A Framework Design of Metacognitive Support System for Novice Programmers (MSSNP)

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ABSTRACT

This paper presents an approach for design of framework for the development of a Metacognitive Support System for Novice Programmers (MSSNP) learning Introductory Computer Programming. The framework is designed based on Tobias and Everson’s model of metacognitive instruction, which consists of planning, selecting strategies, evaluating learning, and knowledge monitoring. Following Tobias and Everson’s metacognitive model, three services and models are introduced in this framework as follows: (1) knowledge monitoring model; (2) evaluation of learning model; and (3) metacognitive strategy selection model. Metacognitive activity and processes in MSSNP take place before, during, and after learning. An instructional approach, known as Cognitive Strategy Instruction (CSI), is also an integral part of the framework. Five identified metacognitive activities, specifically ‘pre – task’, ‘familiarization’, ‘production’, ‘evaluation’ and ‘post-task’, are embedded within the framework.

Keywords: Framework, Novice Programmer, Metacognitive, Tobias and Everson’s Model, Computer Programming

1 INTRODUCTION

In Computer Science’s Education, Computer Programming is a field study which investigates various aspects of complex systems and the various uses of programming languages. Acquiring this knowledge is challenging for the novice learner, as indicated by (Maheshwari, 1997; Riley, 1981). Learning to program is regarded as a difficult both by researchers and often by learners themselves, and there is a need for hands-on training as well as theory (Hoc, 1990; Robins, Rountree, & Rountree, 2003). Problem-solving and analytical skills are the two major factors in learning programming (Henderson, 1987; Ismail, Azilah, Naufal, & Kelantan, 2010). Classroom education alone is not sufficient to produce strong programmers. When confronting with the difficulty and challenge task, novice learners typically seek aid from someone more experienced and well-versed in programming or seek help from other information resources such as books or the Internet.

In theory, knowledge of programming prompts learners to evaluate their solutions and their way of approaching the solutions. This so-called cognitive or thinking process enables the learner to apply newly acquired skills to new situations. Problem solving has been recognized as an essential part of software development, regardless of the approach adopted. Metacognitive is an essential skill that needs to be developed by the student for problem-solving. In didactical taxonomies (Mangione, Gaeta, Orciuoli, & Salerno, 2010), metacognitive knowledge is considered the highest level of knowledge. It refers to the ability and opportunity for learners to comprehend, control, direct, and utilize their knowledge and their learning process. Metacognition can be achieved through Self-Regulated learning (Zimmerman, 1995). Researchers of educational psychology believe that to become a self-regulated learner, one must be capable of self-reflection. Acquiring a skill makes the learning process easier and facilitates the process of knowledge transfer. In turn, this allows greater potential to increase individual’s capacity to learn independently. This present study proposes a framework design for the development of a Metacognitive Support System for Novice Programmer in learning Computer Programming.

II COMPUTER PROGRAMMING: PROBLEM SOLVING AND METACOGNITION

According to (Pearl, 1984), per Figure 1, problem solving activities consists of the following steps:

a. Initiate a specific plan;

b. Analogical problem solving – Applying a solution to a known problem for solving similar problem;

c. To reduce the problem, general plans are applied;

d. Trial-and-error method applied for a possible solution; and

e. The execution of this combination of approaches.
Extensive studies on problem-solving has been carried out by many researchers, studies by (Davidson, Deuser, & Sternberg, 1994), (Eysenck, Ellis, Hunt, & Johnson-Laird, 1994) have defined problem solving as the process of converting a problem’s initial state into the desired one. Acquiring this knowledge has proven challenging for novice learners, and this has been indicated as a universal problem by researchers. Problem solving involves a reciprocal action of a person’s experience with the task demands. Studies by (Artz & Armour-Thomas, 1992; Swanson, 1990; Whimbev & Lochhead, 1999) have stated that those who possess well-developed metacognitive abilities are those who are enduring in problem-solving, and who apply their skills of intellectual consciously. In problem-solving activity, stated by (Mayer, 1999) that several skill of metacognitive regulatory is important, planning and monitoring as the example. Metacognition is an important part of the problem-solving process, and the term, metacognition, has a directing or monitoring connotation depending on the context in which it is used (Kapa, 2001; Teong, 2003).

III THEORETICAL BASIS OF METACOGNITIVE

Tobias & Everson defined the metacognitive as a blend of knowledge and skills formed from components of ‘knowledge of cognition’, learning processes, self-cognitive monitoring and control of those processes. These components are organized into a hierarchy in which the knowledge monitoring metacognitive skill is required for stimulating other metacognitive skills, as depicted in Figure 2.

They defined knowledge monitoring as “knowing of what you know and donot know”. Therefore, it is an important advantage to differentiate between what learners have already learned and have notyet learned. Through this, learners may refrain from studying material in which they have already been found to be proficient. Tobias & Everson also pointed out that these students dedicate most of their energies and time to the new unaccustomed materials. On the other hand, Tobias & Everson (S. Tobias, Everson, & Laitusis, 1999) argued that students appear to be less effective in spending their resources and time, if they are less effective in knowledge monitoring process that consequently have greater problems mastering new subjects. Tobias & Everson intensively studied aspects of metacognition monitoring, with the presumption that in mastering new knowledge, accurate knowledge monitoring is a critical skill in learning and training newly knowledge (S. Tobias et al., 1999). This theoretical model is specifically appropriate for this present study because it enables one to concentrate on particular metacognitive skills associated to problem-solving. In addition, this model provides an assessment instrument for measuring knowledge monitoring. Based on this theory, our new model will focus on the three skills of metacognition, specifically knowledge monitoring, the evaluation of the learning experience, and the metacognitive selection strategies as described below:

A. Model for knowledge monitoring

This is the primary target of this framework. Scaffolding knowledge monitoring skill is to give the ability to assess one’s knowledge or, by extension, one understands. Promoting awareness of the novice’s level in knowledge monitoring accuracy is the first step in fostering metacognitive skill. Improvements in knowledge monitoring give ability that in turn triggers selection attention and facilitates better allocation of cognitive resources.
B. Model for the evaluation of learning

The objective of this model is to develop awareness of how novices behave during problem solving, which resources are used, how long one spends on each task, and which decisions are made in the process of solving programming problems.

C. Model for Selection of metacognitive strategies

The focus here lies on the general heuristics of the metacognitive that connected to learning programming and the task. The focus on developing students’ awareness of three kinds of metacognitive strategies as follows: strategies for monitoring understanding, strategies for monitoring the problem solving process and controlling errors, and strategies for revising.

IV THE FACETS OF MSSNP’S FRAMEWORK

In the design of metacognition support system, we have identified criteria and elements that must be considered. The design has to be parallel with the goal and objectives of metacognition within support system. Tobias and Everson’s model of metacognition has limitation of roles within the system, providing the only underlying frame for the development of MSSNP. This section discusses the elements that need to be integrated within MSSNP’s framework. Metacognitive experiences take place at any time before, after, or during a cognitive enterprise (Efklides, Samara, & Petropoulou, 1999) or provide input to causal attributions (Metallidou & Efklides, 2002). Therefore, the moment in time where the system provides metacognitive instruction is an important consideration. (Zimmerman, 1990) suggested three stages for better self-regulated learning process.

1. Thoughtful provision beforehand, learners carefully think and prepare before performing a task;
2. Willpower, known as "performance control", involves learners’ consciousness and willpower during the learning process; and
3. Self-reflection, which takes place at the end stage when learners re-examine their performance toward the final goals. Meanwhile, concentrating on their strategies during the learning process that is efficient for their final results and outcomes (Williams & Hellman, 2004)

Thus, we have used the three stages (before, during and after learning) to present the metacognitive activities within the MSSNP as follows:

1. **Before the learning exercise situation**
   Objective: Self-reflection takes place before the learning process lead to the potential to put the learner in the correct condition or frame in mind to perform the task. The possible activities take place before any attempt to a new problem or before a new lesson such as planning; setting goal, selecting strategies to perform sequence of operation, potential obstacles identification, predicting desired results and so on.

2. **During the learning exercise situation**
   Objective: Self-reflection occurs during the learning process and can help the student in the self-monitoring process. Possible activities during this stage include the actual cognitive performance, spotting obstacles or errors and knowing how overcome the obstacles or errors.

3. **After the completion of the learning task**
   Objective: Self-reflection happens after the learning process is a natural time for the student to reflect on her learning process and performance. The possible activities that take place at this stage are assessing achievement’s goal, to infer the adequacy and accuracy of the results, evaluating appropriateness of procedures used, assessing handling of errors or obstacles, judging efficiency of the plan and the execution of a plan and so on.

Studies in cognitive psychology have linked a number of constructs to metacognition. Critical thinking is one of the constructive elements that has been relate with metacognition. Critical thinking widely varies in definition but the common elements per(Ennis, 1985; Ernst* & Monroe, 2004; Paul, 1992) are analysing argument, making inferences through the deductive reasoning or inductive reasoning, evaluating or judging, solving problems or making decision. They suggested that instruction should designate a process of groundwork in general principles of critical thinking, likewise practice in applying critical thinking skills in the context of particular domains. An instructional approach called Cognitive Strategy Instruction (CSI) stresses the development of thinking processes and skills as a means to enhance learning,
and is an important criterion to enable learner to be more self-reliant, strategic, productive and flexible in their learning effort (Scheid, 1993). The underlying feature of CSI is the presumption that cognitive strategies are identifiable (Halpern, 2002) and that learning success is connected with these strategies (Garner, 1990). Using metacognition, learner can benefit from instruction (Carr, Kurtz, Schneider, Turner, & Borkowski, 1989; Zile-Tamsen & Marie, 1996) and impel the maintenance and the use of strategies in cognitive skills development. While there are a few existing metacognitive instructional approaches, the most effective is preparing the learner with the knowledge of cognitive processes as well as metacognitive strategies. In the development of metacognitive regulation, exposure or practice in using both cognitive and metacognitive strategies and evaluating the outcomes of their efforts are the key contributors. Simply preparing knowledge without experience (or the other way around) does not appear to be adequate for the development of metacognitive control (Livingston, 1996). To determine a conclusion, we have summarized the criteria that need to be integrated within MSSNP in Figure 4.

A. METACOGNITIVE SUPPORT SYSTEM FOR NOVICE PROGRAMMER (MSSNP) STAGES

Stage 1: Pre-Task – This stage is always regarded to be self-reflection to start the new problem, which happens before the learning process. The primary objective of this stage is to trigger reflection on the monitoring progress of the novice’s knowledge. Novices will be provided with suitable conditions for making them realize the benefits of general strategies, available resources as well as the degree of attention that is necessary to succeed in the problem-solving process and the activity. The performance of the past problems is focused upon and the students will be able to compare their estimation to their actual knowledge and understanding. The screenshot of Pre-Task is presented in Figures 5. The activities involve during this stage are as follows:

i. Performance comparison and knowledge monitoring;
ii. Analysis of performance and knowledge monitoring.

Stage 2: Familiarization - The objective of this phase is to make them reflect on strategies as this activity helps them think the strategies that are relevant and apply it appropriately. The Familiarization screenshot is illustrated in Figure 6. Students are required to select strategies that are presented to them, or they may alternatively select a strategy by composing a new one. This phase focuses on metacognitive strategies that related to the process during problem-solving. The activities involve during this stage are:

i. Understanding the components of problems and Self-assessment;
ii. Metacognitive selection strategies.
Stage 3: Production – The actual ‘problem solving’ activity takes place during this stage, in which students are required to solve the problem given. Figure 7 shows the Production screenshot. This activity is always regarded to student actual performance assessment. The objective of this stage is to reflect student understanding of a problem concept as well as confidence to solve the problem correctly. Quizzing is one of the activities involved in this stage.

Stage 4: Evaluation - ‘Checking Solution’ is the main activity involve during this stage. Students will be able to compare their solution with a solution provided from solution library.

Stage 5: Post-Task - The activities designed at this stage provide the opportunity to the student to review their most recent experience, and explore what happened during the problem-solving activity. The aim is to assist the student in identifying the ‘cause of the mistake’ that relates to the problem, the recourse used and issues relating to time management. Through this, students can build a better insight of problem-solving practice and experience. A Post-Task Dashboard is presented in Figure 8.

V CONCLUSION

In this paper, a framework based on Tobias and Everson’s model of metacognitive has been developed. Three models were introduced as the pillar of this framework. These are the knowledge monitoring model, the model of learning evaluation, and the model of strategy selection. The activities of metacognitive in MSSNP take place before, during, and after learning. An instructional approach called Cognitive Strategy Instruction (CSI) is embedded in the framework. The conceptual stages of framework are composed of five stages, namely pre-task focusing on reflecting, familiarization focusing on assessing knowledge understanding and planning strategy, production focusing on problem-solving activities, evaluation focusing on the activity of checking and comparing solution, and last but not least the post-task focusing on reviewing activities of the past learning experience regarding time spent, resources used and the strategies selection plan.

REFERENCES


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