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A Semantically Enhanced Learning Environment for Cultivating Meta-thinking Skills

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Abstract: Meta-thinking skills, which are skills related to the ability to think about better ways of thinking, have been object of growing interest in the field of educational psychology. It is desirable that learners review their own way of thinking and critically reflect it in order to regulate learning in a better direction. Nevertheless, it is not easy for novice learners to actively put meta-thinking into practice. Moreover, it is also difficult for others to observe learners' metacognitive characteristics that control the performance and improvement of meta-thinking. There has been limited work on proposing Intelligent Tutoring System (ITS) which embeds and organizes teaching strategies based on expert instructors' actual experience. In this research, we propose a learning methodology which includes a mechanism to provide learners with presentation design tasks as meta-learning tasks and thereby diagnose learners' cognitive characteristics based on the results of their tasks execution.

Keywords: Intelligent tutoring system, presentation design tasks, meta-thinking skills

1. Introduction

In the context of adult education, the importance of shaking learners' beliefs about learning by using educational intervention as a stimulus to raise consciousness has been pointed out (Mezirow, 1997). Nilson (2013) claimed that "instruction which promotes metacognitive awareness" relating to "cognition, behavior, emotion" to enhance learning, encourages the internalization of the approach itself and contributes to improving learners' meta-thinking skills. Bransford (1999) stated that teaching to encourage internal aspects of learning should be done based on consideration of contexts of each learning subject. Meanwhile, the nature of employed metacognitive intervention strategies, especially when it comes to target learners' motivation and sense of values, varies according to teachers' experience in the practical education fields. Hence, due to their implicit nature, it has so far been difficult to accumulate and share knowledge about teaching methodologies of such learning.

In this study, we aim to propose a model of computer-assisted methodology for promoting meta-thinking skills affected by internal factors such as motivation and sense of values about learning. To approach this objective, we develop a semantically enhanced learning environment based on theoretical knowledge from fields of educational psychology and cognitive science.

2. Theoretical Backgrounds

2.1 Learning by Explanation as Meta-thinking Skills Training Task

It has been suggested that verbalization tasks of explaining learned contents, especially explanation about self-understanding (*self-explanation activities*), are effective as opportunities to induce metacognitive awareness in various learning domains (Chi et al., 1994), since self-explanation task requires metacognitive skills. Furthermore, learning outcomes depend on how well learners explain the acquired knowledge (Renkl, 1998). Roscoe and Chi (2007) divide learners' level of self-explanation

tasks into two types: *knowledge-telling* and *knowledge-building*. *Knowledge-telling* indicates verbalization that only states what learner themselves already know, while *knowledge-building* corresponds to verbalization which constructs new knowledge by the way of metacognition (i.e., metacognitive reflection and modification of existing knowledge). In self-explanation activities, learners often fail into *knowledge-telling* without appropriate instruction to stimulate their metacognition.

2.2 Self-explanation Tasks in Intelligent Tutoring System

Several studies implemented self-explanation tasks in a category of ITS, commonly known as teachable agents. For example, Biswas et al. (2016) proposed a learning support system called Betty's Brain. The learning scheme with Betty's Brain let learners teach their own knowledge about the target learning domain to the teachable agent (Betty). Since Betty only knows what is taught by the learner, learners gain the opportunity to notice their own lack of knowledge based on their interaction with Betty. Matsuda et al. (2013) proposed a teachable agent called SimStudent which targets elementary algebra. On the system, learners try to teach SimStudent how to find solution to algebra problems. Based on taught knowledge, SimStudent demonstrates the solution of problems, and generate incorrect answers if rules (i.e., calculation procedures) taught by learners are wrong or insufficient. Learners can become aware of their misunderstanding by observing such teachable agent's behaviors. Through these systems, learners try to explain what they understood about the domain in order to make agents acquire necessary knowledge in the target learning domain. These systems essentially aim to provide an opportunity for learners to reflect on their understanding and make necessary corrections on their own, through the usage of self-explanation tasks. In other words, these ITS are not intended to capture metacognitive aspects, such as what knowledge are consciously learned, and moreover, do not to provide adapted feedbacks to transform learners' learning behaviors. Thus, it is difficult for such systems to make learners with low meta-thinking skills perform knowledge-building through self-explanation, because they do not capture which particular learning strategies a given learner is using (i.e., learning context).

In this research, we intend to develop a learning methodology that encourages the occurrence of metacognitive awareness and acquisition of meta-thinking strategies by capturing learners' learning contexts and learning strategies based on their self-explanation activities.

3. Research Objectives and Contributions

The main objective of this study is to propose a methodology that captures learners' inner characteristics associated with the learning contexts and gives adapted feedbacks, in order to cultivate their meta-thinking skills. More concretely, we set the following research objectives:

1. Construct an intervention strategy model based on diagnosis of learners' metacognitive characteristics for cultivating their meta-thinking skills;
2. Develop an authoring system for enabling teachers to prepare rational teaching materials of meta-thinking skills development in various learning domains;
3. Build a strategy-aware learning environment based on the intervention strategy model and enhance it through evidence collected from continuous practice (i.e., evidence-based approach).

The proposed computer-assisted meta-thinking educational model will contribute to provide insights on how to model meta-thinking learning activities. In addition, this work has the potential to clarify the implicit knowledge encapsulated in teaching techniques exerted by experienced teachers.

4. Research Methodology

Figure 1 shows the overview of our research. The three objectives described in the previous section correspond to *Objectives 1* to *3* in the figure. In the following section, we provide an overview of our current work which consists in developing a learning environment as the basis of our proposed learning methodology. Then, we present future plans of this study in section 4.2.

4.1 Building a Learning Environment as a Foundation for Intervention Strategies Model

We are currently developing a learning environment on which will be implemented the intervention strategies model dedicated to foster learners' metacognitive awareness.

In this research, we focus on presentation design activities aiming to make others understand the target learning domain contents and learning methods, as a self-explanation task to activate introspection of learners' own learning. In general, activities dealing with the preparation of a presentation, as well as thinking about what one should explain to the learning partner are not regarded as metacognitive tasks, but rather as problem-solving tasks that build comprehension of the partner's understanding. Thus, it can be regarded as an appropriate opportunity for raising consciousness of meta-thinking. In order to raise learners' consciousness on their own learning methods, we adopt the slide selection presentation design scheme named PDT (Presentation Design Tasks) proposed by Seta et al. (2015). In this learning scheme, learners do not create the presentation slides from scratch, but they rather try to design their presentation by selecting the slides they think appropriate from prepared ones, and making a pyramidal structure which represents intentions (hierarchical learning goal structure) behind their presentation.

Figure 2 represents the conceptual image of the meta-thinking skills development processes through PDT. The learning goals (*LGs* in Fig.2) of the presentation, such as "*make others understand why design patterns are proposed in the software engineering field*," are systemized in advance based on the ontological engineering approach. Learners gradually design teaching strategies reflecting their learning strategies in the form of intentions of their presentation using LGs in a hierarchical manner (i.e., from general to specific goals). This task setting is intended to give learners the opportunity to reflect on what they think is important to be understood about the learning domain.

In addition to giving LGs for learners to represent their intentions (learning strategies) behind the presentation, we also set machine understandable semantics about the learning domain knowledge for associating each LG with slides. Based on these semantics, the system understands what kind of explicit/implicit knowledge is included in each slide. Thus, the system is able to capture learners' understanding state and what kinds of knowledge they intend to explain through the selected slides, even if the knowledge is implicit and not explicitly written in the slides. The resulting learning environment aims to promote learners' consciousness about meta-thinking by diagnosing their metacognitive characteristics based on these semantics, and to trigger their cognitive discomfort according to their understanding state and metacognitive characteristics.

4.2 Repetition of Model Revision and Practice of Ontology-based Teaching Strategies Model

When instructors prepare teaching materials for the proposed PDT, they not only need to define the structure of LGs, but also to annotate the knowledge structure in each slide. To reduce their workload during the preparation of materials, and to support the creation of rational meta-thinking teaching

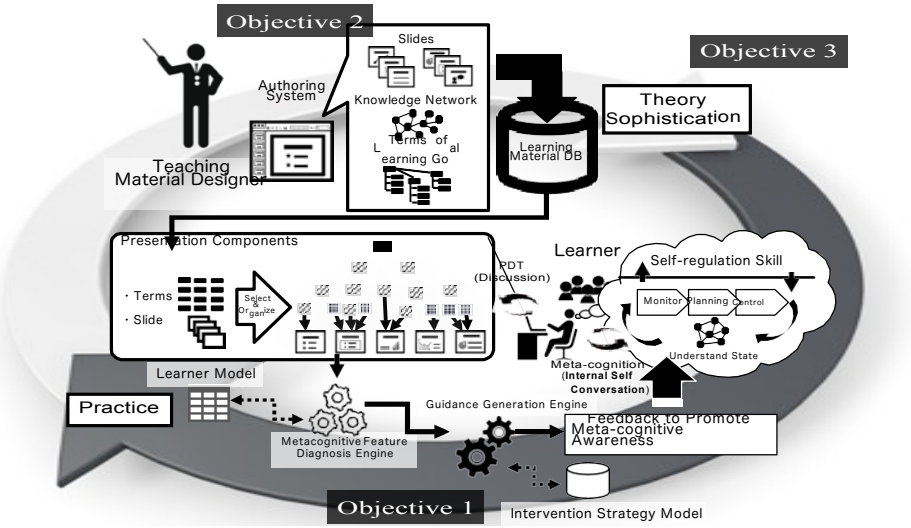

Figure 1. Overview of this research.

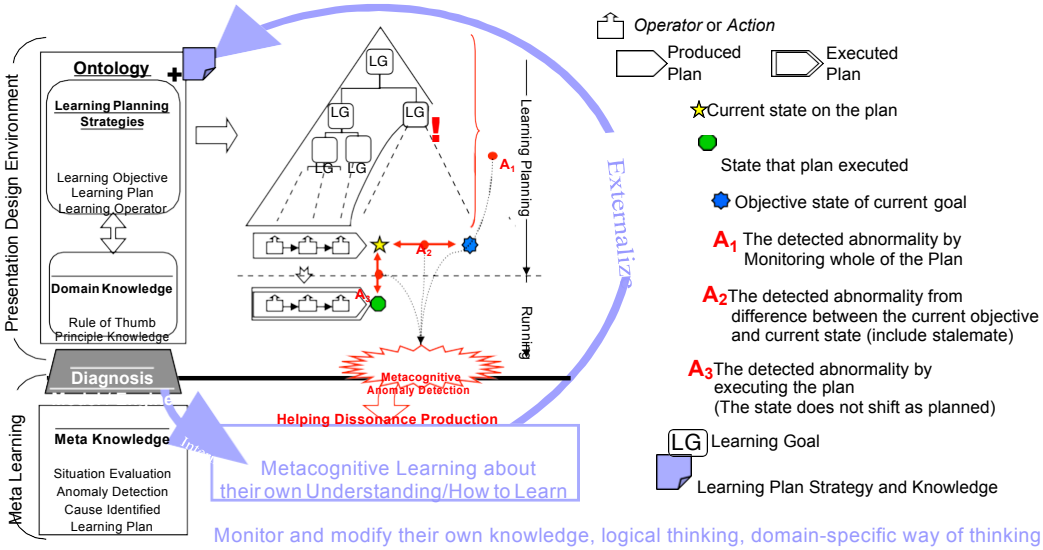

Figure 2. Overview of Presentation Design Tasks.

materials, we plan to develop a learning-strategy-aware authoring system (*Objective 2*).

In the literature, multiple theories and concepts mentioning several aspects of learning strategies have been proposed, but do not explicitly model how such strategies are interactively related. This includes, for example, the goal orientation theory (Dweck & Carol, 1986; Elliot & McGregor, 2001) that captures strategies sustaining the orientation of the objective setting, the performance of cognitive activities, the belief about learning, etc. Thus, we plan to sophisticate our meta-thinking skills educational model through repetitive modeling of the relationship among these concepts, learning knowledge and teaching strategies using an ontology-based approach coupled with practice in authentic higher education settings *(Objective 3)*. Such approach will help us gradually develop and accumulate the base knowledge through mid-long term practical operation of the system. This will finally lead us to the building of a computer-assisted meta-thinking educational model.

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