comparing scenario models with the OMNIBUS ontology enables SMARTIES to make interpretation of a scenario model and to generate explanation of the theories.

Fig 5 illustrates the generation mechanism of a scenario comprehension message. Fig 5 (E) shows a content of a scenario comprehension message and this is displayed on SMARTIES like Fig. 5 (F). This message is generated from the message template (Fig 5 (D)). Words in angle blankets in the template represent slots to be filled in when a message is generated. Each slot is related to the scenario model (Fig 5 (B)) or a piece of WAY-knowledge (Fig 5 (C)) defined in the OMNIBUS ontology. For example, <Instructional action> slot in the template is related to "instructional action" part of the target I_L event explained in the message. This relationship enables SMARTIES to generate a specific explanation messages (Fig 5 (E)) using templates according to a scenario model.

At the implementation level, the templates are described in XSL based on the relation among a template, a scenario model and WAY-knowledge. The detailed generation process is the following. Firstly, a scenario model and a WAY-knowledge are converted to XML files. Secondly, the XML files are transformed into a specific explanation message step by step according to two templates; one is for content generation and the other is for representation generation. Finally, an HTML file representing the explanation message is generated. When an author requests SMARTIES to show the explanation, the HTML file is displayed (Fig 5 (F)).

SMARTIES can generate explanation messages of any I_L event and WAY in a scenario model even if the I_L event or WAY is described by users. The reason is that the mechanism is based on the concepts defined declaratively in the OMNIBUS ontology. In other words, procedures defined ad hoc are not used in the mechanism. In addition, the templates are developed with the concepts defined close to the top-level concepts in the OMNIBUS ontology, for example, I_L event, WAY and so on. Developing templates with such concepts enables SMARTIES to generate explanation messages of variety of scenario models and WAY-knowledge. Therefore, if a template for a more specialized concept is necessary, minimal modification

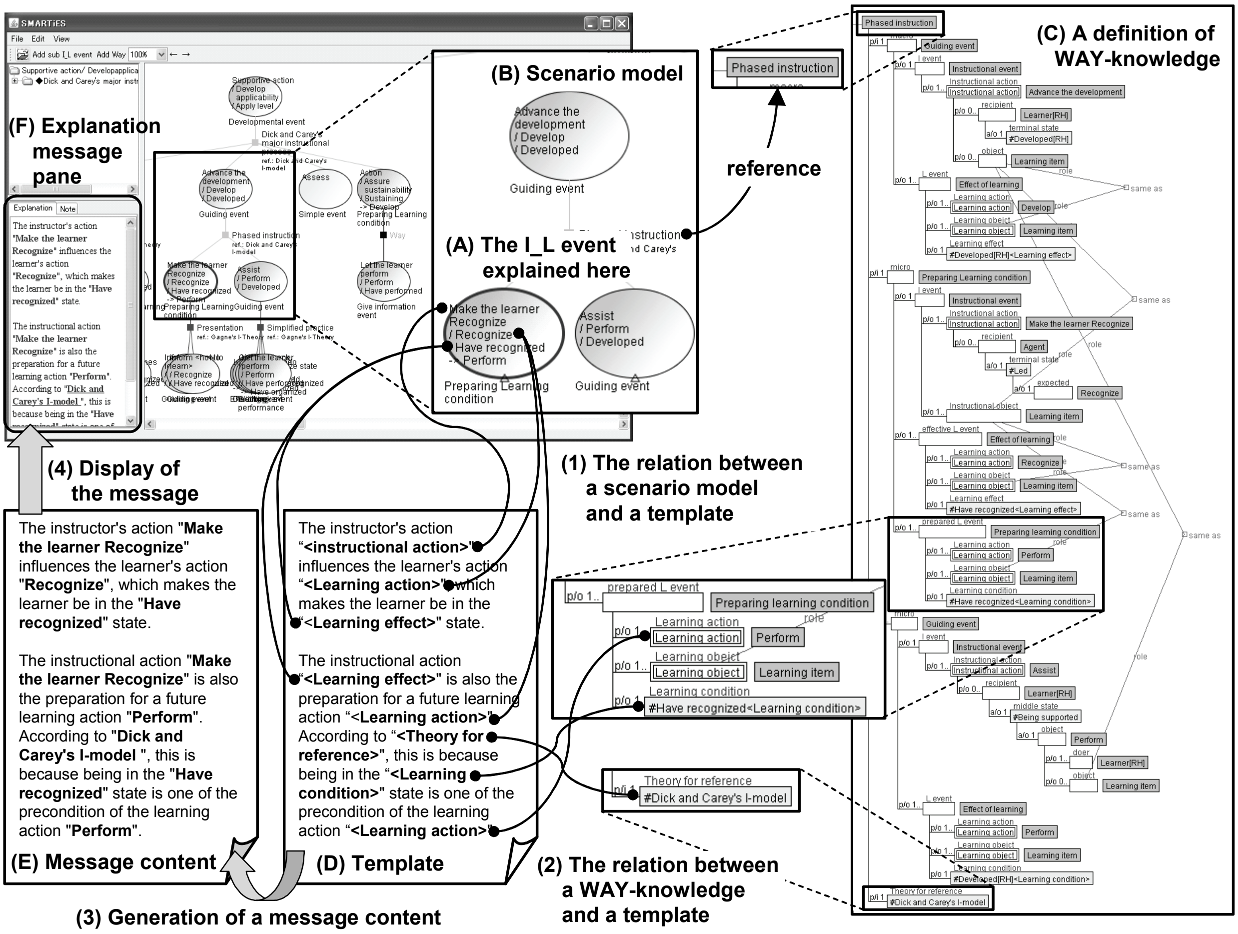

Fig. 5 Generation mechanism of scenario comprehension message

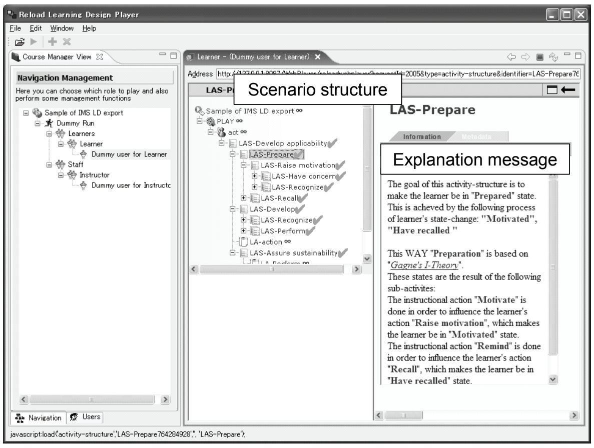

Fig. 5 Scenario model and explanation on IMS LD player

or expansion of the template would be required because the difference between the concepts are managed by the IS-A hierarchy in the OMNIBUS ontology.

Explanation messages generated by SMARTEIS can be combined into IMS LD export of a scenario model and be browsed on IMS LD compliant tools. Fig. 5 shows a scenario model and an explanation displayed on IMS LD player [14]. The explanation includes the link to the web pages which explain the related theory. The author can know the theory further through the web pages. This export mechanism of SMARTIES make authors possible to share the theoretical justification of scenario model on any IMS LD compliant tools. We believe that such collaboration of the theories and the standard technologies bridge the gap between the theory and the practice.

4. CONCLUSION

We have discussed theory-awareness of an ontology-based authoring tool and its contribution to standard technologies, especially focused on IMS LD specifications. Conceptual understanding of scenarios based on the theory-awareness enables information systems to explain theoretical interpretation of scenarios and to record it with theoretical justification. The fusion of our ontological modeling approach and standard technology will achieve a good balance between theoretical justification and interoperability of learning and instructional scenarios.

In order to realize this, one of the most important points is to build a comprehensive ontology that covers different theories and paradigms. At this moment we have developed OMNIBUS ontology as a draft of such ontology. However, we are still on the way to the completion of its development and we need to elaborate it in a bottom up manner by investigating much more theories. In addition, we currently plan to put the OMNIBUS ontology to the core of our infrastructure for educational knowledge sharing. This means that the OMNIBUS ontology enables us to utilize theories for contents design through the top-down approach as well as to building up new theories and sharing best practices through the bottom-up approach. We believe such an infrastructure will harmonize theory and practice of instructional and learning design.

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