A Hypothetical Model toward Establishing a Relationship between Cognition and Metacognition in Technology-Enhanced Self-Regulated Learning

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Abstract - Millions of learners have joined online courses, but far few of them complete those courses to gain full knowledge. The main reasons are a lack of a skill set for online learning and the ineffectively adaptive supports from online learning platforms. Having the ability to plan one’s learning process and to put that plan into action with full learning journey monitoring and control is the key to success in online learning. The former is about metacognitive strategies while the latter contains cognitive strategies. Therefore, this paper proposes a hypothetical model to establish a relationship between cognition and metacognition, which are two critical factors of a learning process, in a technology-enhanced self-regulated learning context.

Keywords: Cognition, Cognitive strategies, Metacognition, Metacognitive strategies, Self-regulated learning

1 Introduction

Learning is undoubtedly a life-long journey. The educational process has been rapidly moving from batch teaching to on-demand learning. In addition, online learning platforms have come into existence to meet the need. However, although millions of learners sign up for online courses, far few of them participate in or complete those courses due to losing motivation, feeling shortage of background knowledge and skills to continue learning [1]. Despite providing many tools such as a forum for collaboration, quizzes for self-assessment, videos, text, lectures, integrated development environments, and so on [2], online platforms seem not to have what it takes to support learners’ learning paths fully.

For on-demand learning, learners need self-regulated learning (SRL). Zimmerman [3] described that self-regulated learners are metacognitively, motivationally, and behaviorally active participants in their own learning process. During a learning process, SRL enables learners to control their cognition, metacognition, motivation, and emotion. These factors do not work independently but collaborate. The relationship between cognition and metacognition could cause positive or negative effects on motivation and emotion, which results in encouraging or preventing the learners’ success. In this research, we focus on the relationship between cognition and metacognition in SRL. The challenge for investigating such relationship is that cognitive activities can be quantified whereas metacognitive activities are implicit.

2 Objectives and research questions

This research aims at developing a prediction model about the relationship between cognition and metacognition in technology-enhanced self-regulated learning. To achieve this goal, we began with the following research questions:

1. What factors help build up SRL skills?
2. How to measure the maturity level of a learner’s SRL skills?
3. Which learner’s cognitive activities in technology-enhanced learning environments determine metacognitive behaviors?

3 Related work

3.1 Cognition and Metacognition

Cognition is a process by which we absorb, analyze, and turn knowledge into our own wisdom. Cognition contains a repertoire of methods or strategies which learners apply to obtain specific knowledge [4]. Those methods and strategies include but not limited to rehearsing, remembering, analyzing, and evaluating.

Effective learners do not learn blindly and unconsciously. However, they use metacognition to self-regulate their learning process [5]. Metacognition is about higher-order processes responsible for being aware of learning paths, establishing strategies and plans for learning, monitoring and controlling the learning paths, and evaluating the learning performance [5].

There are several studies about links between cognition and metacognition, mostly toward academic performance. Most of the studies agreed that the better cognitive and metacognitive strategies are, the better academic performance is [6] [7].

Although confirming the relationship between cognition and metacognition, current studies have yet to show (i) a method of measuring cognitive and metacognitive levels and (ii) a model in which elements of cognition and metacognition collaborate. We think that these two factors will help build a reliable reference framework based on which learners know their current SRL levels and a pathway for improvement.
3.2 Self-regulated learning

SRL is a learning process in which a learner monitors, controls and adjusts his or her learning progress in achieving learning goals. Covering a wide range of influential learning factors such as cognition, metacognition, motivation, and emotion, SRL provides a structured framework on which learners can develop their adaptive learning skill set. For this reason, SRL has become one of the vital areas of research in educational psychology. There has been an increasing amount of SRL models, among which, a significantly rising number of models have based on the investigation of metacognition, motivation, emotion and their effects on learning process [8]. Hence, it is reasonable to base the relationship between cognition and metacognition on a sound SRL model.

For this research, we have selected Zimmerman’s SRL cyclical model [8] as shown in Fig. 1 for its well established educational foundation, process oriented description, and solid performance and validity tested by empirical research. This SRL cyclical model describes a process that learners should apply before, during, and after working on an academic task. The related phases are forethought, performance, and self-reflection respectively. In the forethought phase, learners analyze tasks for deep understanding, set specific goals, and plan solutions to work through the tasks. In the performance phase, the learners put their plan into action to work on the tasks to achieve the goals. During the performance phase, the learners monitor their actual work, compare the work progress against their plan and regulate their strategies to steer the work toward the goals. Finally, in the self-reflection phase, the learners evaluate their actual performance against their plan, condense success and failure into experiences in order to achieve better performance in future tasks [8].

From the framework of this SRL model, metacognition, cognition and the relationship between the two are vividly revealed in the forethought phase, performance phase, and self-reflection phase respectively. In the forethought phase, the learners use their prior knowledge and experiences to analyze tasks and arrange a course of cognitive strategies or behaviors to do the task. In the performance phase, the learners put their plan into cognitive performance. In the self-reflection phase, the learners compare their plan and their cognitive-related work, withdraw opportunities for both planning and performance improvement.

3.3 Revised Bloom’s taxonomy

Bloom’s taxonomy, originally known as Taxonomy of educational objectives, categorizes cognitive competencies into six levels ranging from simply concrete remembering information to sophisticatedly abstract synthesizing and evaluating knowledge. Since its first public introduction in 1956, the taxonomy has been trusted and used worldwide as a measurement for cognitive competencies by many schools and instructors. In 2010, Bloom’s taxonomy was revised. The revised Bloom’s taxonomy maintains the six cognitive levels and separate the description for each level into two dimensions (see Fig. 2) including which type of knowledge a learner will embrace and what he or she should be able to do with it. A remarkable supplement in the revised taxonomy is metacognitive knowledge, which is about learners’ awareness of their own cognition [9].

Having contributions of both metacognition and cognition to a learner’s competency level, revised Bloom’s taxonomy promises to be a stable foundation measurement to discover the relationship between cognition and metacognition.

![Fig. 1. Zimmerman's SRL Cyclical Model [8]](image1)

![Fig. 2. Revised Bloom's taxonomy with Knowledge and Cognitive process dimensions [9]](image2)
4 Methodology

To discover the relationship between cognition and metacognition, we find it necessary to categorize cognition, metacognition, and SRL into measurable complexity levels. We also refer to well-known educational models and processes as foundations based on which the levels are determined.

Cognition, metacognition and SRL themselves are not enough to guarantee a stable relationship in an unstructured educational setting. Hence, we choose a suitable educational setting which strengthens the relationship and supports detailed insights from the relationship between cognition and metacognition.

After categorizing cognition, metacognition and SRL, we develop a hypothetical model which describes the relationship between cognition and metacognition in SRL. Then, we develop a prediction model based on this hypothetical model.

We use the popular learning management system Moodle to structure experiments to test our hypothesis and the prediction model.

5 Design and discussion

5.1 Learning task

When learners study a learning unit or solve a complex problem or task, the relationship between their cognition and metacognition can be projected in the Zimmerman’s SRL cyclical model (see Fig. 1). In other words, we can reveal the relationship between learners’ cognition and metacognition by analyzing their progress through a complex task via the Zimmerman’s SRL cyclical model point of view.

In this research, we develop a hypothetical model and perform experiments in the problem/task solving context.

The task needs to be complex enough to meet the following criteria [10]:
- Requiring abstract levels in revised Bloom’s taxonomy
- Containing Multi-steps
- Containing uncleared outcomes
- Requiring strategies
- Requiring self-planning and monitoring

A simple task might not require learners to revise prior knowledge, plan a course of cognitive strategies, monitor and control performance progress. In this case, the learners’ metacognition is not strongly revealed, and the relationship between cognition and metacognition is also not clear.

In addition, each step in the task has to link to one or several learning outcomes (as shown in Fig. 3) measured and scored against revised Bloom’s taxonomy levels.

5.2 Cognitive measurement

We distribute the learning task scores across the knowledge dimension – cognitive process dimension structure of revised Bloom’s taxonomy [9]. The cumulative score which learners earn from completing the task is their cognitive score. The score can be calculated by a sum formula $f(X)$ in which $X$ is a vector of revised Bloom’s taxonomy level-based scores that the learners earn from completing the learning outcomes. (see Fig. 3 and Fig. 4)

5.3 Metacognitive Measurement

Metacognition is implicit in one’s mind. However, a learner can reveal his or her metacognitive activities by speaking his or her thoughts or by certain explicit behaviors. From the Zimmerman’s SRL cyclical model, metacognitive activities appear in all phases of the SRL process. Hence, this SRL process provides pragmatic evidence about the learner’s metacognitive activities.

Based on the Zimmerman’s SRL cyclical model, SRL has been classified into five distinct profiles:
- non-self-regulators who lack cognitive and metacognitive skills in all the phases
- forethought-endorsing self-regulators who appear to have good skills and actions in the forethought phase
- performance / reflection-endorsing self-regulators who are good at applying cognitive strategies, monitoring and controlling progress in the performance phase
- super self-regulators who show good skills and strategies across the three phases
- competent self-regulators who is good at SRL skills and strategies, and flexible in the usage of those strategies to achieve goals [11].

To score metacognition, we use Metacognitive Awareness Inventory (MAI), which is a 52-items false–true semantic differential formatted questionnaire [12] to measure adult learners’ strengths and weaknesses about knowledge and the application of cognitive strategies.
We distribute MAI questions into the corresponding phases in the Zimmerman’s SRL cyclical model. Thus, learners’ metacognition can be recorded and scored throughout SRL process.

Since SRL profiles show a learner’s cognitive and metacognitive pattern, they promise to be a joint of relationship between cognitive and metacognitive behaviors.

5.4 Cognition - Metacognition - SRL

When working on complex tasks, learners who are good at metacognition tend to gain high cognitive scores. And vice versa, learners who gain high cognitive scores on complex tasks are definitely competent to perform metacognitive strategies. For this reason, we can expect that learners, who gain high cognitive scores, have a high level SRL profile.

From these measurements, we hypothesize that the relationship between cognition and metacognition in SRL could be established as shown in Fig. 5.

![Fig. 5. Cognition - Metacognition - SRL relationship](image)

6 Expected outcome

A prediction model (see Fig. 6) classifies cognition and metacognition into SRL profiles which help reveals the relationship between cognition and metacognition in a technology-enhanced self-regulated learning environment.

![Fig. 6. Cognition - Metacognition - SRL Profile Prediction Model](image)

7 Conclusion

We have presented the design for establishing the relationship between cognition and metacognition basing on promising models and measurements. The precise relationship promises to enable technology-enhanced SRL environment to adaptively enhance and support learners’ SRL ability during their learning process. Furthermore, the relationship also helps learners understand their own SRL profiles. Hence, the learners are able to develop appropriate adjustments into their SRL skills when approaching future complex learning tasks. The future work is to develop a prediction model, then carry out experiments on real learners’ task performance to validate the hypothetical model.

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9 References


