What is Metacognitive Skill?

Collaborative Learning Strategy to Facilitate Development of Metacognitive Skill

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Abstract: Recently, how to support development of a learner's metacognitive skill is one of the most important topics in the research area of educational support systems. However, it is difficult for the researchers in the area to share research findings and reuse them each other, because there is a lack of common vocabulary to represent metacognitive phenomena and shared understandings of them. It causes some confusion in the studies about metacognition and metacognitive skill. In this paper, we provide a common platform towards constructing common vocabulary and shared understandings of them. Then, we introduce our model of metacognitive skill and describe difficulties in learning and executing the skill. Based on our model, we also propose a learning support environment where learners develop their metacognitive skills through collaborative learning.

Introduction

The term metacognition has been used mainly in psychological area since the publication of Flavell's paper (1976). Many researchers have been believed that metacognition is associated with intelligence (e.g., Borkowski, et al. 1987; Sternberg, 1984, 1986a, 1986b) and they refer metacognition to higher order thinking which involves active control over the cognitive processes engaged in learning (Livingston, 1997). So, recently, to support development of learners' metacognitive skills is one of the most important topics in the research area of educational support systems. The purpose of our study is to support processes in which learners develop their metacognitive skills.

Metacognition is often simply defined as "thinking about thinking" (Livingston, 1997), or "cognition of cognition" (Flavell, 1976). However, defining metacognition is not simple. Although the term has been part of the vocabulary of educational psychology for the last couple of decades, there is still much debate over what metacognition exactly means. One reason for this confusion is the fact that there are several terms currently used to describe the same basic phenomenon (e.g., self-regulation, executive control), or an aspect of that phenomenon (e.g., meta-memory), and these terms are often used interchangeably in the literature (Brown 1987, Carver & Scheier 1998, Davidson, et al. 1994, Flavell 1976, Hacker 1998, King 1999, Kluwe 1982, Livingston 1997, Lories, et al. 1998, Nelson & Narens 1994, Winne & Hadwin 1998, Yzerbyt, et al. 1998). Another reason is the confusion that is thrown by two approaches to metacognition. Some researchers consider metacognitive skill as somewhat special cognitive activity and trying to clarify its mechanism (Rivers 2001; Schraw 1998; Kluwe 1982; Nelson & Narens 1994). Other researchers suppose that metacognitive skill is similar process with cognitive skill (Livingston 1997; Lories, et al. 1998). While there are some distinctions between definitions (Van Zile-Tamsen, 1994, 1996), all emphasize the role of executive processes in the overseeing and regulation of cognitive processes.

To advance the study of metacognitive skill and of the methods how to develop the metacognitive skill, we should construct common vocabulary to represent cognitive and metacognitive phenomena (Mizoguchi & Bourdeau 2000). The common vocabulary of metacognitive skill makes us to share mutually understandings, store the result of our studies, and reuse and reconstruct the results of the studies.

In this paper, first, we clarify the target of our educational support system through defining some concepts related to metacognition. Although our definition may be rough and insufficient, we believe it will be useful to share the concepts. Next, we propose our model of metacognitive skill and consider difficulties in mastering the skill. Finally, we propose a collaborative learning strategy as an appropriate method to facilitate development of learners' metacognitive skill.

What Is "Metacognitive Skill" ?

Livingston (1997) describes that metacognition is one of the latest buzz words in educational psychology, but what exactly is metacognition? Flavell's simple definition has already been not adequate to consider how to support

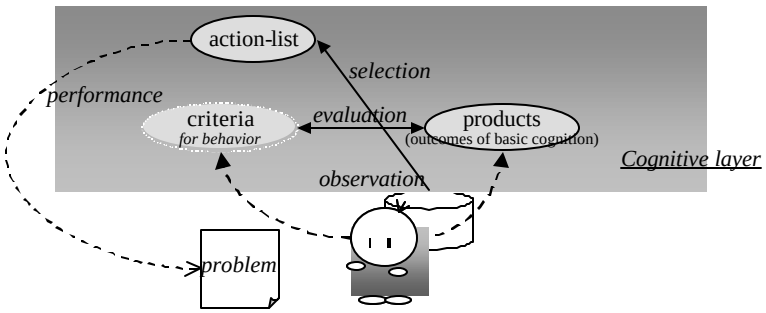

Figure 1: The Basic Cognition and Cognitive Activity

it. There are many "metacognitive skills" as targets of educational support systems. For example, the Reflection Assistant helps learners reflect on their cognitive activities during problem solving (Gama 2001). The system leads learners to three phases; understanding of goals and the problem; recalling and organizing previous knowledge;and thinking about strategies to solve the problem. She calls the learner's activity in her system metacognitive skill. As another example, ASK to THINK – TEL WHY controls peer tutoring in the small group with a template for questions, such as review questions, thinking questions, and monitoring questions (King, 1999). The educational target of the method is to help learners comprehend contents of the text, what they already understood, and what did not yet. She describes that she intends to develop learners' metacognitive skill. The purpose of all of these studies is the same: to support development of learners' metacognitive skills; but they seem to be little consensus on what they mean by metacognitive skill. Gama uses the term "metacognitive skill" to denote retrieval and application of a schema of a similarity problem; King says that a template for questions guides learners to be aware of their own cognitive process. The difference implies that we cannot reuse a method or a system to support metacognitive skill simply.

Here, we want to provide a common platform where researchers can more easily understand the difference or commonality among what all concepts related to metacognition and metacognitive skill. First, we investigate "cognition". The term "Cognition" is cognitive activities to change the current working memory (WM) situation. Cognition is classified into three types. "Cognition (1)" requires us to form actions to achieve the goals that we have such as problem solving, reasoning and judgment. "Cognition (2)" does not require us to form actions but to produce the mental representations of outside world in WM through perception. "Cognition (3)" uses a pre-compiled action such as computing. We call "cognition (1) and (3)" cognitive activity, and "cognition (2)" basic cognition. "Cognition (3)" is a special type of "cognition (1)." Figure 1 shows the basic cognition and cognitive activity. In the figure, products show the mental representations that are the outcomes of the basic cognition. Then, we perform some mental activities based on the outcomes of the basic cognition. The activity is called cognitive activity; such as reasoning, judgment, and evaluation.

Next, we consider metacognition and metacognitive activity. According to Flavell (1976), metacognition is cognition of cognition. As we described above, the term "cognition" has two aspects: basic cognition and cognitive activity. So, the metacognition is also divided into two: basic cognition of basic cognition, and basic cognition of cognitive activity. By basic cognition of basic cognition, we mean to produce mental representation at the metacognitive layer from the products at the cognitive layer. So, the target of basic cognition is states at the cognitive layer. On the other hand, by basic cognition of cognitive activity, we mean to produce mental

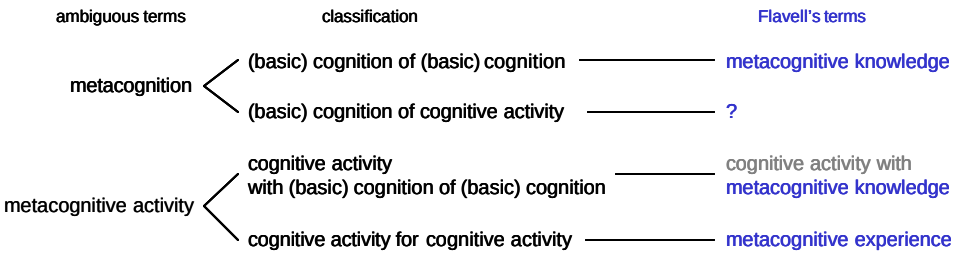

Figure 2: Metacognition and Metacognitive Activity

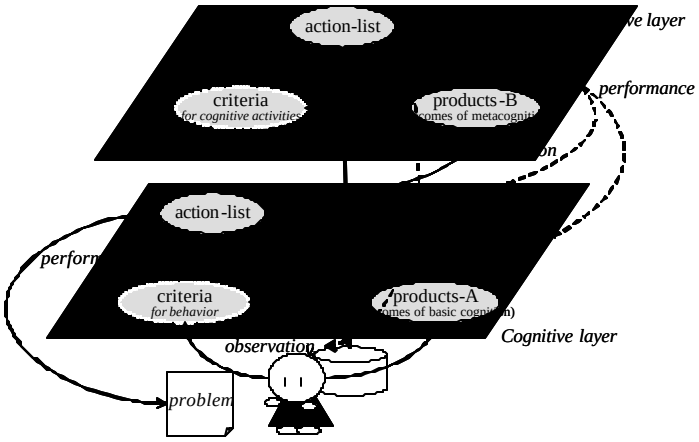

Figure 3: Problem-solving Process with Metacognitive Activity

representation at the metacognitive layer from the activities at the cognitive layer. It is relatively difficult to observe because an activity changes a state to another state. The term "metacognitive activity" has also two aspects: cognitive activity with "basic cognition of basic cognition" and cognitive activity for cognitive activity. Cognitive activity with "basic cognition of basic cognition" means cognitive activity at cognitive layer, which forms actions using a schema knowledge that resembles the products at the metacognitive layer. Cognitive activity for cognitive activity means cognitive activity at metacognitive layer, which forms actions in the metacognitive layer for regulating cognitive activity at cognitive layer. To simplify the discussion, we show the relations in Figure 2. Using the term by Flavell (1976), basic cognition of basic cognition is called "metacognitive knowledge", Cognitive activity with "basic cognition of basic cognition" is called "cognitive activity with metacognitive knowledge", and cognitive activity for cognitive activity is called "metacognitive experiences". According to the categorization, we can interpret the differences among the methods and systems that help learners develop metacognitive skill; Reflection Assistant (Gama, 2001) supports to develop the cognitive activity with metacognitive knowledge, and ASK to THINK – TEL WHY (King, 1999) supports to facilitate to get the metacognitive knowledge.

In this paper, we call "cognitive activity for cognitive activity" "metacognitive activity", because the activity is cognitive activity of cognitive activity, the activity is a part of "metacognitive skill", and it seems to be the most appropriate for the definition of "meta". We are aiming at supporting learners to develop their metacognitive skills which include metacognitive activities.

A Model of Metacognitive Skill And the Difficulties in Mastering It

Here, we consider basic problem-solving process. As Figure 1 shows, when a learner solves a problem, first, he/she observes the problem and captures what the problem is as *products-A* in his/her working memory. The learner may also create *criteria* about the problem in his/her working memory. He/she predicts what the outcome of problem solving will be. It will be the *criteria*. The learner compares the *products-A* with the *criteria*; so that he/she decides whether the outcome of the progress is "good" or "not good" and selects an appropriate action from his/her knowledge base and makes an *action-list*. The learner applies actions in the *action-list* to the problem. These activities: observation, evaluation, selection, and application are basic cognition and cognitive activities at the cognitive layer. [1] We emphasize that the goal of these cognitive activities at the cognitive layer is to solve a problem. The *criteria* at the cognitive layer mean the goal of the problem-solving process. If the learner decides that the process is "not good" on the way to solve a problem, he/she may predict not to be able to derive the correct solution from the current outcome.

Next, we consider problem-solving process with metacognitive activity. As Figure 3 shows, the problem-solving process with metacognitive activity uses two layers, while the basic problem-solving process uses one layer only (Kayashima & Inaba 2003d). The learner will observe the products at the cognitive layer to construct the *products-B* by which we mean basic cognition of basic cognition: one of the outcomes of metacognition. The metacognitive

[1] Strictly speaking, the observation and the application are the activities to link the cognitive layer to the outside world.

activity includes evaluating, and regulating the cognitive activity at the cognitive layer. To perform the metacognitive activity, it is necessary to retrace how products were evaluated and what action was selected at the cognitive layer from what was observed. It is also necessary to encode all of them to the metacognitive layer as *products-B*. He/she compares the *products-B* with the *criteria* at the metacognitive layer, and he/she decides if the solving process or the outcome of the progress is "good" or "not good". The result of the evaluation leads the learner to select an appropriate action from his/her knowledge base, and makes an *action-list*. He/she performs actions in the *action-list*, then, the action will influence the basic cognition and the cognitive activities. As the results, *products-A*, *criteria*, and the *action-list* at the cognitive layer will be reformed into better ones, and then the problem-solving process will be improved. The goal of metacognitive activities is not to solve a problem directly, but to improve the basic cognition and the cognitive activities at the cognitive layer in order to solve a problem.

Many researchers say that the metacognitive skill is difficult to learn and also to execute. Of course, the difficulties include not only the common difficulties for skill learning but also distinctive difficulties specific to metacognitive skill. We have been clarifying the difficulties based on our hierarchical model of skills; skill, cognitive skill, metacognitive skill and self-regulation skill (Kayashima & Inaba 2003a). We divided the difficulties into two categories: difficulties in learning the skill and difficulties in executing the skill (Kayashima & Inaba 2003d). Table 1 shows the difficulties in learning and executing skills.

One of the common problems to learn a skill is the difficulty in explaining how to use a skill explicitly even for a person who has already mastered the skill. So, a learner who wants to master the skill has to use, adjust, and coordinate each action that composes the skill. Cognitive skill is basic cognitions and cognitive activities. There is an additional difficulty. Both input of the cognitive skill, such as a given problem; and output, such as problem-solving behavior, are visible for other persons, but the process a person uses the skill, such as observation, evaluation, and selection, is usually covert and invisible. There are some distinctive problems for learning the metacognitive skill. Metacognitive skill is basic cognitions at the metacognitive layer and metacognitive activities. The targets of observation and performance at the metacognitive layer are in the person's mind, and evaluation and selection are also performed in his/her mind. So, the learner cannot observe the process to use metacognitive skill nor what changes occurred as a result of it. Due to them, it becomes more difficult for the learner to imitate the skill. There is also an additional difficulty. We rarely have the opportunity to practice the metacognitive skill in our usual experiences in schooling. On the other hand, there are three difficulties in executing the metacognitive skill. The first problem is the capacity of the working memory. Performing metacognitive skill needs more resources compared with cognitive skill: two layers in a learner's working memory; cognitive layer and metacognitive layer. The second problem is multi-processing in mind. A learner has only one processing unit in his/her mind, but both of the processes at the cognitive layer and at metacognitive layer have to be executed. Finally, it is difficult for learners to be aware when they should use the metacognitive skill, because the learners sometimes can solve problems even if they do not use the skill. The additional problem is the difficulty in observing and evaluating their own cognitive activities objectively (Kayashima & Inaba 2003c; 2003d).

Collaborative Learning: an Appropriate Strategy for Developing Metacognitive Skill

We propose our learning environment to help learners master metacognitive skill. The learning environment provides learners with opportunities to master the metacognitive skill through three phases: At the first phase, a learner learns regulation of others by observational learning. At the second phase, the learner learns metacognitive skill using it as regulation of others. Finally, the learner tries to use the metacognitive skill with computer system's support. Here, we introduce the second and third phases of the learning environment.

Both cognitive skill and metacognitive skill consist of the same activities; observation, evaluation, selection and

Table 1: Difficulties in Learning and Executing Skills

	Difficulties in learning the skill	Difficulties in executing the skill
Skill	*L-a*: No one can convey how to use the skill explicitly in words. *L-b*: Need to adjust and coordinate actions which compose the skill.	
Cognitive skill	*L-c*: The process using the skill is invisible.	
Metacognitive skill	*L-d*, *L-e*: The input and output for the skill are invisible. It is unclear when a person uses the skill, what its trigger is, and what its result is. *L-f*: It is rare to have an experience to monitor and regulate someone in regular schooling.	*E-a*: Capacity of the working memory *E-b*: Multi-processing in mind *E-c*: To be aware when they should use it *E-d*: Objective monitoring and evaluating of their own cognitive activity

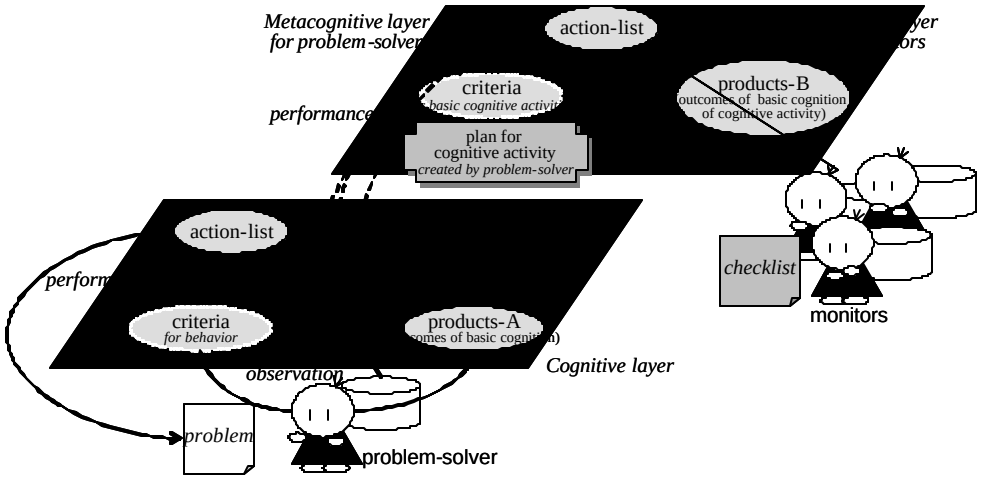

Figure 4: Collaborative Learning Strategy for Developing Metacognitive Skill

application. But, the criteria and the products are different depending on its layer: the cognitive layer or metacognitive layer. It is difficult to create and keep these two products and criteria in his /her mind. The criteria at the metacognitive layer are important to decide metacognitive activities. So, to build a learning environment in which a learner masters metacognitive skill, it is necessary to support the creation of the criteria, to make the processing-target of the metacognitive skill visible, and to help the learner control his/her cognitive activities in accordance with the criteria. Although, little is yet known about the criteria a person uses to evaluate his/her own cognitive activities (Kluwe 1987), we assume that the criteria at the metacognitive layer include a plan for cognitive activities. In Figure 4, comparing the products-B with the criteria, we can assess how well the cognitive activities are working. So, we support a learner by showing the plan of cognitive activity. We provide a plan externalization tool for a problem-solver. This tool directs the problem-solver to plan his/her problem-solving process as a sequence or a structure of his/her cognitive activities. This externalization releases the problem-solver from keeping his/her plan in his/her mind, reduces the difficulty in capacity of his/her working memory, and then, allows him/her to concentrate on observing his/her own problem solving process objectively.

To help a learner control his/her cognitive activities, we adopt a collaborative learning, where a learner plays the role of problem-solver and the other learners play the role of monitor. The monitors can observe the problem-solver's behavior which is the output of the problem-solver's cognitive activity. The monitors also can observe the problem which is the input for the problem-solver's basic cognition, then create their own products and criteria. Although the products at the metacognitive layer of the problem-solver are not visible for the monitors, due to the externalization tool, they can share a part of the criteria at the metacognitive layer with the problem-solver. The monitors have a checklist which has a template of some questions. We adopt the questions that Shoenfeld proposed (Shoenfeld 1987), and it includes the questions like "what are you doing?" and "why are you doing it?". The monitors need to talk each other about which question should be selected in the checklist. This discussion leads monitors to observe carefully the problem-solver's behavior and to decide how to regulate it. The discussion refines observation, evaluation and selection in monitoring of others and regulation of others. Monitoring of others and regulation of others have similar functions with metacognitive skill. Repeating this is a practice of monitoring and regulation at cognitive level. These questions are intended to trigger off the metacognitive skill of the problem-solver. Repeating monitors' questions causes the problem solver to be conscious of his/her cognitive activities.

This learning environment is like one inspired by socio-cultural theory (Vygotsky, 1930). First, the problem-solver is not aware of what he/she is doing, what is reasonable for his/her goal and where he/she is in his/her plans during problem solving process. Next, he/she realizes a function, which includes monitoring their cognitive activity, and checking them with his/her goal, with the monitors' support. Then, the problem-solver is getting to consider the answers for the questions even if the monitors do not ask him/her. These look like the processes of internalization that Vygotsky said:

> *Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). (p.57)*

Conclusion

In many studies about metacognition and metacognitive skill, by the same term, people mean different phenomena, also, by different terms the same phenomenon from time to time. We pointed out the lack of common vocabulary and the confusion, and provided a common platform towards constructing common vocabulary and shared understandings about metacognition. After that, we introduced our model of metacognitive skill and difficulties in learning and executing the skill. Finally, we proposed a learning support environment where learners develop their metacognitive skills. As the next step, we should verify whether our learning support environment is effective or not for development of metacognitive skill. How to verify it is well known difficult problem. Moreover we will continue to construct common vocabulary to represent the metacognitive phenomena and clarify models of supporting methods for development of the skill to facilitate shared understandings and reuse research findings.

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