

# Toward Accumulation of Learning/Instructional Design Knowledge for Authoring Systems

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**Abstract:** On the basis of the achievements of OMNIBUS project, this paper presents the functionality of theory-aware authoring system and discusses how to accumulate learning/instructional design knowledge as the foundations for theory-awareness. The concept of “WAY” proposed by this study would be helpful for both utilizing and abstracting learning/instructional design knowledge. Structuralization of WAY in an IS-A hierarchy is the key point toward accumulation of learning/instructional design knowledge.

**Keywords:** Authoring system, Ontology, Theory-awareness

## Introduction

When instructional designers design learning contents, 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 [13]. This sometimes causes an absence of a consistency and adequateness of the whole instructional/learning process expected in the use of the contents. In order to make up for such absence, there must be support by some sort of guidelines for designing, in order to ensure the consistency and adequateness of the resultant contents.

Learning/instructional theories are considered to be one of the guidelines and some authoring systems succeed in providing theoretical support to authors by incorporating a single learning/instructional theory (e.g. [6][12]). However, the support functions of them are embedded in a procedural way and hence the relationship between the system’s behavior and the background theory is implicit. That is to say, procedural interpretations of the theory are conducted by system developers and it is kept only in their brains. This causes limitations on scalability of the theory-based support functions and a lack of accountability for the system’s support to authors.

One of the key technologies to the solutions is ontology engineering [1][2]. This is expected to cope with both the declarative description of knowledge and its operability. Some ontologies are built in order to model and organize learning/instructional theories (e.g. [6][16]). This will facilitate a better relationship between the system’s behavior and the background theory, and make authoring systems manageable and knowledgeable. Such authoring systems are called “theory-aware” [10]. Based on this idea, we have proposed the OMNIBUS ontology<sup>1</sup> and a prototype of theory-aware and standard-compliant authoring

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<sup>1</sup> <http://edont.qee.jp/omnibus/>

system named SMARITES [11]. This paper discusses how to accumulate learning/instructional strategies derived from learning/instructional theories and best practices, as the foundations for theory-awareness after the presentation of an overview of the OMNIBUS ontology and SMARTIES as past achievements of the OMNIBUS project.

This paper is structured as follows. Section 1 summarizes past achievements of the OMNIBUS project. Section 2 discusses how to accumulate learning/instructional design knowledge based on OMNIBUS ontology. Section 3 shows an example of structuralization of theoretical knowledge. Finally, Section 4 concludes this paper.

## 1. Theory-awareness based on OMNIBUS ontology

Most learning/instructional theories contain a principle as the premise, versatile strategies based on the principle and so on. Utilizing the theories requires the users to select a suitable theory from a variety of theories and then to apply the strategies included in the selected theory to a specific situation with the deep understanding of the relationship among them as well as each theory. In order to satisfy the requirement, it would be helpful to have a common conceptual basis for better comparison between theories.

As a solution to the problem, this study makes a working hypothesis that a certain kind of sharable “engineering approximation” related to “learning” can be found in terms of the change in the state of learners. Based on this working hypothesis we have built the OMNIBUS ontology as a conceptual basis that highlights the differences and commonalities of a variety of theories based on some paradigms.

This section gives an overview of the OMNIBUS ontology and theory-awareness implemented in SMARTIES. Due to space limitations, this section focuses only on the key concepts of the OMNIBUS ontology and some theory-aware functions of SMARTIES based on the concepts.

### 1.1 An overview of the OMNIBUS ontology

One of the characteristics of the OMNIBUS ontology is to conceptualize learning/instruction processes from two viewpoints: *what* to achieve and *how* to achieve [3]. These viewpoints are defined as the concepts named “*I\_L event*” and “*WAY*”. *I\_L event*, in which “*I\_L*” stands for the relationship between the *I*nstruction and the *L*earning, is the concept to describe *what* learner state is achieved by what actions. *WAY* is the concept to describe *how* the state can be achieved by the sequence of the states of smaller grain-size.

Fig. 1 (a) shows an example of a learning/instructional process model based on these concepts. In the Fig. 1 (a), the oval nodes represent *I\_L events*, and black squares linking the macro and the micro *I\_L events* represent *WAYs*. The macro *I\_L event* has two *WAYs*;

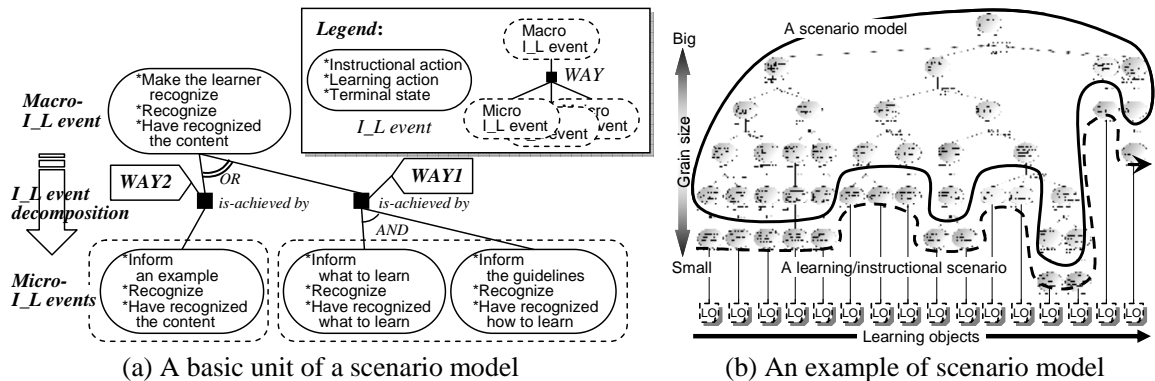


Figure 1. A scenario model based on the OMNIBUS ontology

WAY1 and WAY2, and there is an “OR” relation between them. This indicates that there are two alternatives to achieve the macro I\_L event.

These concepts give a conceptual scheme to model strategies included in learning/instructional theories. We have extracted 99 strategies from 11 theories and defined them as WAYs in the OMNIBUS ontology [5]. Such WAYs based on learning/instructional design knowledge, which include learning/instructional theories and best practices, are called “WAY-knowledge” in the OMNIBUS ontology. WAY-knowledge is an engineering model of strategies and works as the source of theory-awareness for SMARTIES.

Based on these concepts, a scenario model is described as a tree structure of I\_L events decomposed by WAYs as shown in Fig. 1 (b) and WAY-knowledge works as theoretical guidelines for the modeling. The leaf level is a description of a learning/instructional scenario executed by instructors and learners, and is linked with LOs used in the execution. The tree structure above the leaf level explains the design rationale of the scenario and it works as the specifications of the attached LOs. This idea is close to the idea on the LOCO-Cite ontology [7]. The ontology aims at describing the context of usage of learning objects in each scenario with e-learning and semantic web standards. This conceptual framework to describe the context by the LOCO-Cite ontology is complementary to the theoretical guidelines provided by the OMNIBUS ontology in order to record the context of learning objects used in a scenario and its theoretical validity.

## 1.2 Theory-awareness of SMARTIES

Based on the OMNIBUS ontology, we have developed a prototype of theory-aware and standard-compliant authoring system named SMARTIES. SMARTIES understands theories and supports authors to make scenarios that conform to theories from the abstract level to the concrete level, in other words, from goal setting of a scenario to assignment of learning objects (LOs) to it. At the same time, this is a standard-compliant system that can output the resultant scenario deliverables in the IMS LD format [4].

Figure 2 shows the SMARTIES user interface. The Scenario editor (Fig. 2 (1)) is the main window in which the author makes a scenario model (Fig. 2 (a)) through a GUI. In principle, an author (scenario designer) can describe a scenario model freely following the I\_L event decomposition scheme shown in Fig. 1. 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 ontology (Fig. 2 (2)).

If the concepts defined by the ontology are used in the scenario model building, SMARTIES can interpret the scenario model and offers an intelligent support including explanations of and suggestions on the model based on the theories. For example, the WAY-knowledge proposal window (Fig. 2 (5)) displays the list of applicable WAY-knowledge in the order of the matching score<sup>2</sup> along the IS-A structure of the theories classified according to the paradigms (Fig. 2 (d)). SMARTIES can pick up the applicable WAY-knowledge by unifying the target I\_L event to be decomposed in a scenario model and macro I\_L events of WAY-knowledge<sup>3</sup>. When a piece of WAY-knowledge is selected by the author, its structure after application (Fig. 2(e)) and its explanation (Fig. 2(f)) are displayed. All of these contents are created dynamically based on the OMNIBUS ontology. With this information, the author can select one piece of WAY-knowledge that seems to be most relevant.

<sup>2</sup> Matching is done between the I\_L event and the macro I\_L event of the WAY-knowledge.

<sup>3</sup> This mechanism is not something based on an empirical rule and not something that grasps the changes of the object world by updating the working memory through the WAY-knowledge.

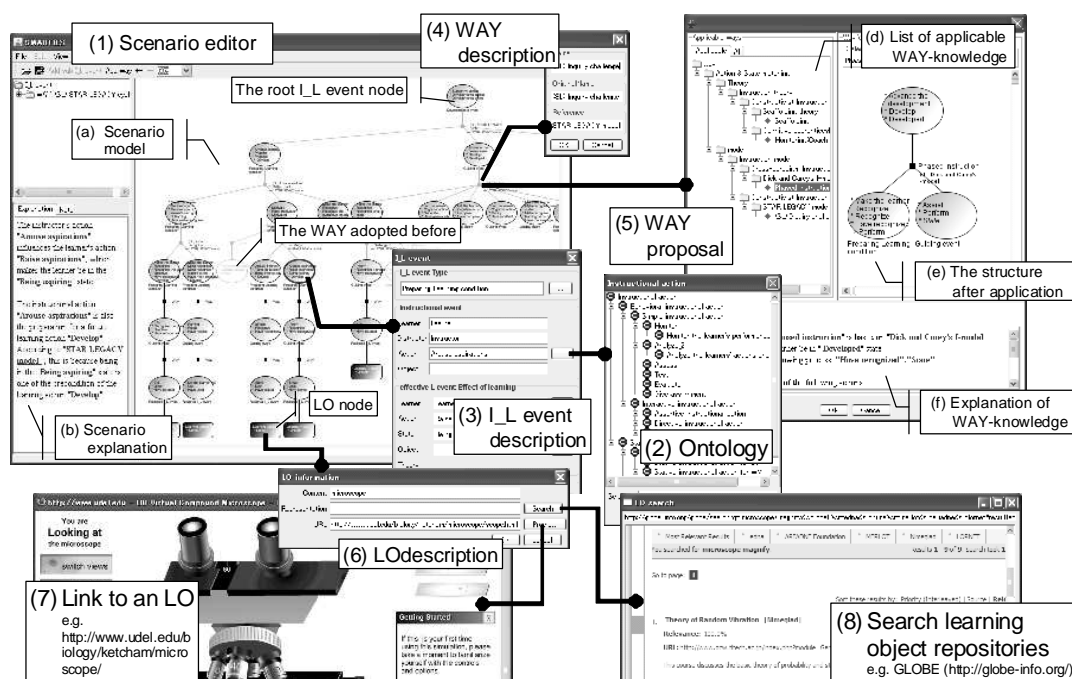


Figure 2. Screenshot of SMARTIES

At the end of the scenario design, learning objects are linked to a scenario model. The leaf nodes depicted by rounded rectangles in the scenario model stand for LOs. In this example, a simulation of a micro scope (Fig. 2(7)) is set in order to materialize the leaf I\_L event. Authors can set an LO that they made or know as well as search LO repositories for LOs appropriate to the requirement (Fig. 2(6)).

By these operations, the scenario model is built hierarchically from the abstract level to concrete level as shown in Fig. 2(a). The declarative models of instructional/learning strategies as WAY-knowledge in the OMNIBUS ontology enable SMARTIES to provide theoretical guidelines for scenario building. Unlike other authoring systems where theories are embedded in a procedural manner, the support provided by SMARTIES is based on the declarative knowledge defined by the OMNIBUS ontology, which is developed on Hozo ontology editor<sup>4</sup> and installed outside SMARTIES. Therefore, SMARTIES can automatically change its behavior when learning/instructional design knowledge included in OMNIBUS ontology is updated.

## 2. A perspective on accumulation of learning/instructional design knowledge

We have thus far discussed how WAY-knowledge works as the source of theory-awareness of SMARTIES. In this section, we discuss how such pieces of WAY-knowledge are accumulated.

We can consider that there are two paths to accumulation of WAY-knowledge as shown in Fig. 3. One is the extraction from theories, which has been done in this study so far (Fig. 3(a)). The other one is the extraction from practice. It is also important to abstract practical knowledge from best practices in order to organize it as useful heuristics (Fig. 3(b)). Although SMARTIES has a WAY-knowledge editor it is currently just a simple graphical editor. In

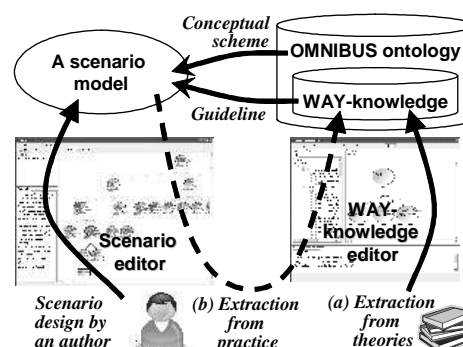


Fig. 3 the two paths for WAY-knowledge accumulation

<sup>4</sup> <http://www.hozo.jp/>

order to accumulate WAY-knowledge from theory or practice effectively, guidelines are required for the abstraction and for organizing knowledge as WAY-knowledge.

## 2.1 Categorization of strategies

According to Reigeluth [14] instructional strategies are composed of three different aspects: organizational strategy characteristics, delivery strategy characteristics and management strategy characteristics. Organizational strategy characteristics refer to how instruction will be sequenced, what particular content will be presented, and how this content will be presented. Delivery strategy characteristics deal with what instructional medium will be used and how learners are grouped. Management strategy characteristics include the scheduling and allocation of resources to implement the instruction that is organized and delivered as planned within the previous two strategy aspects [15]. In addition, by Merrill's definition, management strategies involve motivational techniques, individualization schemes and so on [9]. These categories are considered to be useful as the guidelines for abstracting and organizing knowledge.

According to these categories, this study proposes categories of strategies summarized in Table 1 as the upper level concepts of WAY-knowledge. Basically, these categories are defined according to Reigeluth's definition while Organizational strategy is subdivided into three more detailed sub-categories; Developmental strategy, Communication strategy and Component strategy. The difference among these categories is the target state of decomposition. In other words, the combinations of types of state in the macro and micro I\_L event are different. Using these upper level concepts of WAY-knowledge, this study proposes the structuralization of instructional design knowledge from theory and practice. Actually, those at the upper level are to some extent independent of each theory and WAY-knowledge from each theory or best practice will be placed under the upper level in the IS-A hierarchy. An example of IS-A hierarchy of WAY-knowledge will be taken up in section 3.

Table 1 Categories of strategies

types	Notes	
	Type of macro state	Type of micro state
Organizational strategy	To specify the sequence of learning/instruction	
Developmental strategy	To specify the development process of learner	
	<i>Internal state</i>	<i>Internal state</i>
Communication strategy	To specify the communication between learner and instructor.	
	<i>Internal state</i>	<i>Communicative state</i>
Component strategy	To specify the content to be presented to learner	
	<i>Communicative state</i>	<i>Communicative state</i>
Delivery strategy	To specify the medium used in the communication	
	<i>Communicative state</i>	<i>Physical state</i>
Management strategy	To specify the cultivation of attitude of learner	
	<i>Internal state</i>	<i>Attitudinal state</i>

## 2.2 Layering a scenario model

In this study, as mentioned in 2.1, a learning/instructional scenario is modeled as a hierarchical tree structure composed of I\_L events from the viewpoint of WAY to achieve learning/instructional goals<sup>5</sup>. In this study, the hierarchical structure is called the "scenario model" whereas only the bottom structure (the sequence of the leaf I\_L events) is called the

<sup>5</sup> This structure is not an "is-a" structure but a "whole and parts" one that is based on the relationship of achievement.

“scenario.” The scenario shows the actual events performed by the learner and the instructor when executed.

This scenario model can be separated into three layers; Rationale layer, Communicative layer, and Presentation layer as shown in Fig. 4. Presentation layer corresponds to a scenario. This layer is linked to LOs and specifies which medium is used for presenting the content to learners. *Physical state* related to the LOs is focused here, for example, *Have looked*, *Have read*, and so on (in this section italic words denote concept defined in the OMNIBUS ontology).

The communicative layer is an abstraction of Presentation layer in terms of communication between the learner and the instructor participating in the scenario. This layer deals with *Communicative state*, for example, *Informed*, *Asked* (questions/to do an action) and so on. Rationale layer presents the design rationale of the other two layers. This layer deals with *Internal state*, for example, *have recognized*, *have recalled* and so on, therefore this can explain why the Communicative and Presentation layers are planned in the scenario model from the perspective of the internal change of learners.

According to the types of states dealt with at each layer, the categories of strategy usable in each layer can be specified. For example, Rationale layer deals with *Internal state*, hence Developmental, Communication and Management strategies can be used to decompose I\_L event in the layer according to Table 1. This would be useful not only for abstracting and categorizing WAY-knowledge from both of theoretical literature or scenarios in best practices but also for characterizing each theory and best practice. To put it little more concretely, each theory and best practice can be characterized by which layer of the scenario model the theory or best practice covers.

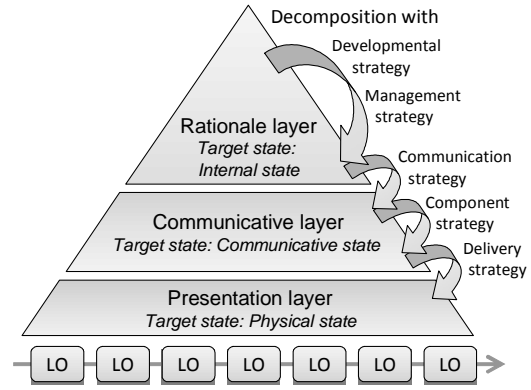


Fig. 4 Layers of a scenario model

### 3. An example of structuralization of WAY-knowledge

We plan to build an upper level concept hierarchy of WAY-knowledge as mentioned above. Based on such hierarchy we aim at organizing WAY-knowledge from abstract level to a certain level for its application to actual learning/instructional scenarios.

Figure 4 shows a part of the IS-A hierarchy of WAY-knowledge including ones based on Component Display Theory (CDT) by Merrill [9]. There are two pieces of upper level WAY-knowledge concepts, which are called *communication strategy* and *component strategy*. These are specialized from left to right in Fig. 5. So, the leftmost WAY-knowledge corresponds to the most general one. The lower level pieces of WAY-knowledge are from CDT in this example. The lowest level pieces of WAY-knowledge can be used for decomposition in a scenario model as shown in Fig. 5(a).

*Communication strategy* deals with how an instructor communicates with a learner. On the other hand, *component strategy* deals with what type of information is provided to a learner by an instructor. The micro I\_L events obtained by the decomposition using *communication strategy* can be further decomposed using the *component strategy* because the micro I\_L event of the former is same as the macro one of the latter (See Fig. 5(b)). This means that an I\_L event decomposed by a subclass of *communication strategy* can be further decomposed by one or some of subclasses of *component strategy*.

The lower level pieces of WAY-knowledge are from CDT. The classification as *Expository* or *Inquisitory* based on the presentation mode by CDT is placed at the lower level

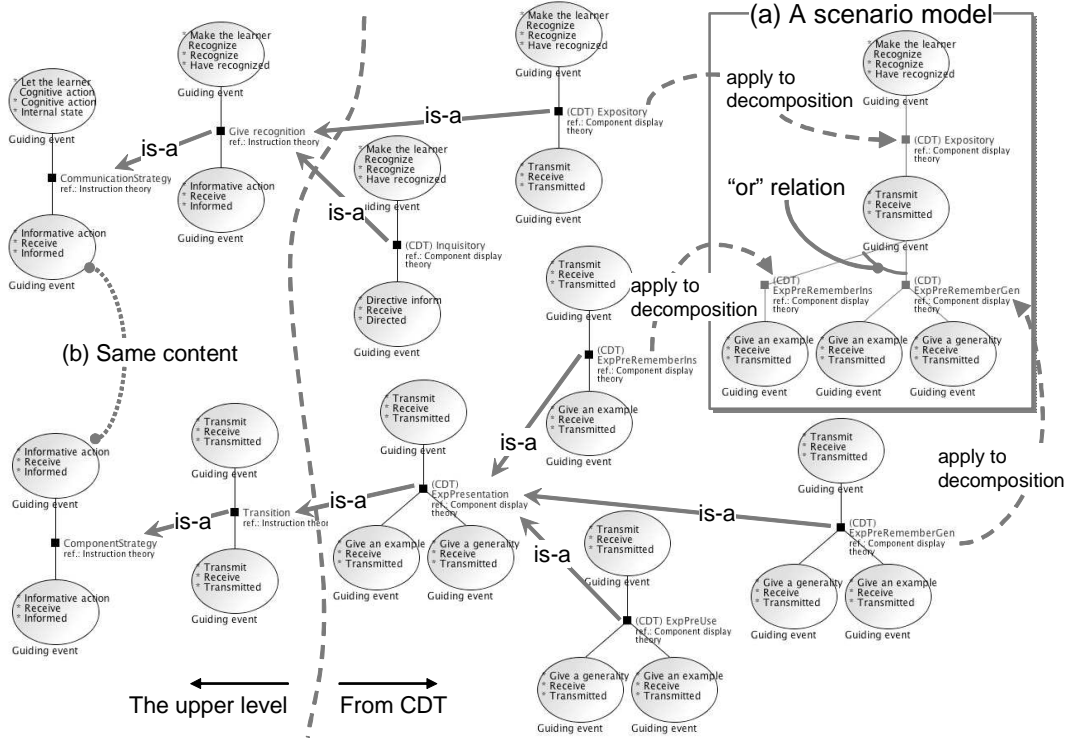


Figure 5. A part of IS-A hierarchies of WAY-knowledge based on CDT

*communication strategies*. On the other hand, the classification according to the process of learning/instruction (in CDT the type of process is classified as “presentation”, “practice”, and “performance”) and to the content depending on the objective of the part of the scenario model decomposed by the WAY-knowledge (in CDT the objectives are classified as the following performance level; “remember instance”, “remember generality”, “use”, and “find”<sup>6</sup>) is placed at the lower level *component strategies*. In the CDT these strategies are summarized in a matrix of Primary Presentation Form (PPF) associated with each performance level (see Fig. 7.3 in [9], p. 206). *Component strategy* can also have other types of subclasses, for example, decomposition according to the content such as positive or negative example. Such IS-A hierarchy that is shown in Fig. 5 suggests a high possibility to arrange a further detailed classification of strategies proposed in CDT from some viewpoints of properties concerned with learning/instructional strategies.

Some pieces of the lowest level WAY-knowledge are used to decompose I\_L event in the sample partial scenario model (Fig. 5(a)). The objective of the top I\_L event is that a learner recognizes the target of learning (the learner is in the state “have recognized”). Firstly the I\_L event is decomposed by *Expository* WAY-knowledge because the I\_L event is same as the macro I\_L event of the WAY-knowledge. Then, the micro I\_L event is further decomposed by either one of the two pieces of WAY-knowledge by CDT because the relation between the two decomposition is OR relation. As discussed so far such an IS-A hierarchy of WAY-knowledge can be a guideline for abstracting WAY-knowledge from both of theoretical literature or scenarios in best practices as well as for deciding a piece of WAY-knowledge to decompose an I\_L event in scenario design.

#### 4. Conclusions

This paper discusses an ontological structure for the accumulation of learning/instructional design knowledge. The concept of WAY-knowledge and the IS-A hierarchy of it proposed

<sup>6</sup> These performance level stand for that a learner can do the performance.

in this paper can be considered to be helpful to both utilization of learning/instructional design knowledge and abstracting it from theoretical literature and/or scenarios found in best practices.

A further direction of this study will be to make a map of learning/instructional design knowledge for clarifying each of them and comparing the relation among them based on the OMNIBUS ontology. In the OMNIBUS ontology, a theory can be grasped as an aggregation of WAY-knowledge in which each piece of WAY-knowledge is a model of a strategy contained in the theory and defined as a “relational concept”. That is, this shows a micro-level view of the theory in terms of strategies which are relations to achievement of a goal (a state of the learner) of learning/instruction. In addition to the WAY-knowledge defined as a relational concept, each theory is also defined as a “wholeness concept” in the OMNIBUS ontology [11]. This definition highlights the characteristics of each theory as a whole, as it were, this is a kind of a macro-level view of theories. By the IS-A hierarchy of theories defined as wholeness concepts, theories are organized according to properties of them such as the paradigm that the theory belongs to, the learning mechanism, the target types of learner and the requirement for learning objects. By combining these macro and micro-level views, the OMNIBUS ontology is expected to afford some perspectives on learning/instructional design knowledge, for example, which states are covered in each theory or paradigm, which strategy type is dealt with for which state to achieve in which theory or paradigm, and so on, even though this may just be an engineering approximation.

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