Towards Helping Learners Master Self-Regulation Skills

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Abstract. There are several terms used to describe the same phenomenon, and the same term is used to describe different phenomena. It confuses us and makes metacognition miracle. What is meta- cognition? We have been tackling the problem by defining our own criteria for determining what metacognition is or what cognition is. Through a survey of related works, we try to define the criteria and classify skills and difficulties for mastering the skills based on the criteria. It shows us there are various concepts called by the same term "metacognition", and we recognize lack of common vocabulary and system of concepts to represent cognitive and/or metacognitive phenomena. So, our research objectives include constructing common vocabulary to represent cognitive and/or metacognitive phenomena, and providing clear criteria to distinguish terms in the vocabulary. In this paper, we propose a hierarchical model of skills and classify difficulties to master them. Then, we introduce a learning environment to facilitate learners' development of self-regulation skill.

Introduction

Self-Regulation skill is one of metacognitive skills, and allows a learner to think about his/her own thinking process, and to control his/her own thinking process for achieving his/her goal by him/herself [2]. It is a skill which is independent of subject-domains [5], that is, once a learner masters the skill, he/she can apply it across domains and even in domains where he/she has little prior background knowledge. So, the skill is important for improving a learner's competence. Some learners develop the skill by themselves; but some learners do not. The former are intelligent novices who can plan how to solve a problem, apply their knowledge to authentic tasks, and monitor and regulate their problem solving process [3]; the latter may have difficulty in learning, especially it is difficult for them to apply their knowledge to authentic tasks, and to monitor and regulate their thinking process. So, it is necessary to help a learner develop his/her self-regulation skill to allow him/her to become an intelligent novice. However, many researchers had paid much attention to how to support acquisition of domain knowledge, but little to improve learners' self-regulation skills.

Recently, several computer-based learning environments and the methods are described in the literatures, whose titles have terms like; 'metacognition', 'self-regulation skill', 'executive control' or 'reflection'. There are several terms used to describe the same phenomenon (e.g., self-regulation, executive control) [11], and the same term is used to describe different phenomena (e.g., metacognition). It confuses us [2, 10, 11, 12] and makes metacognition miracle. What is metacognition? We have been tackling the problem by defining our own criteria for determining what metacognition is or what cognition is [7, 8]. Through a survey of related works, we try to define the criteria and classify skills and difficulties for mastering the skills based on the criteria. It shows us there are various concepts called by the same term

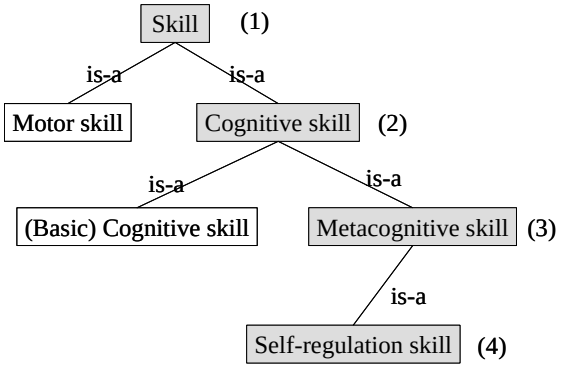


Figure 1. Hierarchy of skills

"metacognition", and we recognize lack of common vocabulary and system of concepts to represent cognitive and/or metacognitive phenomena. So, our research objectives include constructing common vocabulary to represent cognitive and/or metacognitive phenomena, and providing clear criteria to distinguish terms in the vocabulary. In this paper, we propose a hierarchical model of skills and classify difficulties to master them. Then, we introduce a learning environment to facilitate learners' development of self-regulation skills.

This paper is organized as follows; first, we describe our own criterion to distinguish metacognitive skill from cognitive skill and why it is difficult to master metacognitive skill. Then we survey existing learning support systems and methods of helping a learner develop his/her metacognitive skill, and describe which difficulties the systems and methods reduce. Finally, we describe what difficulties still remain in supporting learners' mastering of metacognitive skill and then propose a learning environment to help learners' master the skill with computers.

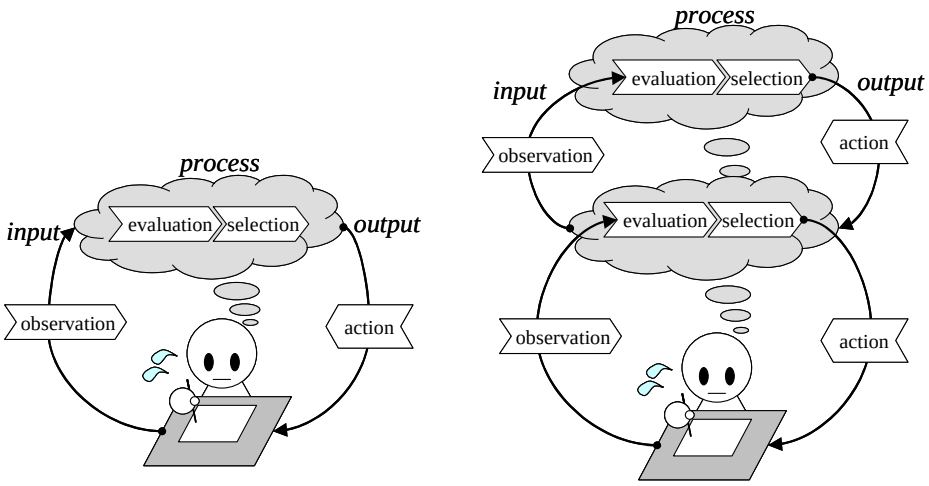
1. The Difficulties in Mastering Self-Regulation Skill

1.1. Hierarchical Model of Skills and Difficulties in Mastering Them

There are many skills, for example, driving skill for a car, teaching skill, speaking skill, calculating skill, reasoning skill, and so on. Every skill encounters its own difficulty in being mastered. We consider a hierarchical model of the skills: Skill, Cognitive skill, Metacognitive skill, and Self-regulation skill. The hierarchy is organized the skills into different levels of its own difficulties in mastering it. We illustrate the hierarchy of the skills in Figure 1. The links in the figure shows 'is-a' relation. The Cognitive skill (2) is one of Skills (1). The Metacognitive skill (3) is one of Cognitive skills, and the Self-regulation skill (4) is one of Metacognitive skills. Some properties of subclass inherit from the properties of super class.

As you know, mastering a skill is difficult as compared with acquisition of specific (declarative) knowledge. It is difficult to explain 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 which composes the skill after he/she gets outline knowledge about how to use the skill. This difficulty is inherited all types of skills.

Motor skill is a perceptual-motor skill such as driving a car, throwing, playing musical instruments and so on. It is possible for a learner who wants to master the skill to observe initial state (input), the process how a person applies the skill, and output of the skill



(a) Basic Cognitive skill (b) Metacognitive skill

Figure 2. Basic Cognitive skill and Metacognitive skill

(outcome).

Cognitive skill is a skill performing in the mind. It can be called as an ability to solve problems in intellectual tasks such as calculating, reasoning, problem solving, and so on. The process by how a person uses the skill is usually covert and invisible. Thus, there is an additional difficulty in mastering the Cognitive skill as compared with mastering Motor skill: the person who wants to master the skill cannot observe how to use it, thus, it is difficult to imitate how to use the skill.

As Figure 1 shows, Basic Cognitive skill and Metacognitive skill are subclasses of the Cognitive skill[1]. What is the criterion to distinguish the Metacognitive skill from the Basic Cognitive skill? There are several criteria in the literature: Nelson and Narens feature their metacognitive system as splitting cognitive process into two interrelated levels that they call the "meta-level" and the "object-level."[14] But, they don't suppose that there must be different physical structures for "object-level" cognition and for "meta-level" cognition [13]. On the other hand, Lories et al. consider metacognition 'as the processing of the contents of (working) memory by standard cognitive processes [12].' Also, cognitive skill is used to help an individual achieve a particular goal while metacognitive skill is used to ensure that the goal has been reached [10]. The difference between cognitive skill and metacognitive skill is that latter is not actually involved in solving the problem [9]. The above-mentioned criteria suggest us to consider simple criterion for the Basic Cognitive skill or the Metacognitive skill as what its controlling-target is. The target of the Basic Cognitive skill is in the outside world of the person (Figure 2-a), while the target of the Metacognitive skill is in the inner world of the person who uses the skill (Figure 2-b). As figure 2 shows, the Metacognitive skill is defined as a double loop model in mind while the Basic Cognitive skill is defined as a single loop model in mind.

The Basic Cognitive skill is likely to be confused with the Metacognitive skill. One of the major causes of the confusion is the Basic Cognitive skill represents different types of "meta" while Metacognition represents cognition of cognition. For example, we classify cognition in specific domain at meta-level into Basic Cognition. A learner often encodes a given problem

[1] Usually, we call both of the "Basic Cognitive skill" at the layer 3 in Figure 1 and the "Cognitive skill" at the layer 2 in Figure 1 as the same term "cognitive skill", and it confuses us. So, we introduce a new term "Basic Cognitive skill to distinguish each layer.

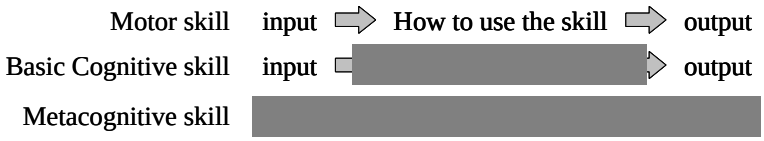


Figure 3. Possibility of observation of each skill

into more abstract problem and forms a representation of the problem. The representation omits some contextual information from the given problem, and is useful to search procedures and knowledge which can be used to solve the problem. This abstract representation implies cognition at meta-level in specific domain. This type of cognition is at meta-level, but it is not cognition of cognition. So, the skill, which is used by this type of cognition, is classified into the Basic Cognitive skill. Complex reasoning is also classified into the Basic Cognitive skill. A person, given a difficult problem, read the problem, and was kept at all possibilities to decide to do something. This type of cognition is reasoning to achieve a goal, but it is not cognition of cognition. So, the skill is also classified into the Basic Cognitive skill. In other words, an individual achieves a particular goal using the Basic Cognitive skill. Although both the input and the output of the Basic Cognitive skill are visible for other persons, the process how a person uses the skill is usually covert and invisible (Figure 3). Thus, the person who wants to master the skill cannot observe how to use it. Thus, it is difficult for a learner to imitate how to use the Basic Cognitive skill.

The Metacognitive skill makes a learner manage his/her thinking process. This management includes (a) making sure that the learner understands what a problem is about before he/she hastily attempts a solution; (b) planning (how to solve the problem); (c) monitoring, or keeping track of how well things are going during his/her solving process; and (d) allocating (mental) resources, or deciding what to do [16]. Both (c) and (d) are identified as the Metacognitive activities. The Metacognitive skill includes operating specific mental processes (Figure 2-b). Thus mastering the Metacognitive skill has the following several additional but essential difficulties: (i) input to the Metacognitive skill, its output, and the process to use the skill are usually covert and invisible (Figure 3), (ii) a learner has difficulty in observing his/her own cognitive activity objectively (Figure 2-b), (iii) since control-target of the Metacognitive skill is cognitive activity during solving a problem, the Metacognitive skill requires a track of cognitive activities as input information. The skill encounters its own difficulties: allocating mental resources. A learner has to allocate his/her mental resources to both cognitive activity, and metacognitive activity which includes monitoring his/her own cognitive activity. Moreover, (iv) it is difficult for a learner to be aware when he/she should use the Metacognitive skill and (v) to understand how important the skill is. A learner can sometimes solve problems even if the learner does not use the Metacognitive skill. For example, during exercising simple numerical calculations, a learner can solve them only using domain knowledge and the Basic Cognitive skills. Thus, it is difficult for a learner to understand how important it is to manage his/her own thinking process, and to be aware when he/she should do it.

Self-regulation skill is one of the Metacognitive skills and there is additional difficulty in mastering the self-regulation skill besides general Metacognitive skills. The task of the self-regulation skill is regulation including monitoring a person's thinking process, recognizing where he/she is in his/her plans, evaluating it with his/her goals, and adjusting his/her cognitive activity. The regulation task requires some specific knowledge and rules to evaluate and adjust a person's cognitive activity, however, we rarely have the opportunity to acquire the knowledge and rules in our usual experiences in schooling. So, it is one reason that makes

mastering the Self-regulation skill difficult.

1.2. What Difficulties Do Existing Methods Reduce for Facilitating Development of the Self-regulation Skill?

There are several methods for facilitating development of the Metacognitive skills and the Self-regulation skill: Reciprocal Teaching [15]; ASK to THINK - TEL WHY [9]; a "KITCHEN SINK" approach [16] and so on. Here, we describe what difficulties these methods reduce based on the hierarchical model of difficulties in mastering skills we described in the previous section.

1.2.1. Providing just triggers to be aware self-regulation: two methods in the KITCHEN SINK approach

There are four methods in the KITCHEN SINK approach, and each method is independent [16]. Here we take up the two methods in the KITCHEN SINK approach: "using videotape" and "teachers as role model for metacognitive behavior". The method "using videotape" is to show learners a videotape recording another learner's solving process of a working problem [16]. The videotape shows that some learners waste their time on a wild goose chase at solving a problem. The learners who watch this videotape (i.e., observers) are asked to discuss the learner's problem solving activities with their peers. In the KITCHEN SINK approach, there is also another method "teacher plays a model of metacognitive activity". The teacher solves a problem at the blackboard as though he is solving it from scratch, and going blow-by-blow through the solution process. Shoenfeld said that these two methods provide learners opportunities to learn the Metacognitive skill by observational learning. The former method provides a learner with an opportunity to observe another learner's problem solving activities in which he/she uses only his/her Basic Cognitive skill. The latter method provides learners with an opportunity to observe an expert's problem solving activities in which the expert's uses not only the Basic Cognitive skill but also the Self-regulation skill. In the method of making learners to observe another learner's problem solving activities, the observers (i.e., learners) monitor the learner's problem solving activities on the video and discuss it. Some observers, who may be aware that the activities are not good, say that they should check their activities with their goal. In the method, in which a teacher plays a model of metacognitive activity, some observers, who may recognize differences between the teacher's problem solving process and their own, are aware of the necessity of self-regulation. And then, they may try to imitate the teacher's problem solving activity. So, Shoenfeld hopes that the observations trigger off the observers' awareness of necessity to regulate their own thinking processes.

In observational learning, what should be learned is required to be visible [1]. Although observational learning is effective for learning the Motor skill, it seems to be difficult to apply the method for learning either of the Basic Cognitive skill and the Self-regulation skill, because the processes of applying these skills are usually invisible. So, these methods provide trigger to be aware of the Self-regulation skill itself for learners, however, the methods reduce no difficulties to develop learners' self-regulation skill: the learners still cannot observe input, process, and output of the Self-regulation skill; and the methods provide no supports for learners' resource allocation, objective observing, and when and how the learners should use the skill.

1.2.2. Learning the Self-regulation Skill in the Basic Cognitive Level: Others-regulation Skill

There are three methods which reduce two difficulties in mastering the Self-regulation skill; making input and output of the Self-regulation skill visible. There are Whole-Class Discussions of Problems with Teacher Serving as "Control", Reciprocal Teaching, and ASK to THINK - TEL WHY.

(1) Learning others-regulation skill with Observational Learning

The method Whole-Class Discussions of Problems with Teacher Serving as "Control" is also proposed in the KITCHEN SINK approach. When learners discuss a problem, a teacher takes a role of moderator for learners' decision making. The teacher does not guide the learners to correct solutions. Rather, the task of teacher is to help the learners make the most of what they themselves generate and to help them reflect on how they do it.

In this learning environment, the teacher provides a function to regulate learners' thinking processes: the teacher monitors the learners' discussion process as input to regulate, and gives advice to the learners to regulate their thinking process. The skill that the teacher uses is called "others-regulation skill". The others-regulation skill is one of the Basic Cognitive skills, because its controlling-target is in outside world of him; however, when and how the teacher uses the skill is very similar to some of the Self-regulation skills, because the task accomplished by the others-regulation skill is the same with the task accomplished by the Self-regulation skill: both of them regulate someone's thinking process. Therefore, the learners can observe input and output of the teacher's others-regulation skill, and learn others-regulation skill by observational learning. So, we can say the method reduces the difficulties in mastering the Self-regulation skill: making input and output of the skill visible. But the process to use the skill is still invisible, and the common difficulties that the Metacognitive skill has in itself are not reduced.

(2) Learning others-regulation skill with a teacher's scaffolding: cognitive apprenticeship

Reciprocal Teaching [15] provides guided practice in the use of four strategies designed to promote understanding text. The learner who is a discussion-leader and teacher lead discussion in small group on shared text. Reciprocal Teaching is a cooperative learning: learners in the small group take turns in playing as the discussion-leader. The teacher plays an important role to support the discussion-leader as scaffolding.

In this learning environment, the method induces learners to use the others-regulation skill by playing the role as discussion-leader. Similar to the method mentioned in (1), first, the learner who plays the discussion-leader can observe the teacher's others-regulation. Then, the learner tries to practice others-regulation skill with the help of the teacher.

This method likes Cognitive Apprenticeship [4], and reduces some difficulties in mastering the Self-regulation skill: making input and output of the skill visible, and providing a teacher's support to learn the process to use the skill. But the common difficulties that the Metacognitive skill has in itself are still not reduced.

(3) Learning others-regulation skill with a template of questions

ASK to THINK - TEL WHY [9] controls peer tutoring in the small group with a template for questions, such as review question, thinking question, and monitoring question. The learner, who plays as a peer tutor, helps other learners comprehend text. In the method ASK to THINK - TEL WHY, a tutor asks only five types of questions, and tutees only answer and they do not ask questions to the tutor. ASK to THINK - TEL WHY is also cooperative learning, and the learners take turns in playing the role tutor.

In this learning environment, the input of the other-regulation skill becomes to be visible

by externalizing tutees' thinking process and cognitive activities through their answers. The output becomes to be visible by the tutor's regulation through asking questions. Similar to the method mentioned in (2), the learner who plays the tutor tries to practice the other-regulation skill with some supports providing as the template of questions. This method reduces some difficulties in mastering the Self-regulation skill: making input and output of the skill visible, and providing some supports to learn the process to use the skill. But the common difficulties that metacognitive skill has in itself are still not reduced.

1.2.3. Making the output of the Self-regulation skill visible: Internalization

During the problem solving in a small group in the KITCHEN SINK approach, a teacher asks learners the following three questions at any time:

- What (exactly) are you doing?
- Why are you doing it?
- How does it help you?

Although learners answer nothing at first, they are getting to prepare answers to the questions even if the teacher does not ask them. Considering these questions induces learners to keep track of what they are doing is reasonable or not, and where they are in their plans. This learning environment is like one inspired by socio-cultural theory [17]. First, learners are not aware of what they are doing is reasonable for their goals and where they are in their plans during problem solving process. Next, they realize a function, which includes monitoring their cognitive activity, and checking them with their goals, with a teacher's support (actually, three types of questions). Then, they are getting to consider the answers for the questions even if the teacher does not ask them. These look like the processes of internalization that Vygotsky said [17]:

> *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)*

These three questions exactly evoke monitoring and evaluating functions in the Self-regulation skill. This method provides how to use the Self-regulation skill explicitly as the template of questions. Therefore, this method reduces the difficulty in mastering the Self-regulation skill: making learners aware how important to manage his/her own thinking process, and when they should do it, and providing some supports to learn the process to use the skill. But even if applying this method, there are still some difficulties in mastering the skill: it is difficult for learners to observe their cognitive activity objectively, and to allocate their mental resources to both cognitive activity and metacognitive activity.

1.2.4. Constructing metaknowledge about problems

There is a computer-based learning system called the Reflection Assistant that helps learners reflect on their metacognitive skills during problem solving [6]. The system consists of three phases to help learners do three reflective activities; understanding of goals and givens of the problem; recalling and organizing previous knowledge; thinking about strategies to solve the problem.

These reflective activities allow learners to identify knowledge about problem solving; strategically encode the nature of problem and form a mental representation of its elements;

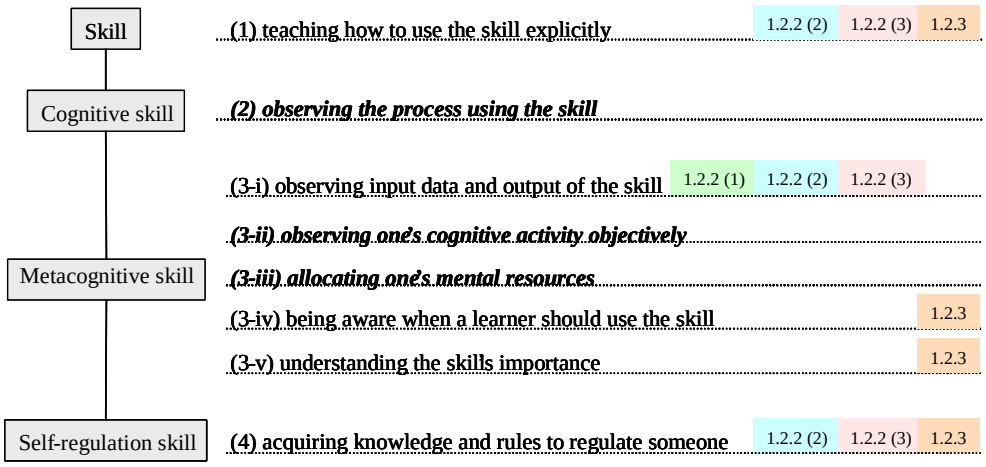


Figure 4. The difficulties reduced by existing methods and remains

select appropriate strategies depending on the mental representation. But these reflective activities do not lead learners to regulate their own cognitive activities. Therefore this system does not help learners develop the Self-regulation skill but promote their reflection and acquisition of metaknowledge.

2. A Method of Supporting Learners' Development of Their Self-regulation Skill

We propose a method of supporting learners' development of their Self-regulation skill. The method is designed in order to reduce the difficulties we described in the section 1 based on the hierarchical model of skills. In the method, we aim to provide learners with opportunities to develop their Self-regulation skill gradually: first, they learn the skill by observational learning, and then, they learn the skill by using it as a kind of the Basic Cognitive skill. Finally, they try to use the skill as one of the Metacognitive skill with computer system's support.

2.1. What Difficulties Still Remain To Support Learners' Development Of the Self-regulation Skill?

Figure 4 summarizes difficulties in mastering skills and reduced difficulties by existing methods based on the hierarchical model of skills. In the figure, (1) to (4) show the difficulties described in the section 1.1, and numerals, like 1.2.2 (1) or 1.2.2 (2), show the existing methods described in the section 1.2. For example, 1.2.2 (1) shows the method "Whole-Class Discussions of Problems with Teacher Serving as Control" described in the section 1.2.2 (1). As the figure shows, reducing the difficulties (1), (3-i), and (4) are relatively considered well, and no method is designed to reduce the difficulties (2), (3-ii) and (3-iii). So, adopting the existing methods, we propose our supporting method to facilitate learners with development of their Self-regulation skill gradually to help learners overcome all those difficulties. We adopt the method which gradually increases cognitive (or metacognitive) loads for learners. For the difficulty (2), we design some learners use the other-regulation skill through discussion. It makes the process how, when and why the learners regulate other learner's activity visible. For the difficulties (3-ii) and (3-iii), we design a plan externalization tool to support learners' resource allocation and objective observation on their cognitive activity.

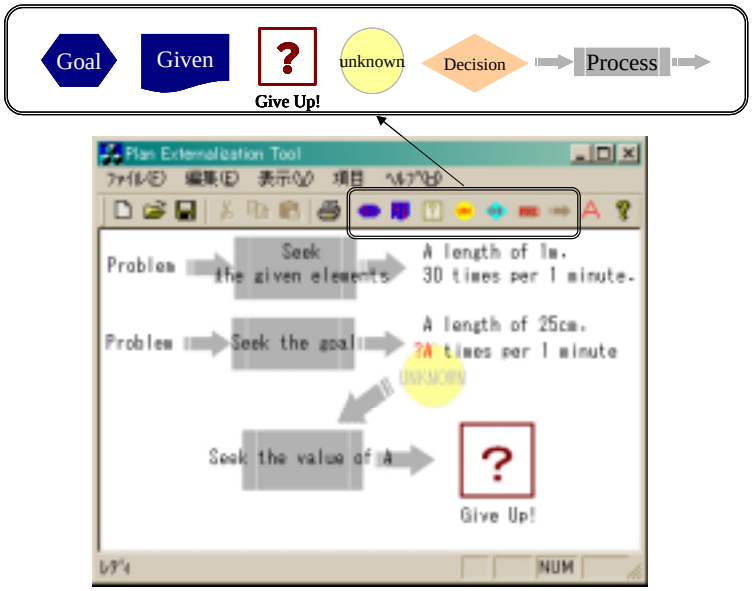


Figure 5. The plan externalization tool

2.2. Plan Externalization Tool to Reduce the Difficulty for Resource Allocation

Here we describe the plan externalization tool to reduce the difficulty for resource allocation. The plan externalization tool allows a learner to externalize his/her plan for problem solving, and helps the learner confirm his/her execution process of the plan. It also allows the other learners to observe the learner's cognitive activity which includes the learner's plan and his/her recognition about where he/she is in his/her plan during problem solving.

This computer based externalization tool has six elements for planning of problem solving (Figure 5). The element "Goal" is put on the goal of the desired solution. The element "Given" is often put on the starting point of the plan and means given data of the problem. The "Process" has input and output. It represents the process to transform the given input into a desired output, and is written by a simple sentence. If the output of "Process-A" becomes the input of "Process-B", a learner can connect both "Process-A" and "Process-B" by putting the element "Unknown" between them (Figure 5). When a learner has alternative plans, the learner can leave both plans as they are and put the element "Decision" on it. It means if one of the plans is successful, another plan can be ignored. The element "Give Up!" can be put if it is impossible for the learner to make any progress from there on. The learner can put "Unknown" on unknown input or unknown output. Usually, input and output of the element "Process" are "Unknown".

The problem-solver uses the tool to plan how to solve a problem. When the problem-solver actually solves the problem, the plan is shared by all participants: the problem-solver, monitors, and observers. The problem-solver is instructed to point where he/she is in his/her plan while he/she solves a problem. For example, if the problem-solver gets the value of an "Unknown" element, he/she should points the "Unknown" element by mouse clicking. All participants also share the information that what the problem-solver is doing and where he/she clicks in his/her plan. This allows the problem-solver's cognitive activity and his/her recognition visible.

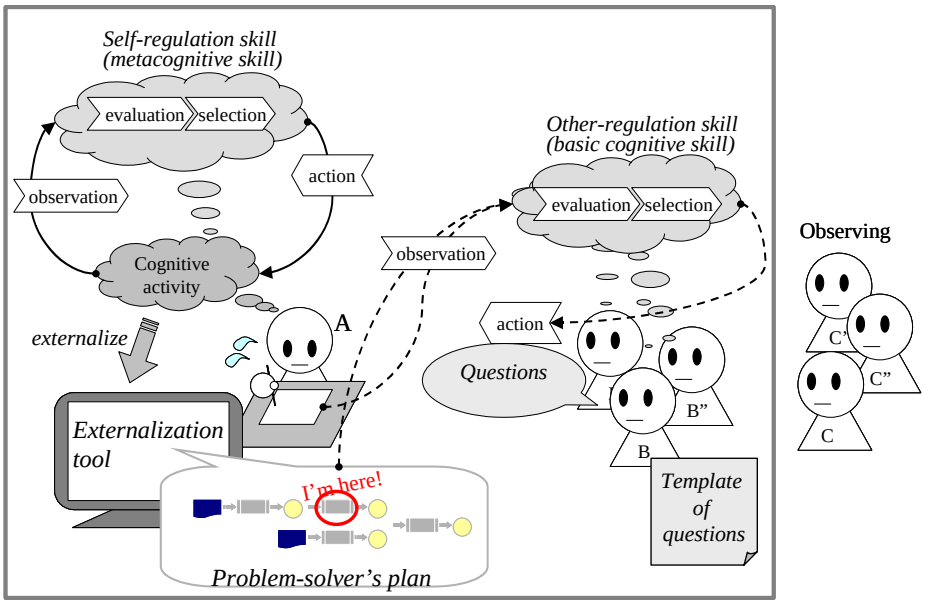


Figure 6. The learning environment gradually supports learners' development of self-regulation skill

2.3. The method for facilitating learners' Self-regulation skill based on the hierarchical model of skills

The method for facilitating a learner's development of the Self-regulation skill has three phases: first phase, a learner observes the process that other learners use the other-regulation skill, which is one of the Basic Cognitive skills and requires the learners for similar knowledge and rules with the Self-regulation skill; second phase, the learner tries to use the other-regulation skill through discussion and there is a template of question as a support for regulating the other; finally, the learner tries to use the Self-regulation skill as one of the Metacognitive skill supported by the computer system.

Figure 6[2] shows the learning environment we propose here. First, a learner plays the role of observer (learner-C in the figure) and learns the Self-regulation skill as the other-regulation skill, which is regulation skill at cognitive level, by observational learning. Next the learner plays the role of monitor (learner-B). The learner monitors the problem-solver's behavior and tries to regulate his/her cognitive activities. Finally the learner plays the role of problem-solver (learner-A) and tries to monitor his/her cognitive activities and regulate them by him/herself.

2.3.1. Learning the Self-regulation skill by observational learning

In order to learn the Self-regulation skill by observational learning, it is ideal that input to the skill, process using the skill, and output of the skill are visible for the observer. In this learning environment, the observer (learner-C) learns it by observing the process in which the monitor (learner-B) uses the other-regulation skill. Its input information is the problem-solver (learner-A)'s cognitive activity, and its outputs are questions that the monitor asks the problem-solver. The process using the skill is observed as discussion process among the monitors. It reduces

[2] In this figure, computers for each learner and network among them are not drawn to avoid complicating the figure. Actually, each learner uses a computer and all computers are connected to network. Every learner can share the same screen information and use communication channel like a chat system.

the difficulty (2) in figure 4 which cannot be reduced by any existing methods. Both of the process and output are visible for the observer. Thanks to our externalization tool for the problem- solver, the input information is also visible. Therefore, in this phase, the observer can observe all elements: input, process where the monitors use the other-regulation skill, and output: observational learning is realized.

2.3.2. Learning the Self-regulation skill as the other-regulation skill

The monitors observe, evaluate, and try to regulate the cognitive activities of the problem-solver through discussion among the monitors. The monitors have a checklist which has a template of some questions. These questions are intended to trigger off the Self-regulation skill of the problem-solver and it includes the questions like "what are you doing?" and "why are you doing it?" that Schoenfeld proposed. The problem- solver designs a problem-solving plan and then executes the plan while he/she points where he/she is in his/her plan using our externalization tool. The monitors can observe the plan, where the problem-solver points in the plan, and what he/she actually does, because the screen is shared among the problem-solver and the monitors (also the observers) via network. This means that the monitors can observe the problem-solver's cognitive activity. If the monitors evaluate the problem solver's behavior as wrong, for example, the behavior is not suitable for the plan, or he/she does not point correctly where he/she is in his/her plan, the monitors select one of questions in the checklist and ask the problem-solver. If this question would trigger the Self-regulation of the problem-solver, the problem-solver's plan or/and behavior would be changed. In this phase, the monitors can practice to monitor another learner (learner-A)'s cognitive activity and to control it with the checklist. Repeating this allows the monitors to internalize the questions which provide some viewpoints how a learner checks and regulates his/her cognitive activity. The monitors learn how to use the other-regulation skill using the checklist as a practitioner.

2.3.3. Learning the Self-regulation skill as one of the Metacognitive skill

To reduce one of the difficulties, resource allocation, we propose to use computer as a part of a learner's working memory. It means that we provide an externalization tool for the learner's problem-solving planning. This externalization also allows him/her to concentrate on observing his/her own thinking process objectively. So, in this phase, we aim to reduce the difficulties (3-ii) and (3-iii).

In this learning environment, the problem-solver draws his/her problem-solving plan using the plan externalization tool. After planning, the problem-solver executes his/her plan while he/she points where he/she is in his/her plan. This behavior allows the problem-solver to be conscious of his/her cognitive activities: what (exactly) am I doing? Also, the monitor's questions cause the problem-solver to be conscious of his/her cognitive activities. If the problem-solver becomes unable to point where he/she is in his/her plan, he/she may need to re-plan and execute the new plan.

This method is based on the socio-cultural theory that comes from Vygotsky [17]. He argued that the development appears on two planes: first on the inter-psychological, then on the intra-psychological. This theory means inter-psychological processes are themselves internalized by the individuals. At first, the monitor's questions act as a trigger the problem-solver's Self-regulation skill. Then the problem-solver would internalize the monitor's questions based on the checklist. The monitor's questions are internalized by the problem-solver, and could act as a trigger to cause his/her own Self-regulation skill.

3. Conclusion

There are many skills, and every skill encounters its own difficulty in being mastered. We considered the hierarchical model of the skills: Skill, Cognitive skill, Metacognitive skill and Self-regulation skill, and classified the difficulties according to the hierarchy. Mastering the Self-regulation skill has difficulties in (a) understanding how to use the skill verbally or in writing, (b) observing the process to use the skill, (c-i) observing input and output of the skill, (c-ii) observing one's cognitive activity objectively, (c-iii) allocating one's mental resources, (c-iv) being aware when a learner should use the skill, (c-v) understanding the skill's importance and (d) acquiring knowledge and rules to regulate oneself. We surveyed existing learning support systems and methods, which facilitate learners' mastering of metacognitive skills, and analyzed which difficulty the systems help. Thus, we found that some difficulties still remain in supporting learners' mastering of the Self-regulation skill, and then proposed a learning environment to help learners' master the skill.

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