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Author
Dr. Mohammed Ali
Associate Professor in the Department of Technology at the University of Texas at Tyler

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ATMAE
3801 Lake Boone Trail
Suite 190
Raleigh, NC 27607

www.atmae.org

Dr. Mohammed Ali is an Associate Professor of Industrial Technology and Industrial Management at the University of Texas at Tyler. As a proud professional member of the ATMAE since 2007, he has been actively involved in the capacity of CMS certification exam commission, and program evaluator of the ATMAE accreditation board. His research articles have published in 40 plus peer reviewed journals and books, and in 50 national/ international conference proceedings. His teaching and research interests are: innovative pedagogy in technology and applied engineering, additive bio-manufacturing and advanced manufacturing facility, automatic data identification and capture, CAD, CIM, PLC, SCM, manufacturing of smart drug delivery devices, nano and submicron particles spectrometry.

Self-Regulated Learning Pedagogy for Teaching Applied Engineering and Technology Class

ABSTRACT

This paper reports on the implementation of Self-Regulated Learning (SRL) tactics, a teaching innovation method where test subjects and embedded prompts simulate the iterative cyclical progression of Self-Regulated Learning. Self-Regulated Learning skills can be developed with various tactics, including activities that provoke the self-assessment or reflection of learning. Prior studies reported that when an instructor teaches students to construct their own SRL skills rather than predefined strategies, students gain better knowledge of course content. The four-phase SRL model has been implemented in computer aided drafting, a common course in applied engineering and technology curriculums. The four phases are as follows: planning and designing, identifying priorities and allocating resources, executing and self-monitoring, as well as evaluating and controlling. The four phases are intended to provide students with training and experience to efficiently practice and develop metacognitive strategies for a successful completion of the course content. For this study, students were informed in advance to prepare for an upcoming quiz on the content. They were asked to make self-efficacy assessment, measure confidence in correctly completing the quiz, plan for preparation for the quiz, and identify learning priorities and resources. After finishing the quiz, students were asked immediately to make self-evaluative judgment on correctly completing the quiz again. The instructor graded the quiz and intimated correct answers as feedback. Additionally, students were encouraged to think what strategy(s) worked well and how to improve unsuccessful methods. Students were informed of a second quiz, and instructed to apply successful strategies, prioritize and adopt learning resources. The instructor graded the second quiz, and returned it to students so they could reflect on their SRL skills. Results showed that the SRL doubled students' quiz scores. Overall, findings of this study demonstrated the innovative method's positive impact to student learning, which can be replicated in other applied engineering and technology courses.

Introduction

Metacognitive strategies are intrinsic to student self-regulated learning (SRL) activities, such as awareness of planning (setting learning goals), monitoring (self-testing), regulating (determining the best way to learn), and control their cognition, motivation and behavior (Teng & Zhang, 2016). Flavell (1997) defined metacognition as the active monitoring and management of cognitive process to achieve cognitive goals. If learners apply these methods to generate information about the efficiency of these strategies and successfully implement their learning processes, they can control their cognitive activities. Cognitive activities are ways in which people learn, acquire knowledge and interact with their surrounding environment to solve problems and make decisions (Meyers & Loehr, 2009). Students are most likely to succeed when they have control and accountability over their learning.

In the epilogue of many SRL studies, it has been agreed that self-regulation is a recurring process and comprised of three following phases: Planning, Execution, and Self-Reflection (Panadero 2017; Zimmerman, 2000; Zimmerman & Campillo, 2003; Greene & Azevedo, 2007). In the Planning phase, learners set goals, make strategic plans, and judge their self-efficacy. Next in the Execution phase, learners perform and control their learning efforts, and apply learning management and self-monitoring strategies. Lastly, in the Self-Reflection phase, learners evaluate their personal mastery and causal attributions. Here, they respond to the learning task and evaluate their performance after learning efforts. This process leads them back to the planning phase that precedes the efforts in the next learning cycle. In a learner's psychology study, Boekaerts (1997) identified that several learner's competencies of self-regulation which foster self-regulated learning such as cognitive, metacognitive, and motivational aspects.

The importance of SRL practice for effective learning is further strengthened by points raised in other studies. Those studies revealed where self-regulated learners are commonly able to recognize their learning strengths and weaknesses, possess a repertoire of cognitive and metacognitive strategies, select and apply those strategies to achieve their learning outcomes. Also, students are able to assess and reflect on their learning and skills based on feedback, and articulate effective strategies for their use and transfer in the future learning (Paris & Paris, 2001; Dweck & Leggett, 1988; Dweck, 2002).

In order to familiarize students with developing SRL skills, Somuncuoglu & Yildirim (1999) suggested that metacognitive strategies in SRL could be taught by integrating self-regulated activities. This process can increase the students' awareness of planning (setting learning goals), monitoring (self-testing), and regulating (determining the best way to learn) into students' learning processes. In another application, students were encouraged to construct their SRL skills rather than teaching predefined strategies, and suggested that SRL skills could be constructed by promoting self-regulation. That regulation could come in the context of meaningful work, requesting students to articulate strategies in their own words, and/or asking students to reflect on when and why certain strategies promote success (Butler, 2002, Paris & Paris2001). The study also came to the conclusion that SRL skills could be developed with various procedures, including activities that provoke the self-assessment or leaning reflection.

Purpose

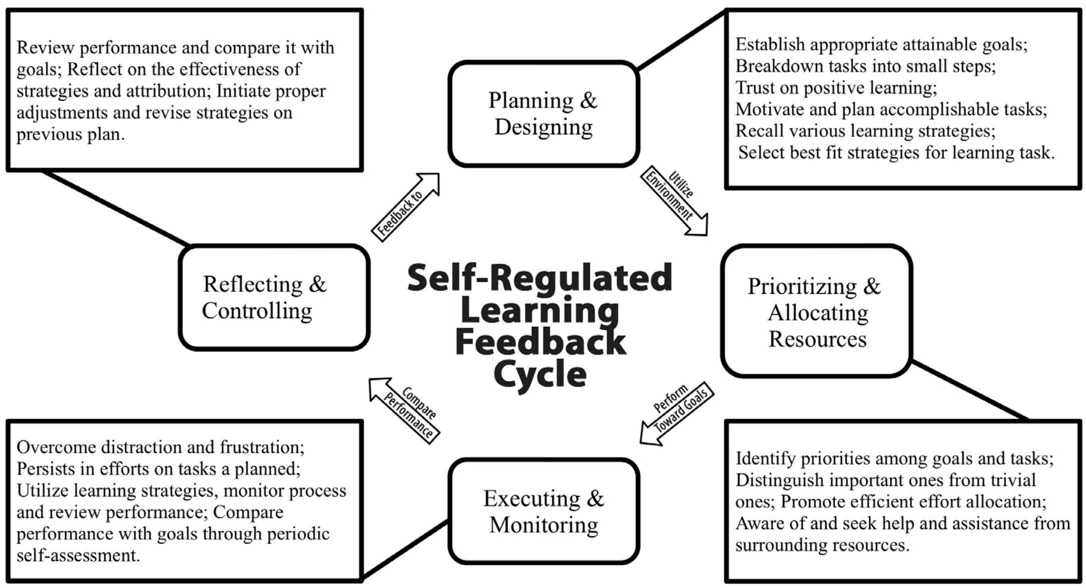
Even though the SRL skills have been applied to disciplines other than engineering and technology education in the past, it has drawn attention recently. In the course of two-year engineering technology program, Blank et al. (2006) applied the SRL strategy based on assessment through the self-assessment-for-learning (SAL) method. Likewise, the main purpose of this study was to make a hypothesis on SRL strategies application as well as testing that hypothesis on a four-year applied engineering and technology (AET) course with little modification to proposed SAL by Blank et al (2006). In their method, a series of self-assessment questionnaires embedded into class tests were adopted to help students learn more effectively through tracking and assessing their academic learning and developing self-regulation skills. These questionnaires replicated a three-phase SRL in a series of self-directed feedback cycles. Those cycles include planning, practice, and evaluation phases. Whereas, in this study we added a prioritizing and resource allocation phase between the planning and practice phases. Their study revealed that while employing the deliberate practice with SRL assessment, students of an engineering technology class were able to acquire additional skills. These skills were used while applying both metacognitive and external feedback to continuously adjust and improve their learning efforts. Likewise, this work aimed to test the four-phased SRL strategies impact on AET students' learning outcomes.

Methodology

As explained in the "Purpose" section, this study adopted the SRL assessment and its implementation procedures developed by Blank et al. (2006) with some modifications and then implemented those techniques in AET courses. The adapted SRL assessment framework essentially integrated SRL skills development with traditional course quizzes/exams. The assessment also facilitated students to utilize their test preparation process as the learning platform to select, practice and build SRL strategies and skills. It also promoted them to use their quiz grades as the feedback to assess, reflect and adjust their learning. The modifications made by the author of this paper include emphasizing the stage of identifying the learning priorities and resources, adding the repertoire of learning strategies and their corresponding prompts in self-assessment. Additionally, the modified approach provided more time for students to reflect on their previous learning and planning and finally testing among different SRL cycles. Those modifications are further described subsequently in details.

Before implementation of the SRL assessment in AET class, the SRL conceptual model and selected SRL strategies were presented to students through the course lecture and handouts. The presented SRL process model is a four-phase model as shown in Figure 1 and was modified from the three-phase model as proposed by Zimmerman (2000) and implemented by Blank et al. (2006).

Figure 1.
The four-phase SRL recurring process model.



The four-phase model divides SRL into four phases. Those four phases of learning goals are as follows: planning and designing, identifying priorities and allocating resources, self-monitoring, evaluating and controlling particular SRL components for each phase. In this SRL process model, identification of priority and resource are separated from the planning phase in the typical SRL three-phase model. This separation was made to particularly emphasize the importance of students' organizing their information and knowledge. This theory was based on their priority and allocation of available resources or help from their environment as suggested by Paris and Winograd (2003). Based on this new SRL process model, a specific phase is added into students' self-assessment and learning processes. Here, students are required to identify the priority in the learning topic and learning resources (e.g., reference, peer discussion, or instructor help) for assisting and improving their learning efforts.

The overall general procedures for implementing the SRL assessment in the computer aided drafting (CAD) course are outlined as follows:

1. The instructor presented the SRL conceptual model and selected SRL strategies to students through the course lecture and handouts at the beginning of the course.

2. The instructor selected a core comprehensive learning objective of the CAD course. Upon successful completion of the course students will be able to understand CAD user interface, menus, toolbars, and modeling techniques by successfully passing quizzes and exams with a 70% or better.

3. The instructor created first set of quiz questions keeping in mind: a) students are in the third week semester; b) they are to some extent familiar with the course's technical content but not deeply exposed; c) testing on conceptual understandings rather than memorable points.

4. The instructor informed students in advance to prepare for this upcoming quiz.

5. Before taking the quiz, students were prompted to think by answering questions that were embedded in the quiz (see Table 1). They were first asked to make a self-efficacy assessment on how confident they were in correctly doing the quiz. Next they were asked if they made a plan for preparing the quiz, and identified learning priorities and resources as well as to what extent they had used the cognitive or metacognitive strategies presented before for preparing for the quiz.

Table 1.
SRL Assessment-Plan (before taking the quiz)

INSTRUCTIONS: Think on each of the following questions, and circle the number that represents the extent to which you agree. The ranking on the numerical scale indicates where 1 = not true, ……, 3 = partly true, ……, 5 = very true	
Are you very confident to solve the quiz problem correctly without help?	1, 2, 3, 4, 5
Have you made a plan for preparing the quiz or exam, after you were informed about this quiz or exam?	1, 2, 3, 4, 5
Have you identified the priorities in preparing the learning subject that the quiz or test would cover, such as reading notes, textbook, and sample problems?	1, 2, 3, 4, 5
Have you sought or would you be willing to seek the help from the instructor or peers if you have problems in understanding the subject?	1, 2, 3, 4, 5
Have you read the textbook and class notes on possible questions that would be asked in the quiz?	1, 2, 3, 4, 5
Have you used these strategies when you prepared for the quiz?	1, 2, 3, 4, 5

6. After finishing this first quiz, students were asked to immediately make a self-evaluative judgment on their confidence in correctly doing the quiz again.

7. The instructor graded the quiz and provided students with suggestions about the right answers on the students' test sheet or in the class lecture.

8. After obtaining their graded tests, students were prompted to think and answer questions that were provided in the additional reflection sheet (see Table 2). They were first asked to compare their confidence ratings before taking the quiz and after receiving graded score. Also, they were asked to describe what SRL strategy(s) did/didn't actually help in their learning and encouraged to use successful strategies, revise unsuccessful strategies or select new strategies for their future learning.

Table 2.
SRL Assessment - Evaluate and Reflect (after reviewing the graded quiz)

STRATEGY DESCRIPTION	**RESPONSE TYPE**
After getting your quiz back, what did you learn by comparing your grade with the confidence estimates you made before doing the test and after getting the test grade?	Statement by Student
Explain what strategies or processes helped you correctly solve the quiz problems.	
• I have searched my memory on the topic content that I have read or learned.	1, 2, 3, 4, 5
• I have recalled the solution procedures to similar problems.	1, 2, 3, 4, 5
• I found answers from understanding the concept of problem subject.	1, 2, 3, 4, 5
• I transferred the solution of similar problems to the quiz problem.	1, 2, 3, 4, 5
• Other method: (specify)	1, 2, 3, 4, 5

Table 2.
Continued

STRATEGY DESCRIPTION	RESPONSE TYPE
You conceptualize or imagine how to transfer the successful strategies or processes into other settings.	Statement by Student
Explain what strategies or processes helped you correctly solve the quiz problems.	
• I cannot remember an important concept or principle I learned on the quiz subject.	1, 2, 3, 4, 5
• I cannot remember an important concept or principle on the prerequisite subject, such as math.	1, 2, 3, 4, 5
• I did not read the quiz problem carefully and misunderstood the problem.	1, 2, 3, 4, 5
• I cannot understand the content I learned on the quiz subject.	1, 2, 3, 4, 5
• I cannot connect/ apply what I learned to the quiz problems.	1, 2, 3, 4, 5
• I cannot break the problem into sub-problems and come up with solution.	1, 2, 3, 4, 5
• I cannot connect what I have learned and put it with a solution.	1, 2, 3, 4, 5
• I cannot examine whether my solution is the correct one and/or find the errors to correct.	1, 2, 3, 4, 5
• Other strategies: (specify)	1, 2, 3, 4, 5
Please make comments and reflection on the above learning strategies that make you successful.	
Please make comments and reflection on the above learning strategies that make you unsuccessful.	

9. Upon completion of the SRL Assessment-Reflection-Evaluation, students were informed of the upcoming quiz addressing the same course learning objective in advance and were prompted to think and answer questions in the questionnaire (see Table 3). Here, they were asked to think what strategies they would use to prepare for the next quiz, and prompted to identify strategies, priorities, and successful preparation techniques. Then they were encouraged to practice these techniques.

Table 3.
SRL Assessment - Re-plan for the next phase (after reviewing the graded quiz)

ADJUST AND PLAN	
What strategies will you use to prepare and correctly solve the new problem on the same subject?	Statement by Student
Are you now confident that you can correctly solve this similar item?	Statement by Student
PRIORITY AND RESOURCE	
What are your priorities in preparation for the next problem?	Statement by Student
What resource will you use for your preparation?	Statement by Student

Table 3.
Continued

PRACTICE	
Have you practiced the strategies that you found helpful?	Statement by Student
How many times in a week you have practiced helpful strategies?	Statement by Student

10. The instructor created the last set of quiz questions while keeping in mind the following circumstances: students are at the end of the semester, they are supposed to be most familiar with the course's technical content, and students were tested on conceptual understandings rather than memorable points.

11. The instructor administered the last quiz, and the steps 5 through 8 were repeated.

The above implementation procedures, selected test subjects, and embedded prompts were actually designed to simulate the iterative cyclical progression of self-regulated learning and problem solving in the context of a series of specific learning subjects and problems from the simple level to the complex. Thus, the progress in these learning tasks actually imitated the four-phase SRL by providing students with training and experience to efficiently practice and solve problems in an evolving manner.

HYPOTHESIS FORMATION

The study's objective was to determine if SRL pedagogy indicated a positive contribution to student achievement in an AET course. The increase of most students' score of post-SRL-implementation quizzes will demonstrate the positive contribution to students' achievement. Therefore, collected data was tested at the five percent significance level ($\alpha = 0.05$). The hypothesis of the study is as follows:

Null hypothesis: H_0: $\mu_a - \mu_b = 0$, there is no contribution of SRL to the students' achievements, i.e., sample's mean scores before (μ_b) and after (μ_a) are remained same.

Alternative hypothesis: H_1: $\mu_a > \mu_b$, there is a positive contribution of SRL to the students' achievements, i.e., sample's mean score increased upon implementation of the SRL.

Findings and Implications

FINDINGS FROM RESULTS ANALYSIS

The iterative cyclical progression of SRL and problem solving in the context of specific learning methodology in an applied engineering class by the same set of student participants generated two groups of data with means and standard deviations (SDs). Because the sample size is small, we use Equation 1 to get the SDs of each data set.

Equation 1.

$$s = \sqrt{\frac{\sum x^2}{n-1} - \frac{n(x-bar)^2}{n-1}}$$

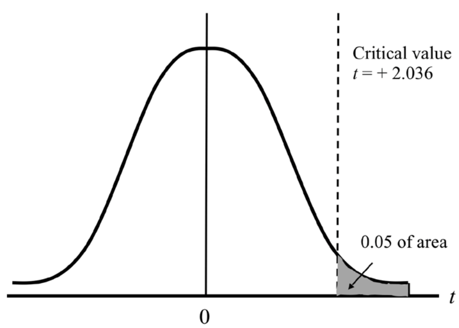
In Equation 1, symbol s is the sample standard deviation, x is an individual participant's score, x-bar is the observed average (mean) of the sample, and n is the sample size. This data is recorded in Table 4.

Table 4.
Quiz score out of 10 before and after the application of self-regulated learning techniques, and improvements with their mean and standard deviation (SD)

Quiz Score of Student Participants		Mean and SD
Student ID	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33 (sample size $n = 33$)	
Before	4, 3, 4, 3, 2, 2, 4, 3, 1, 5, 4, 5, 3, 3, 4, 5, 3, 3, 4, 5, 3, 3, 3, 4, 5, 5, 2, 2, 3, 3, 5, 4, 5	3.55 and 1.26
After	6, 6, 10, 8, 5, 5, 5, 6, 5, 6, 10, 10, 5, 6, 10, 10, 5, 10, 10, 10, 5, 10, 6, 10, 9, 7, 5, 6, 10, 6, 6, 10, 6	7.39 and 2.58
Improvement in score	2, 3, 6, 5, 3, 3, 1, 3, 4, 1, 6, 5, 2, 3, 6, 5, 2, 7, 6, 5, 2, 7, 3, 6, 4, 2, 3, 4, 7, 3, 1, 6, 1	3.85 and 2.90

Literature suggested that dependent and small size samples enabled more precise analysis of hypothesis testing using t-distribution, because such samples allowed investigators to control unimportant factors (Levin et al., 2016). Figure 2 illustrates the results analysis graphically. Because the study was focused to know whether the SRL contributes to the students' achievements positively or not, an upper-tailed test was not necessary.

Figure 2.
SRL impact on student achievement, one-tailed hypothesis test at the 0.05 level of significance



The 0.05 significance level is shown in Figure 2 as the filled area under the t distribution. The appropriate number of degrees of freedom is 32 (33-1). The positive area under the t-distribution at $\alpha = 0.05$ is 2.036. Analysis of the results began by computing individual increase of quiz scores, their mean and standard deviation as recorded in Table 4. Now we can estimate, $\delta_x = 0.505$ the standard error of the mean by using following equation:

Equation 2.

$$\delta_x = \frac{s}{\sqrt{n}}$$

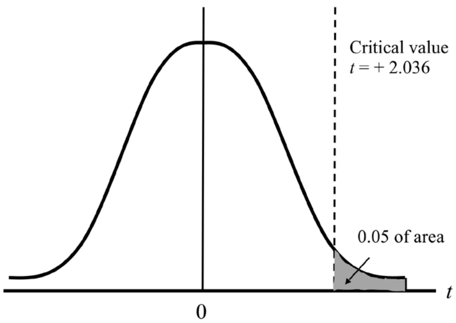
Next, the observed average score increase was standardized, x-bar = 3.85, by subtracting the null-hypothesized value $(\mu_a - \mu_b = 0)$, and dividing by δ_x. The estimated standard error of the mean is shown in the following equation:

Equation 3.

$$t = \frac{x - bar - (\mu_a - \mu_b)}{\delta_x}$$

The standardized statistic or t value was 7.62 upon plugging in the values of the parameters in the equation 3. Figure 3 illustrates the location of the sample score improvement on a standardized scale. It is now observed that the sample mean lies outside the acceptance region. Thus the null hypothesis can be rejected, and one can conclude that the implementation of SRL techniques gave a positive outcome to student achievement.

Figure 3.
SRL impact on student achievement, showing the acceptance region and the standardized sample mean at the one-tailed hypothesis test with 0.05 level of significance



Further analysis of the recorded data also revealed more noteworthy findings. For example: none of the students made above 6 before implementation of the SRL, and about 25% students scored 6 irrespective of implementation of the SRL. Furthermore, about 25% students raised their score 80% or higher from Pre-SRL quiz. Survey data from student participants demonstrated a few more important findings as shown in Table 5.

Table 5.
Self-regulated learning strategies and their effects reported by study participants

STRATEGY	CONTRIBUTION TO SCORE INCREASE
Memorize & practice everything you're told to memorize (e.g., CAD icons, short-cuts)	78%
Spend some time on CAD everyday	65%
Use the study cycle with intense study sessions	50%

IMPLICATIONS

The SRL body of knowledge has developed an umbrella of models and research directions over the past two decades, which warranted the testing of variables that influence students' learning. This work tested SRL on students of an applied engineering class. The study demonstrated that SRL can positively and effectively intervene and enhance learning efficacy of under-performing students. Specifically, the four-phase model showed that SRL doubled students' quiz scores upon execution in their learning processes. Furthermore, SRL is based on proven instructional techniques when paired with strategy instruction and metacognitive processes. The SRL technique becomes powerful learning tool to uson learners. Ultimately, if the educators' goal is to create successful student learners through monitoring and managing their own learning skills and habits, then they must teach students the strategies necessary for that journey.

LIMITATIONS

The survey items in the Tables 1-3 provided self-reported data by the students i.e., perceptions of participants which may not be completely reflected in the scores achieved after going through the SRL. However, an attempt to check the credibility of the data was done by comparing questionnaire responses against actual performance in the quiz score (Table 4) for each participant. A close correlation was found between them. Present study sample size (33) may be low in order to derive wide generalization across the entire AET discipline. In spite of that, it is believed that the study findings have practical values and pedagogical implications, and suggest that the educators may apply SRL techniques for other AET courses.

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