AC 2010-158: INTEGRATING SELF-REGULATED LEARNING INSTRUCTION IN A DIGITAL LOGIC COURSE

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Integrating Self-Regulated Learning Instruction in a Digital Logic Course

Abstract

Self-Regulated Learning (SRL) involves self-monitoring and self-correction of three components of learning: motivation, behavior, and cognition. Abundant research has supported that optimal academic performance is strongly tied to the extent to which the learner uses SRL. SRL is currently viewed as a vital prerequisite for the successful acquisition of knowledge in school and beyond. Thus, teaching students self-regulatory skills in addition to subject-matter knowledge is one of the major goals of education. However, SRL is not well known and utilized by the Engineering and Technology education community for facilitating student learning.

Self-regulated learners are purposive and goal-oriented, incorporating and applying a variety of strategies to optimize their academic performances. However, the application of self-regulation to learning is a complicated process involving not only the awareness and application of learning strategies but also extensive reflection and self awareness. This paper describes the development of the instructional strategy and its implementation plan, which integrates the SRL model through two instructional strategies (Direct Instruction and Immersion Instruction) into the Digital Logic course. The outcomes of the implementation are provided and discussed.

1. Introduction

According to national statistics, the number of bachelor-degree holders in Engineering and Technology (E&T) declined by 5% over the last decade. Only 5.6 % of the bachelor-degree awardees were from E&T in 2004[1]. Based on the experience of working with students and the discussion among faculty members reveals that most of those students, who left the engineering and technology programs, possess the ability for achieving the required performance to succeed in the program. The specific reasons that resulted in their failing or dropping out are: (1) lack of motivation and interest in learning technology; (2) lack of good learning habits, strategies and efforts in their studies; and (3) lack of association with other engineering/technology students and faculty for seeking support.

Most of the engineering/technology courses focus mainly on disciplinary topics. Little attention is given to help students develop cognitive skills that can effectively regulate learning efforts. Students who failed in their studies may attribute their failures to lack of ability in learning rather than a lack of effective use of strategies. They may quit from engineering and technology programs due to frustrations from their setback in learning. In addition, these courses lack instructional strategies to motivate those students who stay in the programs.

Furthermore, possessing learning motivation and self-confidence is a critical prerequisite for students to apply effective strategies, persist in their effort, and eventually succeed in learning engineering and technology. Particularly, as students from minority groups are interested in E&T learning, the challenge is to believe they can succeed, as well as support and nurture their interest[2]. Thus, there is an imperative need to adapt and develop new instructional strategies that

integrate cognitive skill development and learning content to help students to effectively regulate their learning motivation, efforts, and strategies.

In addition, the formal schooling system cannot possibly prepare people for all the skills and knowledge needs they will ever have during their lives. After graduation from college, young adults must learn many important skills informally. Therefore, it is important for the educational system to help students develop the ability to get up to speed quickly in new domains. Students have to know how to manage their learning, (e.g. by setting goals, planning their learning, monitoring their progress, and responding appropriately to the challenges) as they progress through higher education.

These learning skills are often referred to as self-regulated learning[3,4]. Self-regulated learners possess a "tool kit" of strategies for dealing with challenge and are motivated to use appropriate strategies at the appropriate time. Self-regulation has been found to be positively correlated to academic achievement. Research shows that self-regulated learning is not a single personality trait that individual students either possess or lack[5]. Instead, it involves the selective use of specific processes that must be personally adapted to each learning task. Instructors can teach in ways that help students become self-regulating learners.

SRL has just started drawing attention among engineering and technology education community. This study, which is supported by NSF, focuses on using the SRL model to help students become more effective, successful learners. Our study also explored how components of SRL might be integrated into teaching and learning in the areas of engineering and technology. The process of learning self-regulation requires extensive time and feedback. The present study begins to follow the development of this process in a Digital Logic course. Students in the Digital Logic course learned to apply a series of self-regulated learning strategies (such as goal setting, self-monitoring, and self-assessment) through a semester-long course. Instructor provided students constant reminder of the steps (Goal, Action, Monitor, and Evaluate) to follow in a self-regulated learning process. This should help students develop SRL skills sets as well as apply those skills to any given learning situation.

2. Theoretical Background

Self-Regulated Learning (SRL) is a theory of educational psychology built on the developments in cognitive science. Self-Regulated Learning has become a current focus for research, and one of the essential axes of educational practice. SRL is defined by Zimmerman[6,7] as "students personally initiate and direct their own efforts to acquire knowledge and skill rather than relying on teachers, parents, or other agents of instruction". Self-regulation is a broad and dynamic concept. Self-regulated learning has also been defined by Pintrich[8] as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features of the environment". Generally speaking, self-regulated learners can be characterized as active participants who efficiently control their own learning experiences in many different ways, including organizing and rehearsing information to be learned, and holding positive beliefs about their capabilities, the value of learning, and the factors that influence learning[9].

According to literature[10], SRL involves self-monitoring and self-correction of three components of learning: motivation, behavior, and cognition. It refers to active learning guided by three important aspects of learning: (1) motivation to learn; (2) meta-cognition (awareness of one's knowledge and beliefs); and (3) strategic action (planning, evaluating, and acting). In other words, SRL can be viewed as a process in which individual students actively and constructively monitor and control their own motivation, cognition and behavior toward the successful completion of academic tasks. Other aspects of self-regulated learning include time management, regulating one's own physical and social environment, and the ability to control one's effort and attention[11].

3. Digital Logic Course

The Digital Logic course introduces students to the fundamentals of digital systems, including number systems, combinational and synchronous sequential digital logic, state machines, VHDL, and digital system design. Digital Logic course consists of lectures and hands-on labs. The lectures discuss concepts and theories. The learning of concepts usually involves listening to lectures, taking notes, participating in discussions, and taking tests that are aimed to provide an overall measure of how much is learned. In the lab, on the other hand, students will learn to implement actual digital systems using components, hardware, and software tools. The lab projects and assignments are evaluated for mastery of the practical skills.

The digital logic course is one of the most important courses for Electronics and Computer Technology students. Usually, students take digital logic during their sophomore year. The skills used in the design and troubleshooting of digital systems should be acquired in this course. Instructors have to dedicate their efforts to stimulate students' desire for learning this subject. Thus, there is a need for methods of connecting the teacher and the students that will enhance the learning experience.

The transition from high school to college puts many demands on science, technology, engineering and mathematics (STEM) students. The greatest challenge may be the move from the declarative knowledge, which typically emphasized in high school, to the higher level thinking skills required in college. Therefore, in order to be successful in college, STEM students need to have SRL skills that were not necessarily essential in high school. Although research shows that students can learn to be more self-regulated[12], instructors still have a central role in developing their students' capacity for self-regulation. Boekaerts[13] asserts that although SRL can be complex, it can be taught.

As mentioned, Digital Logic course is offered for sophomore students and is one of the basic technical courses for Computer and Electronics Technology Program. This course should be the ideal class to introduce self-regulated learning. Instructor needs to implement SRL and help students to become self-regulated learners. If the students can develop the SRL skills in this class, they should be more capable of coping with the academic challenges during their junior and senior years.

4. Purpose of the Study

Today, the preparation of engineering/technology graduates, who deeply understand the fundamental principles behind state-of-the-art technologies, but also exhibit analytical, problem

solving, and expert thinking skills, is impossible without incorporating new teaching methodologies into curricula. The construct of self regulated learning has been extensively studied in recent years. Research shows that self-regulation has a positive effect on academic attainment[14,15]. However, it is still relatively new as regards to implementation for improving student performance and achievement in the engineering and technology education community. Self-regulation can make a positive contribution to student behavior, discipline and self belief. This study sought to help technology-major students become successful self-regulated learners. It is believed that supporting students in focusing on the motivational, behavioral, and meta-cognitive aspects of their learning processes would result in higher academic performance.

5. SRL Strategy

Self-regulation can be improved through appropriate guidance, modeling of effective strategies, and creating supportive and challenging contexts[16]. Instructors can help students develop and apply strategies such as planning, setting goals, organizing, self-monitoring, and self-evaluating at various times during the learning process. This process should help students to effectively control their study and to enhance academic performance. Self-regulated learning is particularly appropriate for college students, as they have great control over their own time schedule, and how they approach their studying and learning[17].

It needs be emphasized to students that self-regulation learning is a continuous and integrated process. It utilizes meta-cognitive knowledge and reflection skills, as well as involves three interrelated processes: (1) planning (i.e., setting goals, identifying task knowledge, and selecting strategies for achieving the goals); (2) self-monitoring (i.e., assessing chosen strategies, reflecting upon progress, and planning for strategies to utilize next); and (3) self-evaluating (i.e., examining the overall learning process, determining effectiveness in achieving learning goals, anticipating and overcoming obstacles, and determining effectiveness of the plan so it can be modified for similar tasks in the future). Students have to understand that SRL is repeated cycles of these three phases (as shown in Figure 1) towards learning goals.

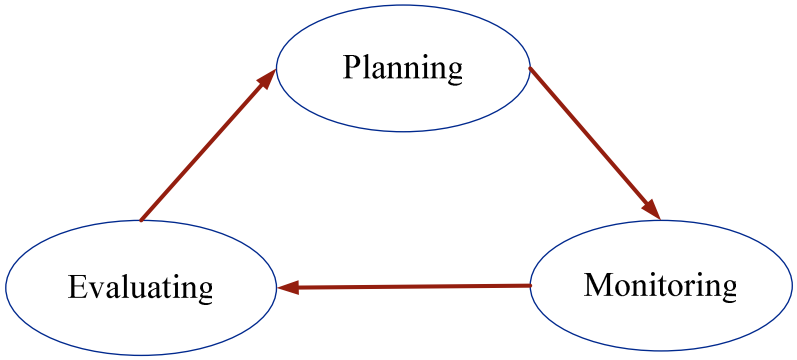

Figure 1. Three-Phase Self-Regulated Learning Model

6. Instruction Strategy

To promote personal and academic success, effort needs to be placed on developing and incorporating self-regulatory capabilities. Self-regulation does not occur overnight. There are numerous strategies instructors can use to promote effective self-regulation. A structured approach to SRL must be undertaken. The model for self-regulated learning presented in this study comprises of two main components: motivational beliefs and the use of self-regulation strategies. The proposed model is based on the assumption that motivational beliefs promote and sustain different aspects of SRL[18]. Research shows that the motivational beliefs and the use of self-regulation strategies can influence academic achievement[19]. Studies also revealed that high efficacious students, who believe that their course work is important, interesting and useful and adopt a mastery goal orientation, are more likely to engage in various cognitive and meta-cognitive activities in order to improve their learning and comprehension[20]. In addition, in the context of learning and teaching, self-regulation strategies can influence the development of positive motivational beliefs and, especially, self-efficacy.

6.1 Expandable Intelligence

One important aspect in SRL is to regulate the learners' motivation. Psychological instruction model of Expandable Intelligence (EI) is established based on new psychological findings that learners' belief on their intelligence has a profound influence on their motivation to learn. With the belief that intelligence can be expanded (as opposed to the view of fixed intelligence), learners are able to attribute their successes or failures to factors within their control (e.g. effort on a task, or effective use of strategies) rather than their ability. They can be motivated to use learning strategies and persist in their learning efforts for expanding their intelligence[21].

6.2 Enhance Students' Motivation

As mentioned, research suggests that there is a connection between motivation and SRL. Students must have motivation to use the SRL strategies and regulate their learning efforts. Thus, students must be motivated to learn SRL concepts, acquire SRL strategies, and practice these strategies through self-directed active learning. In order to effectively motivate students' effort, students' motivation for pursuing SRL needs to be conceptualized using a theoretical framework of the general motivation model[19]. Step one of the proposed instructional strategy is to address the three motivational components from Pintrich's model[19] for promoting use of SRL, and deliver them to students through lecture with the following principles:

- Enhancing Self-efficacy: Self-efficacy is an individual's belief and confidence in their ability to accomplish goals. High self-efficacy functions as incentive for the pursuing of a goal. On the contrary, low self-efficacy functions as barrier that urges avoiding the goal[22]. The expandable intelligence concept is introduced to students. It can help students establish learning confidence and belief that their learning efforts can improve their intelligence or ability, and they can succeed if they make effort and use effective strategies.

- Increasing Task Value: Task value is an individual's perception of the importance of a task, personal interest in the task, and perception of the utility value of the task for future goals. Expandable intelligence theory can help students perceive that challenge in

learning engineering and technology through SRL can provide intellectual stimulation for enhancing their own intelligence or ability.

- Setting Goal Orientation: Goal orientation includes mastery goal orientation (referring to concern with learning and mastering the task using self-set standards and self-improvement), extrinsic goal orientation (focusing on getting good grades and pleasing others may be attained without much in-depth self-regulated learning), and relative ability orientation (concerning with comparing their performance to others). The instructors instruct students to shift their focus from comparing their performance to peer to self-comparison toward mastery goal orientation. The mastery goal orientation can also be reinforced by the expandable intelligence concept.

6.3 Promote Self-Regulated Learning

Self-regulation is a continuous and integrated process. To promote students to develop self-regulated learning skills, the conceptual SRL model and its strategies have to be explicitly introduced to students in the classroom and integrated into their learning activities. Step two of the instructional strategy is to implement the following two types of instruction strategies.

6.3.1 Direct Instruction Strategy

The learning materials that cover the SRL concept, model, and related strategies are presented to students. These SRL strategies focus on three aspects outlined as follows:

- Personal: these strategies involve how one organizes and interprets information; goal setting and planning; keeping records and monitoring; and rehearsing and memorizing.
- Behavioral: these strategies involve actions that the student takes, e.g. self-evaluating or regulating (checking quality or progress); and self-motivation and self-reinforcement.
- Environmental: these strategies involve seeking assistance and structuring of the physical study environment, e.g. seeking information (library, Internet); environmental structuring (selecting or arranging the physical setting, minimizing distractions, breaking up study periods and spreading them over time); emulating exemplary models; and seeking social assistance (from peers or instructors)

6.3.2 Immersion Instruction Strategy

The request of higher level learning and thinking can emerge only when students are motivated and make their own plan and take control of their learning. The immersion instruction strategy is developed to meet the student's autonomous request. It incorporates authors' experience and successful Problem-Based Learning (PBL) Model[23,24] into the framework of SRL Assessment System. It has been implemented in students' lab project to promote SRL.

Particularly, the development of PBL projects follows the same cyclic model as SRL implementation (Figure 1). Thus, instruction for SRL implementation can be naturally merged into the development of the lab project. The lab project is assigned early and allows students to have more than two months to plan, conduct, evaluate, revise, and finish the project. Two to three students can form a project team with clearly defined responsibilities.

SRL instructional scaffolds are provided to guide students' cognitive skill development as salient cues for each SRL phase. Student teams are required to meet with instructor at least three times in accordance with the three phases in SRL cycle to seek feedbacks. For the project technical aspect, the instructor provides assistance as students need.

7. Implementation

The Digital Logic course combines lecture and laboratory projects. In the classroom, instructor ensures that students acquire both the subject and SRL strategy knowledge. To help students become self-regulated learners, instructor has adopted systematic instructional approaches based on the SRL Model (presented in the above section), which are exemplified in following:

- Guide students' self-beliefs, goal setting, and expectations.
- Help students focus on behavior.
- Provide timely corrective feedbacks that are positive about the learning task and use of strategy.

For the laboratory component, the projects are developed for providing students with hands-on experience. The objectives of laboratory activities are: 1) to provide students with a better understanding of the digital logic; 2) to help students develop hands-on skills through self-motivating, team-based design activities; and 3) to stress the importance of problem solving skills and critical thinking. It should be noted that presenting cognitive strategies to students does not guarantee their achievement. Implementation of these strategies is not an easy task and needs persistent effort. SRL can be taught indirectly with laboratory activities to evoke reflection and meta-cognitive understanding. The immersion instruction strategy described in the above section has been implemented in the laboratory portion of the class.

8. Assessment

To collect data on demographics and prior knowledge, students were administered a demographic survey at the beginning of the semester. During the 2009 Fall semester, eighteen undergraduate students enrolled in the Digital Logic course. All students were university students enrolled as technology majors. Among them, there were three female students. The majority of technology majors continue to be male.

To assess students' SRL strategies used, during the second, sixteenth and tenth weeks of class, as well as one week before the final examination, students were administered the self-assessment questionnaires[25,26]. To explore changes in self-regulation, it is important to examine how the changes of one student compare to the changes within other students. Therefore, all students who enrolled in the class participated in the survey. As mentioned in the previous section, the SRL model presented in this study comprises of two main components: motivational beliefs and the use of self-regulation strategies. Thus, this self-report instrument is designed to measure students' in the stated two components, as well as to let students learn to track and assess their academic learning and self-regulation skills.

The motivation subscale consists of twenty-five (25) items, assessing students' goals (e.g. "I expect to do very well in this class" and "Getting a good grade is a satisfying thing for me"),

value beliefs (e.g. “Understanding this subject is important to me” and “I think I will be able to apply what I have learned in this class in other courses”) and their self-efficacy (e.g. “I am certain I can understand the most challenging problems” and “When I take a test, I think about how poorly I am doing”). The self-regulated strategy subscale also comprises of 25 items regarding students’ use of cognitive strategies (e.g. “I memorize key words to remind me of important concepts of digital logic”), meta-cognitive strategies (e.g. “When trying to solve problems, I make up questions to help focus my reading” and “When studying, I copy my notes over to help me remember the materials”) and volitional strategies (e.g. “Even when I do poorly in a test, I try to learn from my mistake” and “Even when materials are uninteresting, I keep working until I finish”). All statements were ranked on a scale of 1 to 5 (from 1 “Not at all true for me” through 5 “Always true for me”).

Given the new learning opportunities, students engaged in goal-setting, strategy selection and adaptation, self-monitoring, and self-evaluation. Based on results after administering the questionnaires, students became more skilled at using SRL strategies. Through deliberate practice with self-assessment, even low-performing students gradually increased their self-efficacy. They no longer shy away from the challenging tasks. Students believe that they can learn and improve.

In addition to the data obtained by administering the questionnaires, additional interviews with students confirmed that engaging in the SRL strategies and participating in the activities that were intentionally built into the course did encourage such skill acquisition. There was a shift in students’ attitudes, behaviors, knowledge, and motivation. Overall, students became more active and collaborative participants in the classroom and laboratory. These experiences will impact their ability to perceive themselves as capable of regulating their own learning.

The relationship of meta-cognitive awareness, pre-test confidence, and self-regulation is an important variable that needs to be explored. In the Digital Logic class, students took specifically formatted bi-weekly tests[27] which required them to make a self-efficacy judgment. Prior to taking the test, students were asked to report the number of hours they had studied, how many points they would have to achieve to be satisfied with their performance (satisfaction goal), and how confident they were about achieving their satisfaction goal. After completing the test, but before they were graded, students also needed to identify how many points they believed they would achieve on the test and how confident they now were about their achieving their satisfaction goal.

In addition, when the students received their corrected tests, they received a Self-Reflection Form at the same time. For each incorrectly answered question, students needed to explain the discrepancy between their actual performance and their perceived level of performance. Then, students were given an opportunity to solve a similar problem and earn additional credit. Self-regulation involves small changes over time within, as opposed to across, individuals. This process can provide students with continuous evaluating information and give them the chance to self-evaluate their learning.

At the beginning of the semester, the results showed that there were significant differences between low-performing students and high-performing students regarding their ability to predict (before taking a test) and postdict (after taking a test but before receiving their grade) their test results. The high-achieving students were more accurate at predicting their test results and more realistic in their goals. They were better able to distinguish between known and unknown

information. In other words, high achieving students were effective at estimating their understanding. These students are more inclined to adjust their goals and self-efficacy based on their test results. However, low performing students were poor at predicting test results. It seems that they were unable to monitor their knowledge of the course material. They usually overestimated the test results in both prediction and postdiction. They were unable to regulate their studying to assure mastery of a body of information.

Thus, as students are required to take on more challenging academic tasks, it is important that students have the meta-cognitive skills to assess their mastery of the material. Students who are aware of the level of their mastery of material can adjust their study time and strategies. This meta-cognitive awareness is essential to the application of self-regulated learning. This study shows that frequent evaluation and immediate feedback can assist students in improving their self-awareness of their learning. Throughout the semester, students have become more meta-cognitively aware.

At the end of the semester, every student in the class, except one, received a passing grade (C or above). This group of students outperformed those from the previous years'. The student who received the D grade has changed his major and has decided to transfer to the School of Education. The rest of the students will stay in the program and continue their education. In this paper, we presented the initial results of an ongoing study in which we examine the relationship between self-regulation and learning outcomes for technology students. In general, these preliminary results seem to indicate that students could profit from instruction that emphasizes the understanding and use of the strategies and attitudes of SRL.

9. Conclusion

Interest in academic self-regulation has increased considerably in recent years. This study provided instructional strategies that address a wide spectrum - the cognitive, behavioral, and motivational aspects of self-regulation. However, the strategies presented here do not exhaust all that instructors might do to enhance self-regulated learning. They merely provide a starting point. This study also produced several meaningful findings. These findings might serve as a baseline for future research. Overall, much more research is needed. In order to broaden the scope of this study, future research studies should utilize larger student populations from other engineering/technology classes.

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Appendix

Self-Assessment Questionnaires (Sample Items)

Instructions: Please *circle* the most appropriate response when answering the questions. Your rating should be on a 5-point scale (from 1 "Not at all true for me" through 5 "Always true for me").

I expect to do very well in this class.	1	2	3	4	5
Getting a good grade is a satisfying thing for me, value beliefs.	1	2	3	4	5
Understanding this subject is important to me.	1	2	3	4	5
I work hard to get a good grade even when I don't like a class.	1	2	3	4	5
I think I will be able to apply what I have learned in this class in other courses.	1	2	3	4	5
I am certain I can understand the most challenging problems.	1	2	3	4	5
When I take a test, I think about how poorly I am doing.	1	2	3	4	5
I approach most of my classes with considerable confidence because I know what I am capable of academically.	1	2	3	4	5
I memorize key words to remind me of important concepts of digital logic.	1	2	3	4	5
When trying to solve problems, I make up questions to help focus my reading.	1	2	3	4	5
I try to pick out and write down the main points during a class lecture.	1	2	3	4	5
When studying, I copy my notes over to help me remember the materials.	1	2	3	4	5
I work on practice exercises even when I don't have to.	1	2	3	4	5
Even when I do poorly in a test, I try to learn from my mistake.	1	2	3	4	5
I turn my assignments in on time and keep up with the assigned reading in my courses.	1	2	3	4	5
Even when materials are uninteresting, I keep working until I finish.	1	2	3	4	5