Structuring Learning/Instructional Strategies through a State-based Modeling

Yusuke HAYASHI [a,1], Jacqueline BOURDEAU [b] and Riichiro MIZOGUCHI [a]
[a] *I.S.I.R, Osaka University, Japan*
[b] *LICEF Research Center, TÉLUQ-UQAM, Canada*

Abstract. This study, through the ontological engineering approach, aims at building a conceptual basis that encourages instructional designers in better understanding of learning/instructional theories, which mean that instructional designers can *select* and *integrate* appropriate strategies from theories within an instructional context. This paper proposes a methodology of structuring the theories in terms of strategies included in them, in which strategies can be structured independent of paradigms and theories.

Keywords. Ontology, instructional design, and learning and instructional theories

Introduction

Ertmer and Newby [6] state that theories[2] are sources of verified instructional strategies, tactics and techniques. In scenario design, instructional designers select strategies appropriate to the intended instructional context and integrate them within the context. However, there is a difficulty in the utilization of theories and they tend to call to mind previous solutions and strategies that they have used, have experienced, or have seen that fit the particular constraints of the current situation [18].

Selection of strategies from theories within an instructional context requires some perspectives for looking into theories. Reigeluth assembles theories, each of which is the independent and piecemeal knowledge base, and aims at encouraging building a common knowledge base that integrates them in his series of books starting from [19]. These literatures collect the explanation of theories basically by the originator and make annotations about relation between theories. Smith & Ragan organize strategies by the target such as concept, procedure, principle, problem-solving, attitude and so on [21]. Dick & Carey's ID Model [5] incorporates an eclectic set of strategies drawn from each of theories in several paradigm mentioned above and organize them according to learning/instructional process model. Such perspectives are helpful to find out appropriate strategies to an instructional context.

Integration of strategies from theories within an instructional context requires certain procedural interpretations. Even authoring systems, currently considered to be the best in the TEL (Technology Enhanced Learning) field incorporate a single learning/instructional theory in a procedural way (e.g. CREAM [17], CTAT (Cognitive

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[1] Corresponding Author, E-mail: hayashi@ei.sanken.osaka-u.ac.jp

[2] In this paper, the term "theory" is used in a broad sense, which includes learning/instructional model, for convenience sake. A detailed discussion of the distinction of them in our study can be found in [1].

Tutor Authoring Tools)[13], etc.), and such intelligent systems has been realized mainly implicitly and in proprietary formats [8]. Basically, such a procedural interpretation is conducted by system developers and solely remains in their minds, causing difficulties in the management of knowledge bases, due to the modifications of knowledge and the evolution of theories.

This study, through the ontological engineering approach [3][4], aims at building a conceptual basis that encourages instructional designers to utilize learning/instructional theories in better understanding of them. In this study, by "a designer gains better understanding of learning/instructional theory", we mean that he/she can *select* and *integrate* appropriate strategies from theories within an instructional context. So far, this study has proposed OMNIBUS, which is an ontology that comprehensively covers different learning/instructional theories and paradigms, and SMARTIES, which is a prototype of a theory-aware authoring system that can help designers select and integrate strategies from theories in order to create learning scenarios [15][16].

There are some studies related to ontologies for learning/instructional design knowledge. Meisel et al. propose an ontology-based framework for managing teaching methods [14]. Although it does not commit to any particular theory in the same way as OMNIBUS, it provides just a conceptual framework to describe such knowledge. The LOCO-Cite ontology [12] aims at describing the context of usage of learning objects (LOs) in each scenario. This is considered to be complementary to OMNIBUS for considering the theoretical validity of LOs used in a scenario.

This paper discusses structuring of learning/instructional theories mainly in terms of strategies included in them and the contribution of the structuring to better understanding of learning/instructional theories. The structure of this paper is as follows. The next section gives an overview of structuring theories on OMNIBUS from two viewpoints of a theory as a whole and a theory as an aggregation of strategies. Section 2 presents how the structuring works in theory-aware support realized in SMARTIES. Finally the last section presents conclusion and future work.

1. Structuring learning/instructional strategies

The paradigms in the area of education express their own theories by essentially adopting different terminology, concepts and models. To build an ontology that comprehensively covers different learning/instructional theories and paradigms, this study proposes the working hypothesis that a sharable "engineering approximation" related to "learning" can be found in terms of the changes that are taking place in the state of the learners. Based on this working hypothesis, such a conceptual basis was extracted that highlights similarities of and differences between the paradigms, and then enables us to structuralize them into OMNIBUS. This section firstly gives an overview of structuring of theories on OMNIBUS and then focuses on the structuring of strategies from learning/instructional theories.

1.1. Conceptualization of learning/instructional theories

We have proposed a structuring of learning/instructional theories from two viewpoints; one is a theory as a whole and the other is a theory as an aggregation of strategies.

From the view as a whole, theories are defined with the properties such as the principle, the hypothesis and the evidence, and categorized according to paradigms [1].

Paradigms such as behaviorism, cognitivism, and constructivism [2] provide a knowledge theory to construct learning theories, which can then be grouped according to these different paradigms. In OMNIBUS learning/instructional theories are classified according to the paradigms and organized in an *is-a* hierarchy.

From the view as strategies, each theory is modeled as aggregation of some strategies. Each strategy is conceptualized as achievement/decomposition relationship between state changes of a learner as shown in Fig. 1. The conceptualization of the relation is called WAY in this study [16]. Especially, a theory-based WAY is called WAY-knowledge. So far, 99 pieces of WAY-knowledge have been defined based on strategies from theories [10].

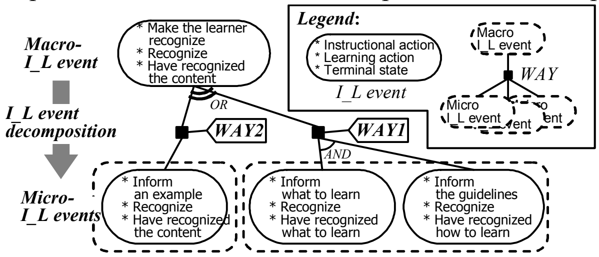


Figure 1. The conceptualization of strategies

1.2. Structuring educational strategies

This paper proposes *is-a* hierarchy of WAY-knowledge. Currently, in the *is-a* hierarchy, the pieces of WAY-knowledge are classified according to firstly the strategy types [9] and secondly the types of learner state to be decomposed. Figure 2 shows a portion of the *is-a* hierarchy of WAY-knowledge. In this figure only instructional action is denoted in I_L events of each piece of WAY-knowledge. The classification of WAY-knowledge in this *is-a* hierarchy is independent of the classification of paradigms and theories.

In Fig. 2 three theory/models are included; Gagne &Briggs's theory [7] as a cognitivist theory, Keller's theory (ARCS model) [11] as an instructional management theory, and Star legacy model [20] as a constructivist model. Each theory/model has a strategy to motivate learners. The difference among them is the type and the

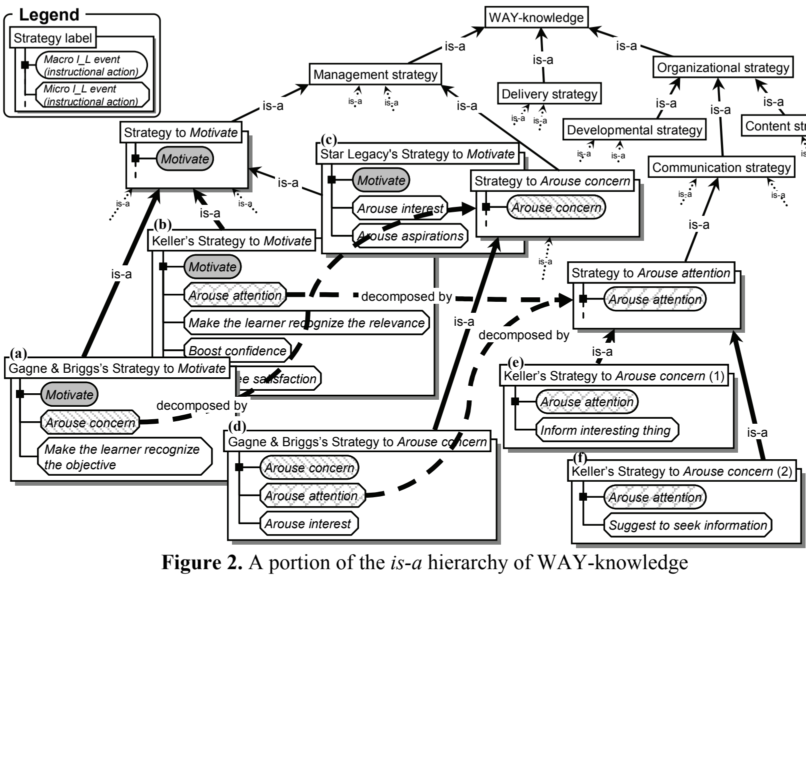


Figure 2. A portion of the *is-a* hierarchy of WAY-knowledge

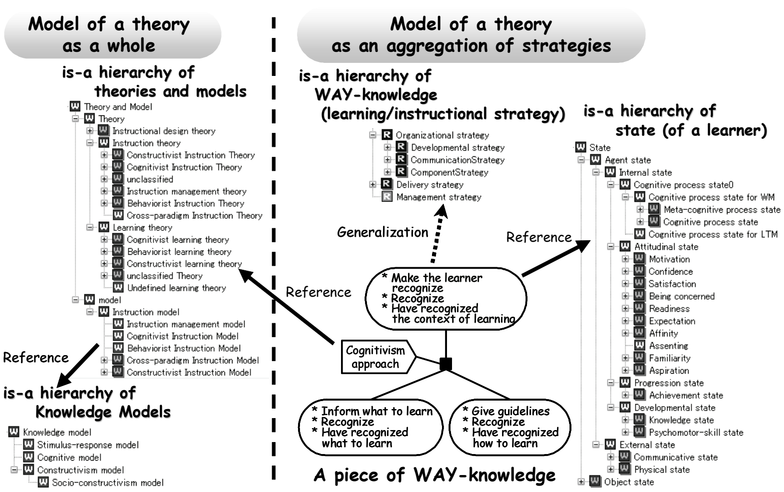
combination of state to be achieved in the micro-I_L events, that is, how to achieve it. In "Gagne & Briggs's strategy to Motivate" (Fig. 2(a)), "Motivate" is decomposed into two micro I_L events: "Arouse concern" and "Make the learner recognize the objective". On the other hand, in Keller's (Fig. 2(b)) or Star legacy's (Fig. 2(c)) strategy, "Motivate" is decomposed different micro I_L events, respectively.

While these are seemingly different, there is a common point between them if these are further decomposed. For example, "Arouse concern" in Gagne & Briggs's theory can be decomposed further into two I_L events with "Arouse attention" and "Arouse interest" (Fig. 2(d)). The part "Arouse attention" is common to the first micro I_L event of "Kellar's strategy to Motivate". This I_L event can be decomposed by two pieces of WAY-knowledge from Keller's theory (Fig. 2(e, f)) in common. In this manner, through the lines of *is-a* links and the reference to the other WAY-knowledge (heavy lines in Fig. 2), it becomes clear which pieces of WAY-knowledge can be applied to decompose the micro I_L event of a piece of WAY-knowledge. For example, both of "Keller's strategy to Motivate" (Fig. 2(b)) and "Gagne & Briggs's strategy to Motivate" (Fig. 2(a)) can be decomposed by "Strategy to Arouse attention", which has two sub-classes, that is to say, there are two alternatives.

1.3. Getting perspective of learning/instructional theories based on OMNIBUS

We discussed two viewpoints of conceptualizing theories/models in the previous sections, which are from the views of a theory as a whole and an aggregation of strategies. Fig 3 shows the relation between the two viewpoints. The conceptualization of a strategy as a piece of WAY-knowledge plays a pivotal role in linking the paradigms and the states of learners that are the key of the conceptualization of "learning" in this study. A piece of WAY-knowledge refers to a theory defined in the *is-a* hierarchy of theories as the principle, as well as to a state defined in the *is-a* hierarchy of states as the target to be achieved. In addition the pieces of WAY-knowledge are categorized in the *is-a* hierarchy of WAY-knowledge according to the type of strategies.

Through these links we can reveal the characteristics of the paradigms and theories. For example, tracing the relations from a theory to states through pieces of WAY-



Firure 3. The relation between the conceptualization of a theory as a whole and an aggregation of strategies

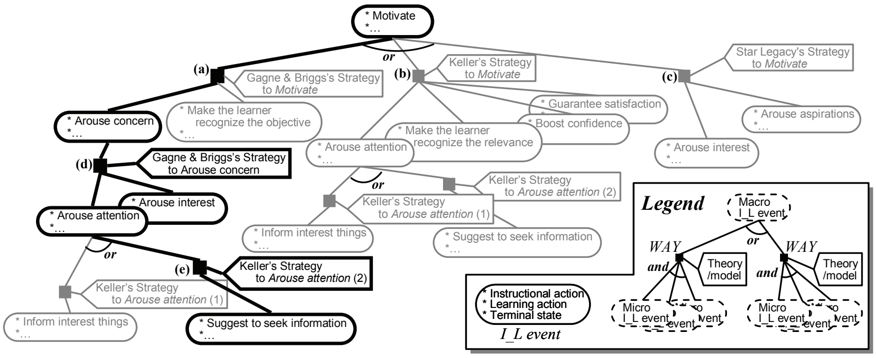


Figure 4. A portion of a scenario model

knowledge reveals which states are covered with the theory. That is, the characteristics of each theory are revealed in terms of learner's states. To the contrary, tracing the relation from learner's states to theories reveals which theories deal with the state. That is, the commonality and the difference among theories are revealed in terms of the intended states. Such analysis can be done thanks to the primary design policy employed in OMNIBUS, that is, state-based conceptualization of "learning" regardless of the paradigmatic differences of theories. In this study such a methodology of structuring theories is called "SEASONING", which means structuring of expertise as a state-centered model based on ontological engineering.

2. Theory-awareness based on the structuring of theories

2.1. Scenario design with OMNIBUS

Based on OMNIBUS a learning/instructional scenario is modeled as a hierarchical tree structure of I_L events. Fig. 4 shows an example of a portion of a scenario model. This hierarchical tree structure is not *is-a* structure as shown in Fig. 2 but the whole-part structure of I_L events with WAY as a relational concept. Each node is an I_L event and the hierarchical relations of them depicted as a square are WAYs.

The decomposition tree shown in Fig. 4 includes some alternatives to decompose some I_L events. For example, the learning goal set in the root I_L event is that a learner is motivated to learn, and there are three WAYs to achieve this goal: strategies to Motivate based on Gagne & Briggs's theory, Keller's theory and Star legacy model. These WAYs are defined as the sub-class of "Strategy to Motivate" in Fig. 2. The goals of them are the same, which is to motivate learner, therefore these strategies can be applied to the root I_L event with OR relationship. These are also the sub-classes of Management strategy, which is as one of the top-level concept of WAY-knowledge and decomposes an attitudinal state to the other internal states of learner. Based on this top-level categorization, each WAY in a scenario model is clarified in terms of the design decision. For example, choosing a management strategy here means that the designer does not design communication to achieve it between the learner and the instructor but tries to consider learners internal states in detail and then design communication[3].

Designing a scenario with OMNIBUS is basically to select a strategy from

[3] Although currently there is no piece of WAY-knowledge to decompose "Motivate" to communication directly in OMNIBUS, it is possible for an author to describe such a WAY on his/her thinking.

alternative pieces of WAY-knowledge derived from theories (or to describe the author's own strategy as a WAY). The decomposition tree in Fig. 4 poses the possibility in scenario design as the OR relation of WAYs, in this example, Fig. 4(a), (b) and (c). The decomposition tree presented with heavy lines is one of the results of decision making in scenario design. Firstly the Gagne & Briggs's strategies are selected at (a) and (d), and then the Keller's strategy is selected for further decomposition at (e). Consequently, scenario design with OMNIBUS can be said pruning of a decomposition tree including the possibility of decomposition.

Another characteristic of scenario design with OMNIBUS is that the selected WAY-knowledge by the author is automatically integrated into the scenario model. That is, *selection* of an intended strategy from the theories and *integration* of it into an instructional context is done at the same time. Such a mechanism is realized on the declarative definition of strategies as WAY-knowledge, which is a relational concept between the macro and the micro I_L events, and the procedural use of it based on the top-down interpretation of WAY-knowledge [9].

This mechanism has been implemented in SMARTIES. Figure 5 shows a screenshot of SMARTIES, in which an author is selecting a piece of WAY-knowledge from the candidates SMARTIES proposes. The target I_L event to be decomposed is shown at Fig. 5(a) and the applicable pieces of WAY-knowledge are displayed in the tree structure and sorted by categories of paradigms, theories, and strategies, in that order (Fig. 5(b)). Displaying not only the categories of paradigm but also the ones of strategies, the author can select a much better piece of WAY-knowledge reflecting his/her intention as discussed above. In addition this can be guidelines for design providing possible decision making. The leaves are applicable pieces of WAY-knowledge. On the right side of the window (Fig. 5(c)), the author can see the proposed decomposition by each piece of Way-knowledge. When the author chooses one of them, the proposed decomposition is embodied in the scenario model (Fig. 5(d)).

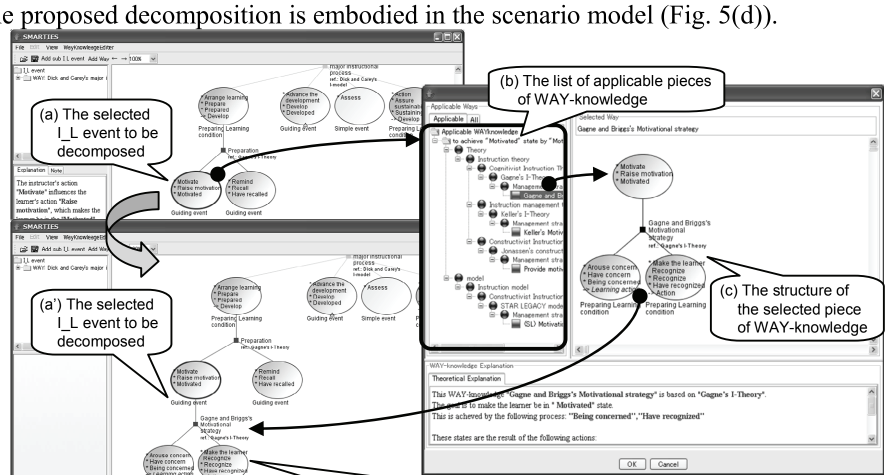


Figure 5. Strategy selection and integration on SMARTIES

2.2. Affording a panoramic view of theories for better understanding of them

Although, in the previous section, it is simply stated that a piece of WAY-knowledge is integrated within a scenario model if one is selected, the difficulty is to

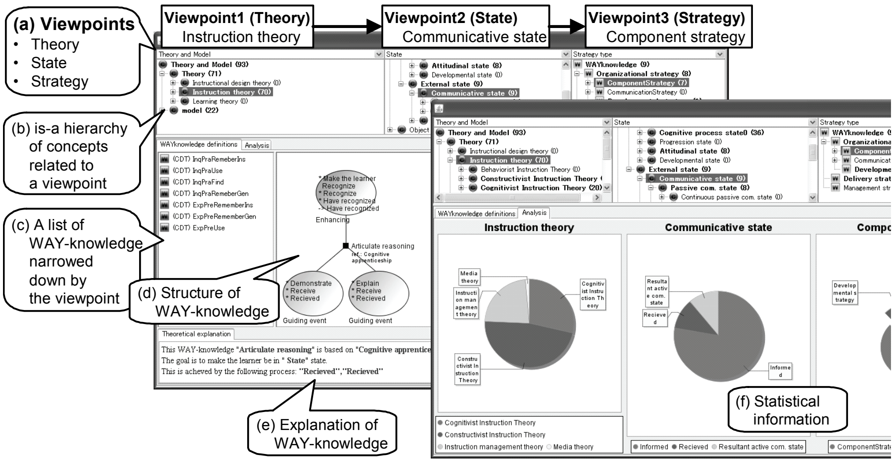


Figure 6. Screenshots of WAY-knowledge browser

select an appropriate one from applicable pieces of WAY-knowledge. As mentioned with Fig. 5, SMARTIES shows the applicable candidates with the background such as category of paradigms and theories to which the strategies belong. In order to utilize such information effectively, it is important to know the features of each categories of paradigms and theories in general. From this standpoint, a tool to allow users to browse the pieces of WAY-knowledge from combinations of several viewpoints is implemented in SMARTIES.

Figure 6 shows a screen shot of the tool, WAY-knowledge browser. On this window users can choose the viewpoints to browse the pieces of WAY-knowledge. Three viewpoints can be chosen here: types of theory, state and strategy (Fig. 6(a)). For example if "theory" is selected as viewpoint 1, the *is-a* hierarchy of theories are shown (Fig. 6(b)). This bold letters in the *is-a* hierarchy mean that some pieces of WAY-knowledge related to the concept are defined in OMNIBUS. When a concept in the *is-a* hierarchy is selected, a list of WAY-knowledge related the concept is shown below (Fig. 6(c)).

These viewpoints can be combined. In this figure, for example, the viewpoints are selected according to the order of Instructional theory, Cognitive state and Component strategy. This order of combination means which instructional theories deal with Cognitive state and how the communicative states are achieved in each WAY-knowledge. At the request of users SMARTIES dynamically finds out pieces of WAY-knowledge fulfilling such a requirement and displays on the window.

The lower half of the window displays structure of each piece of WAY-knowledge (Fig. 6(d)) and the explanation of it (Fig. 6(e)). In addition to such detailed information statistical information about distribution of each viewpoint is also provided to users (Fig. 6(f)). In this manner, this tool provides users with panoramic view of learning/instructional theories. WAY-knowledge plays a pivotal role in such perspective management.

3. Conclusion

This paper discusses the structuring of theories in terms of strategies based on OMNIBUS. Following the SEASONING methodology, learning/instructional strategies can be structured independent of paradigms and theories. The structuring contributes to better understanding of learning/instructional theory through the following two points: the procedural use of WAY-knowledge, and the pivotal role of it in linking the paradigms and the learner's state that is the key of the conceptualization of "learning" in this study.

The future work of this study is to establish the *is-a* hierarchy of WAY-knowledge including much more strategies from theories and to apply the SEASONING methodology to patterns and best practices. In addition, this study is still at a preliminary stage in conducting a substantial evaluation and its practical benefits have not yet been fully realized. In order to prove our claims, it is necessary to conduct research on its actual use with real authors.

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