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Self-Regulated Learning Strategies of Engineering College Students While Learning Electric Circuit Concepts with Enhanced Guided Notes

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Abstract

The current study evaluated engineering college students' self-regulated learning (SRL) strategies while learning electric circuit concepts using enhanced guided notes (EGN). Our goal was to describe how students exercise SRL strategies and how their grade performance changes after using EGN. Two research questions guided the study: (1) To what degree students' grade performance change after using the EGN?; and (2) To what degree students' SRL profiles change after using the EGN? The subjects for this study were 97 engineering students enrolled in the Fundamental Electronics for Engineers course at a university in Utah. A survey instrument developed using Butler and Cartier's SRL model was used to capture SRL strategies with a focus on the sixth feature which includes including planning, monitoring, and regulating. Regular examinations and the DC/AC conceptual inventory were used to assess grade performance. Descriptive statistics, independent and paired t-tests, and a cluster analysis technique were used to analyze survey data. A phenomenological data analysis was used to analyze interview transcripts to support findings from questionnaire data. The findings revealed an improvement on students' grade performance. Data analysis of the SRL survey revealed that students' had different SRL profiles. Students in the improved group reported a greater awareness of planning, monitoring, and regulating strategies. On the other hand, those in the declined group showed a lower awareness of the SRL strategies at the end of semester. In addition, emergent themes related to students' SRL and learning experience while using the EGN were found. This article will also discuss the potential implications for electric circuit concepts instructions.

Keywords: electric circuit, enhanced guided notes, note-taking activity, self-regulated learning

1. Introduction

A growing body of literature suggests that, in general, classroom activity does not stimulate students to actively engage in learning (e.g., Lord, 1994; Steward-Wingfield & Black, 2005). Specifically in engineering education, many instructors currently focus on writing engineering formulas and solving problems on the whiteboard, and sometimes ask students to verify their understanding. Elshorbagy & Schonwetter described this teaching practice as "deductive instruction, where the instructor is viewed as `the sage on the stage'" (Elshorbagy & Schonwetter, 2002, p. 297). During traditional lectures, students are generally passive (Dorestanni, 2005; Felder & Brent, 2004; Steward-Wingfield & Black, 2005), and consequently, information received passively with no attendant action is not readily retained in long-term memory (van Eynde & Spencer, 1988). Research also suggests that students learn best when they take an active role in learning through discussion, practicing, games, and applying concepts and ideas (Chickering & Gamson, 1987; Cortright, Collins, & DiCarlo, 2005; Mierson, 1999; Sarason & Banbury, 2004). A recent study involving engineering students found that active learners achieved greater levels of learning and motivation than did their passive peers (Gonzalez, Rodriguez, Olmos, Borham, & Garcia, 2012). However, these activities are often impractical to conduct, particularly in large classes.

A major concern of most instructors is about the effectiveness of the lectures in facilitating students' learning. Studies have shown that students' attention during lectures declines after 10-15 minutes (Anderson & Armbruster, 1991; Davis, 1993; Hartley & Davies, 1978). According to Hartley and Davis (1978), the amount of notes written declines over the course of a lecture. Unless the students' attention is focused on what the instructor is saying, there is little chance that meaningful processing and note taking will follow. Another study revealed that only approximately half of important ideas from learning content were recorded by students (Anderson & Armbruster, 1991). Konrad, Joseph, and Itoi (2011) suggested that a note-taking activity can improve an individual's concentration. Guided notes are prepared by instructors and contain incomplete text, diagrams, and graphs. Students must listen to their instructor and think critically in order to answer the prompted questions and fill in missing parts of the information. According to Kobayashi (2005) and also Hohn, Gallagher, and Byrne (1990), one of the benefits of note taking is the development of higher-order thinking skills. Previous studies have been conducted to develop and evaluate guided notes, and a limited study has been conducted by involving a variation of self-regulated learning prompts used to learn electric-circuit concepts. The objective of this study was to describe how EGN influenced students' practice of SRL strategies and how their grade performance changed after using the enhanced guided notes.

2. Relevant Literature Review

2.1 How Do Enhanced Guided Notes Differ from Standard Guided Notes?

A previous study revealed that up to 94 percent of college students believe note taking is an important component of the educational experience (Williams & Eggert, 2002). Peper and Mayer (1978) found that note takers recalled more conceptual ideas than did non-note takers and suggested taking notes helps students to integrate the lecture content with their existing knowledge base. There is also a positive correlation between note taking during lectures and learning performance. Students who record notes during lectures generally demonstrate a better learning performance than those who only listen to the lectures (Kiewra, 1985). Although the note-taking process is believed to positively impact learning performance (Narjaikaew, Emarat, & Cowie, 2009), other studies have found that students lack the note-taking skills to record relevant information, a situation that may create problems for students in later experiences (Austin, Lee, & Carr, 2004; Kiewra, 1985; van der Meer, 2012).

This study focuses on "semi-structured" notes provided by the instructor. Popularly called "guided notes," these may reduce students' cognitive load, thereby helping engineering students to focus their attention on and engage in cognitive processing of the lecture contents while developing relatively complete notes for later review. Guided notes contain incomplete information with blank spaces consisting of essential concepts, ideas, diagrams, graphs, problems to solve, and conclusions. Standard guided notes, which also called semi-notes or skeleton-notes, have been used in undergraduate teaching for quite some time. Unlike the guided notes introduced in many studies (e.g., Hohn, Gallagher, & Byrne, 1990; Hosain, 1994; Narjaikaew, Emarat, & Cowie, 2009), the enhanced-guided notes (EGN) developed in this study include questions that prompt students to assess their self-regulated learning (SRL) strategies. This component is not present in the standard guided notes. The questions appear throughout the guided notes, including the introduction of each topic, elaboration of the theoretical concepts, and during problem solving. Through the EGN, students engage in the learning process with their instructor during lectures. Students practice their SRL strategies by responding what/why/how questions regarding the material covered on the EGN. Besides conceptual theories, formulas, and problems to solve, EGN include questions that prompt students to assess their understanding about theories, problem-solving strategies, and the principal concepts related to the topic of discussion. Moreover, students can reflect on their learning activities through a self-reflection section designed to elicit their understanding of particular topics at the end of the class meeting. Compared to traditional lecturing methods in most colleges, these new learning materials and strategies may offer students an enhanced learning experience that more effectively utilizes the lecture time.

2.2 What is Self-Regulated Learning?

Zimmerman argued that self-regulated learners are "metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 1989, p. 329). While many models of SRL have been offered (Butler & Winne, 1995; Pintrich, 2004; Winne & Hadwin, 1998; Zimmerman, 2002; Zimmerman & Schunk, 2001), this study chose Butler and Cartier's model of self-regulation. The main reason was because the Butler and Cartier model described the association between cognitive and metacognitive strategies that represent SRL as a dynamic and contextual learning process (Butler & Cartier, 2004, 2005; Cartier & Butler, 2004; Butler & Winne, 1995). The model consists of eight major features (i.e., SRL features) that interact with each other:

Part A **Before We Begin** **EGN Set 1: *DC Voltage, Current & Resistance***

Readings

DC Voltage-pg 35-38, 41-54	DC Current-pg 38-41	Resistance-pg 65-88

Part B **Conceptual Layout**

1. DC Voltage

Objectives: (1) To understand how the terminal voltage of any DC supply is established; and (2) To understand how the terminal voltage of any DC supply creates a flow of charge in the system.

What is the difference between DC & AC supply?

What do you already know about DC "voltage"? How does DC voltage exist in connection to AC voltage?

Example 1 Let's find the amount of energy that would be required to create 12 volts of potential by moving 1 coulomb of negative charge.

What theoretical principles or laws do you need to use
How do you use your theoretical principles or laws?
Should you expect to get these answers?

Part C **Problem Solving**

…

Problem 2: Let's calculate how many hours a 16 volt DeWalt drill will be useful if it has an 8 ampere-hours rating and provides a current of 2.5 amps.

Sort the use of relevant concepts/formulas in the box to solve this problem:

-
-

Write your solution below:

Part D **Quick Reflections**

1. Conclusions

- Every source of voltage is established by creating a separation of positive and negative charges.
- One coulomb of charge is the total charge associated with 6.242 x 10^{18} electrons.
- ……
  ……

2. Self-evaluation

	Statement	My Answer
1	If an electrical circuit can operate for XX hours with a 2-Ah battery, what is the average current that the circuit demands? (A) 0.2 A ; (B) 2 A ; (C) 5 A ; (D) 20 A	A B C D

…

Figure 1. Enhanced Guided Notes: An illustration

Layers of context, what individuals bring, mediating variables, task interpretation, personal objectives, SRL processes, cognitive strategies, and performance criteria.

The *first feature*, layers of context, may include the learning environments such as school, classroom, teachers, instructional approaches, curricula, and learning activities (e.g., reading, writing, and problem-solving). Recognizing the ways in which multiple interlocking contexts shape and constrain the quality of student engagement in learning is essential for understanding SRL. The *second feature*, what individuals bring to the

context, includes factors such as student strengths, challenges, interests, and preferences. Over time, students accumulate a learning history that shapes their development of knowledge and skills, self-perceptions, attitudes toward school, and concepts about academic work. The *third feature*, mediating variables, involves knowledge, perceptions about their competence and control over learning, and perceptions about activities and tasks. These variables also include emotions experienced before, during, and after completing a task. The *fourth feature* is student task interpretation. Task interpretation (or task demand) is the heart of the SRL model insofar as it shapes key dynamic and recursive self-regulating processes. Students' interpretation of task demands is a key determinant of the goals set while learning, the strategies selected to achieve those goals, and the criteria used to self-assess and evaluate outcomes.

Students set personal objectives, the *fifth feature*, such as achieving task expectations that impact their direction for engaging or not engaging in learning. Students manage their engagement in academic work by using a variety of SRL strategies, the *sixth feature* in the Butler and Cartier model: planning, monitoring, evaluating, and adjusting approaches to learning. Students prepare their learning activity, select strategies for task completion, self-monitor progress, and adjust goals, plans, or strategies based upon self-perceptions of progress or feedback and performance. These strategies are iterative and dynamic endeavors. The *seventh feature*, cognitive strategies, refers to students' cognitive activities employed as they engage in their learning, as planned, monitored, and adjusted through self-regulating strategies. Performance criteria, the *eighth feature*, are the standards against which students judge their progress during learning. Our focus in this study was more specifically on the sixth feature of Butler and Cartier model (i.e., planning, monitoring, evaluating, and adjusting approaches to learning).

Numerous studies reported that self-regulated learning strategies benefit students in their learning activities (e.g., Matuga, 2009; Zimmerman, 1990). However, the use of SRL strategies is varied among students depending on their understanding of and experience with self-regulation. Previous studies revealed that self-regulated learning can be improved through specific interventions including the teacher's guidance in problem-solving activities (e.g., Marchis, 2011; Samuelson, 2008). Using note taking to measure the improvement of self-regulated learning strategies is a relatively new approach. The enhanced guided notes, an example of note-taking tools, can be used as the intervention because they encourage students to plan appropriate strategies to solve problems, monitor their understanding, and adjust strategies when difficulties occur. For example, before solving problems, students are prompted with questions such as "What theoretical principles or laws do you need to use to solve this problem?", "How do you use your theoretical principles or laws", and "Should you expect to get these answers?" After solving the problem, students are prompted with questions such as "Are you sure of your answer?" or "Does the solution make sense to you?"

2.3 Self-Regulated Learning and Information Processing

Self-regulated learning represents essential aspects of learning which consist of motivation, metacognition, behavior, and emotion of learners (Butler & Cartier, 2005; Zimmerman, 1989). This characteristic reflects that information processing is a central component of self-regulated learning. Different from behaviorists' points of view, cognitive researchers argued that learning processes are related to human mental processes, while managing relevant information such as monitoring, remembering, relating, searching, etc. (Huitt, 2003). Metacognition as a self-regulatory strategy may be considered as an executive or control function of cognitive processes in that planning, monitoring, and evaluating or regulating strategies are related to learning information (e.g., Brown, 1980; Flavell, 1979).

Students' skills in processing learning information are varied. Rozendaal, Minnaert, and Boekaerts (2001) suggested that two types of information processing, surface- and deep-level information processing are related to regulation. While surface-level processing is related to external regulation (e.g., memorizing the lecture), deep-level processing is related to self-regulation. Students who perform critical thinking, such as relating one concept to other concepts, clearly exhibit the self-regulation process. Guided notes help students focus on the lecture content. During lectures, students are expected to develop understanding far beyond knowing the surface facts. Instead, when they learn something new about a discipline, they integrate that learning with their prior knowledge, resulting in a growing complement of knowledge.

The enhanced guided notes in this study utilize the second concept of the information processing theory introduced by Miller (1956), which holds that there are three kinds of memory: sensory registers, short-term (or working), and long-term memory. Miller argued that once information is processed for 5 to 20 seconds in short-term memory, it will be then transferred to long-term memory. While the first concept is associated with the capacity of short-term memory, Miller's second concept suggests that information processing involves gathering and representing information, holding information, and accessing the information when needed.

Effective encoding occurs when information received is meaningful and activates one's prior knowledge. Miller (2011) emphasized that students' attention need to be maintained as she said, "Obtaining and holding student attention is critical, as is students' willingness and ability to focus on the material at hand" (p. 121). Prompts were given in the enhanced guided notes to trigger students' SRL strategies.

3. The Study

Our goal in this study was to describe how EGN influenced students' practice of SRL strategies and how their grade performance changed after using the enhanced guided notes. Butler and Cartier's SRL model was used to guide and shed light on the understanding of SRL practice regarding students' task interpretation and their planning, monitoring, and regulating strategies. Students' exam scores and DC/AC conceptual understanding were assessed to measure their grade performance. Two research questions guided the study: (1) To what degree students' grade performance change after using the EGN?; and (2) To what degree students' SRL profiles change after using the EGN?

3.1 Study Participants and Context of the Course

The participants for this study were one hundred and fifteen engineering students enrolled in the course, Fundamental Electronics for Engineers, during the fall 2011 semester, at a university in Utah. Eighty-four percent of these students who completed the survey (10 females and 87 males) had a cumulative GPA of 3.00 or higher. Sixteen percent had a cumulative GPA ranging from 1.00 to 2.99. Sixty-one percent were sophomores, followed by juniors (34%), seniors (4%), and freshmen (1%).

Table 1. Demographic information

Demographic factor	*N* (out of 97)	Percentage
Gender		
Male	87	90
Female	10	10
GPA		
3.00 or higher	81	84
2.99 or lower	16	16
Class		
Freshman	1	1
Sophomore	59	61
Junior	33	34
Senior	4	4

The course covered the study and application of direct DC/AC and digital concepts including circuit fundamentals, theorems, laws, analysis, components, digital design fundamentals, and combinational circuits design, equipment, and measuring devices. In the study during the fall 2011 semester, the instructor distributed eleven sets of enhanced guided notes to students in lecture sessions (e.g., "DC Voltage, Current & Resistance," "Voltage and Current", "Network Theorems", "Basic Elements and Phasors", and "Series and Parallel AC Circuits"). Students were encouraged to regularly review their EGN as the difficulty level of lecture contents were increasing throughout the semester. The use of these guided notes was intended to replace the one-way communication that was typical of class meetings. Students were asked to fill in the blank spaces found on the pages. The enhanced guided notes prompted students with what/why/how questions regarding the material covered to exercise their SRL strategies. Examples of these prompts were: "What would you expect of the relationship between v and i for a resistive circuit? Why?", "Can we use the same strategy to find the expression for v (if the expression for i is given?", and "Predict the formula to calculate the total impedance for a parallel circuit." Furthermore, at the end of the class meeting, students were asked to evaluate their learning process through a self-reflection section designed to elicit their understanding of particular topics.

3.2 Data Collection Procedures and Analysis

A self-regulated learning (SRL) questionnaire and DC/AC conceptual inventory were used in this study. Each questionnaire was distributed at the beginning and end of the semester. Both questionnaires were delivered through Qualtrics™, an online survey tool. The SRL questionnaire was adapted from the Inquiry Learning Questionnaire (ILQ) developed by Butler and Cartier, based on their theoretical model (Butler & Cartier, 2004, 2005; Cartier & Butler, 2004) and pilot-tested. As Butler and Cartier's SRL model emphasizes that learning is situated (Butler & Winne, 1995), the development of this questionnaire contextualized to the learning activity of Fundamental Electronics for Engineers class. The SRL questionnaire used in this study consisted of three subscales: planning, monitoring, and regulating strategies. Students were asked to rate themselves on a 4-point Likert scale (1 = *almost never*, 2 = *sometimes*, 3 = *often*, 4 = *almost always*). Subscales of the questionnaire have Cronbach's Alpha scores range from .637 to .870 (see Table 2 for examples of the SRL questionnaire items). The overall Cronbach's Alpha value was .862.

Table 2. SRL strategies and examples in the context of learning electric circuit

SRL strategies	Examples
Planning strategies (PS)	Before I begin the activity of learning and solving math, science, or engineering problems involving new concepts, I start by just reading the learning resources.
Monitoring strategies (Mon)	When learning and solving math, science, or engineering problems involving new concepts, I check whether I can describe the main topic of the subject.
Regulating strategies (Reg)	When I have difficulties learning and solving math, science, or engineering problems involving new concepts, I check to make sure I have completed everything required for the activity.

Furthermore, to capture the impact of EGN usage to students' grade performance, scores of regular exams and DC/AC conceptual understanding were evaluated. During the semester, three regular exams and one final exam were scheduled. In addition, the DC/AC Circuits Concept Inventory (20 multiple-choice questions) was used in this study. This questionnaire was designed by Holton (Holton, 2006; Holton & Verma, 2009) to identify students' misconceptions and what fundamental conceptual knowledge they lack. The Concept Inventory has acceptable reliability based on statistical tests including Item Difficulty, Kuder-Richardson 20 (i.e., reliability of internal consistency of the whole test), Ferguson's Delta (i.e., ability of test to discriminate by how broadly it spreads out the scores), and Item Discrimination Index (for detailed information, see Holton, Verma, & Biswas, 2008).

As a first step in analyzing data from the SRL survey, we excluded data of students who did not complete any parts of the questionnaires. In addition, the data were evaluated for irregularities. Specifically, we looked for anyone who responded to each survey item with the same answers (e.g., marked "4" for all items or blocks of items). From 115 engineering student participants in this study, 97 valid data sets were analyzed. Data analysis consisted of descriptive statistics, parametric tests, and cluster analysis. Descriptive statistics described profiles of the clusters of students. Furthermore, independent and paired *t*-tests were conducted to investigate whether significant differences exist. Cluster analysis was conducted to categorize students without using predetermined assumptions from the researcher. The procedure was conducted by cluster analysis technique that "groups data objects based on information found in the data that describe the objects and their relationship" (Tan, Steinbach, & Kumar, 2006, p. 490).This statistical technique was used to group students by using SRL strategies as parameter.

The researcher also used qualitative approach by conducting interview sessions as another source of data for this study (Creswell, 1998; Patton, 2002). The objective was to gather additional information about students' learning experience and their self-regulated learning (SRL) strategies. A semistructured interview was carried out at the end of the semester and audio recorded (Santoso, Boyles, Lawanto, & Goodridge, 2011). Students who had additional time after completing the last lab session participated in the interviews. Interviews were conducted by an external evaluator of the current research project. The interview analysis was not intended to confirm the level of students' SRL as found on questionnaire data; rather, the effort was conducted to provide a better understanding of how students use the EGN. Phenomenological data analysis, which includes identifying significant statements and construction of meaning or themes based on categorized transcripts, was used to

analyze the interview (Creswell, 2009; Hycner, 1985; Trenor, 2009). In this process, the researcher must carefully grasp the meaning of statements expressed by the students (Hycner, 1985). For purposes of this study, students' interview transcripts were examined for evidence of SRL strategies and learning experience while using the EGN. Interrater reliability was conducted to evaluate the degree of agreement between two research assistants in segmenting and coding. Specifically for the segmentation process, one complete statement from an interviewee could be identified as one segment or more than one segment. Both interraters were involved to code the segments into the learning experience of using EGN and the SRL strategies. Interrater reliability met acceptable levels for segmenting (98% agreement) and coding (92% agreement).

4. Findings

Our presentation of findings is organized by a report of analyses relevant to our two research questions. Analyses of quantitative and qualitative data are presented, first in relation to students' grade performance during the semester, and then students' SRL profiles.

4.1 Students' Grade Performance during the Semester

It is important to see how the use of EGN impact students' grade performance. We evaluated students' grade performance in three regular and one final exams to see how the use of EGN impacted learning. The findings showed that, on average, all students (n = 97) showed a steady increase in their exam scores, from exams 1 through 3, but they performed less well on the final exam. From paired t-tests, we found that the students reported significant improvement between exams 1 and 2 (t = -7.97, df = 96, p = .00), and between exams 2 and 3 (t = -4.13, df = 96, p = .00). The tests also revealed they had lower scores on the final exam compared to exam 3 (t = 5.04, df = 96, p = .00).

In addition to students' grade performance on regular exams, it was hypothesized that students (n = 97) could improve their DC/AC conceptual understanding after using the EGN. Paired t-tests (1-tailed) were conducted to determine whether significant improvement of student conceptual understanding occurred. We found significant improvement (t = -6.07, df = 96, p = .00) on student DC/AC conceptual understanding after using EGN (M_{before} = 9.58, SD_{before} = 2.61; M_{after} = 11.53, SD_{after} = 3.28). These mean scores reflected improvement of the number of students' correct answers on the 20-question multiple-choice Concept Inventory.

Moreover, identification of relevant statements and formation of themes from interviews were carried out to better understand how the EGN had helped the students learn electric-circuit concepts during lectures. Phenomenological data analysis revealed that students experienced a new approach in their learning activities. Four themes emerged from their statements in the learning experience category: "The EGN made learning much easier"; "The EGN improved test preparation"; "The EGN improved the availability of course content when classes missed"; and "The EGN enriched learning resources". Overall, these themes suggested that the use of EGN helped students to learn electric circuit concepts in comparison to traditional learning in a classroom. To illustrate, the following excerpts in Table 3 present students' opinions on how the EGN improved their learning experience to understand circuit concepts.

Table 3. Formation of themes for learning experience based on identification of significant statements

Themes (clusters of meaning)	Significant statements
Made learning much easier	"The notes have made my learning [*more efficient*]."
	"The notes [*help me to learn*] because sometimes in class I am so busy writing down all I can, that I can't spend the time that is needed to understand the material. They help me to [*process the information*] and [*think about what questions I need to ask*]."
	"EGNs have [*a lot of examples*] in the back, so when he shows you how it all works, it makes a lot more sense."
	"What I learned [*using the notes varied by chapter*], but the notes seemed to be more important in the latter part of the class."
	"I really like them in classes like this where you have to draw a lot of circuits – that gets tedious. Having notes like this [*makes that a lot easier*]."
	"I think it is very useful to have summary sections in textbooks, so I think that the [*EGNs serve in some ways as a summary, which helps*]."
	"I found that [*a lot of the information in the EGNs corresponded to the text, which was very helpful*]."
	"[*Having a summary of the important points*] in a given set of notes would improve their usefulness."
	"In a lot of my classes, [*I print off the professor's notes and make my own comments off to the side. It really helps*], so that is something that I would want to have in other classes."
Improved test preparation	"When preparing for the tests, [*I studied the EGN's more than the homework*]."
	"[*The notes were a great resource*] when I was doing the homework and preparing for the exams."
	"I found information in the EGNs to be [*very consistent with the exam questions*], even more so than the book, so that was [*very helpful*]."
	"Quite frankly, there were large sections of the book that we were not even tested on and material in each chapter that we weren't going over; not that it wasn't valuable information, but we weren't being tested on it, so [*the notes helped*]."
Improved the availability of course content when classes missed	"[*If I missed a couple of days, it's a lot easier for me to get caught back up*]."
	"I really like the note sharing because [*if I missed class, I didn't need to go back and talk to somebody…*]. It's a really nice way of doing that."
	"[*If you didn't catch something in class, anywhere you are at you can go and get that information*]."
	"I know that one day I wasn't able to make it to class, so [*it made it really easy to get caught up – I didn't have the lecture, but at least I had enough to go back and piece together what I missed*]."
Enriched learning resources OR supported the use of other learning resources	"[*I can understand the notes better than the book*]. [*When I go over the notes, then go to the book, I get the very minute details*], whereas the professor teaches the broad ideas. The book goes over 10 times what the teacher does, so the book is useful."
	"I like the examples in the book – it walks you through each step – so [*after the materials are introduced with the EGN's, the book teaches the details*]. So, the book isn't something you can replace or get away from."

4.2 Students' Self-Regulated Learning Profiles

Data from SRL questionnaires were analyzed to investigate students' SRL strategies during the semester. From descriptive statistics (n = 97), we found students' SRL strategies, before and after using EGN, were relatively similar on overall strategies (M_{before} = 3.09, SD_{before} = .36, M_{after} = 3.10, SD_{after} = .40), planning (M_{before} = 2.81, SD_{before} = .43; M_{after} = 2.81, SD_{after} = .56), monitoring (M_{before} = 3.17, SD_{before} = .42; M_{after} = 3.19, SD_{after} = .43), and regulating strategies (M_{before} = 3.18, SD_{before} = .43; M_{after} = 3.16, SD_{after} = .46). Although overall there was no significant SRL difference found between before and after using the EGN, our findings suggested a trend of improvement in the questionnaire-item level specifically on monitoring and regulating strategies. Some important differences were observed on monitoring strategies. We found that significant improvements occurred particularly on items such as "check whether I can describe the main topic of the subject" (t = -2.03, df = 96, p =.02), "check that I have found all the important concepts" (t = -2.18, df = 96, p =.02), and "ask myself whether my methods for solving problems are good" (t = -2.21, df = 96, p =.02). We also found a significant decline occurred on "judge the quality of my work" (t = 2.80, df = 96, p = .00) and "keep track how much time I have to finish my work" (t = 2.08, df = 96, p = .02). See Table 4 a-c.

Table 4a. Comparison of planning strategies' descriptive statistics before and after using EGN (n = 97)

No.	Before I begin the activity of learning and solving math, science, or engineering problems involving new concepts, I start by…	Before	After
		M (*SD*)	*M* (*SD*)
1.	just reading the learning resources	2.59 (.75)	2.56 (.95)
2.	planning my time	2.53 (.83)	2.60 (.92)
3.	choosing a method for completing the problems	3.18 (.74)	3.08 (.85)
4.	creating a strategy	3.03 (.84)	3.01 (.81)
5.	checking the scope of the activity	2.71 (.74)	2.82 (.85)

Table 4b. Comparison of monitoring strategies' descriptive statistics before and after using EGN (n = 97)

No.	When learning and solving math, science, or engineering problems involving new concepts, I…	Before	After
		M (*SD*)	*M* (*SD*)
1.	judge the quality of my work* (↓)	3.20 (.75)	2.97 (.71)
2.	check now and then to see if my work is going well	3.35 (.68)	3.23 (.74)
3.	check to make sure I have completed everything required for the activity	3.61 (.55)	3.61 (.57)
4.	identify what I do and don't understand	3.32 (.65)	3.29 (.63)
5.	check whether I can describe the main topic of the subject** (↑)	2.72 (.79)	2.93 (.79)
6.	check that I have found all the important concepts** (↑)	2.92 (.75)	3.11 (.75)
7.	check what I can remember from what I learned	2.94 (.75)	3.08 (.76)
8.	keep track of how much time I have to finish my work** (↓)	3.19 (.88)	2.98 (.96)
9.	ask myself whether my methods for solving problems are good* (↑)	2.82 (.78)	3.02 (.78)
10.	ask myself whether I will get a good grade	3.44 (.69)	3.42 (.79)
11.	ask myself if I am concentrating well	2.95 (.85)	3.05 (.82)
12.	check to make sure I come up with an answer that makes sense to me	3.57 (.58)	3.60 (.57)

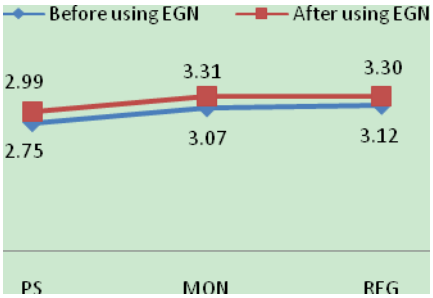
Table 4c. Comparison of regulating strategies' descriptive statistics before and after using EGN (n = 97)

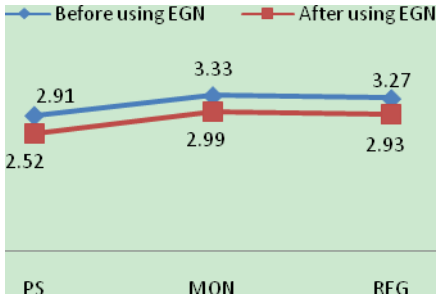
No.	When I have difficulties learning and solving math, science, or engineering problems involving new concepts, I…	Before	After
		M (*SD*)	*M* (*SD*)
1.	check to make sure I have completed everything required for the activity	3.54 (.58)	3.43 (.64)
2.	review the difficult concepts again	3.24 (.75)	3.26 (.74)
3.	try to make links between concepts	3.08 (.66)	3.13 (.70)
4.	make links between concepts I am learning and problem I solved	3.20 (.69)	3.26 (.67)
5.	try to memorize concepts	2.94 (.88)	2.95 (.83)
6.	try to use better methods for working	3.13 (.66)	3.08 (.73)
7.	think about how I could do this kind of activity better next time	3.11 (.79)	3.01 (.81)

We investigated further to evaluate if students' SRL profiles in our sample population were diverse. The use of the cluster analysis technique enabled the researcher to achieve a detailed profile of students' SRL. We found

two categories of students based upon different SRL levels before and after using the EGN: improved or declined. It was found that 61 (62.89%) and 36 (37.11%) students were clustered in improved and declined groups, respectively. After calculating the number of students from the improved and declined groups, we then evaluated students' SRL profiles of each group. The mean value of each self-regulated learning (SRL) strategy was used to describe students' SRL profile that belonged to the two groups (see Figures 2a-b).

We were interested to understand whether improved and declined groups had different level of SRL strategies during the semester across the three SRL strategies. Independent t-tests showed that the improved group outperformed the declined group after using the EGN on overall strategies (t = 4.67, df = 60, p = .00), planning (t = 4.09, df = 60, p = .00), monitoring (t = 3.62, df = 60, p < .01), and regulating strategies (t = 4.18, df = 60, p = .00). On the other hand, the declined groups reported higher awareness of overall strategies (t = -2.75, df = 35, p = .00), planning (t = -1.81, df = 35, p = .04), and monitoring strategies (t = -2.99, df = 35, p = .00) than the improved group before using the EGN (see Table 5). Effect sizes (ES) analysis indicated that before using the EGN, the awareness SRL strategies of the improved group of students were lower than those of the declined group on planning, monitoring, and regulating strategies (ES = -.38, -.64, and -.35, respectively). Data analysis of survey data after using the EGN found that the SRL strategies of the improved group were higher than the declined group (ES = .88, .78, and .87, respectively).Demographic information of the students (specifically GPA and class level) may yield insights into this phenomenon. Most of improved group had a GPA > 3.25 (79%), and 38 percent of them were at the junior and senior level. On the other hand, 75 percent of the declined group had a GPA > 3.25. This number is a bit lower than the improved group. The number of junior and senior level students in the declined group is also a bit lower than the improved group (33%).





(2a) *Improved group (N = 61)* (2b) *Declined group (N = 36)*

Figure 2(a-b). Students' SRL profiles in improved and declined groups

Furthermore, paired *t*-tests were carried out to investigate whether SRL changes as depicted in the figures were statistically significant for each group. Statistical tests showed students in the improved group were significantly improved on all SRL strategies (i.e., PS, Mon, Reg). On the other hand, students in the declined group were significantly worse off on all SRL strategies at the end of semester (see Table 5).

Table 5. Differences in SRL strategies for each group before and after using enhanced guided notes

Groups	Overall strategies			Planning strategies			Monitoring strategies			Regulating strategies		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*	*T*	*df*	*p*
Improved (n = 61)	-9.75	60	(.00)↑*	-4.52	60	(.00)↑*	-6.62	60	(.00) ↑*	-4.28	60	(.00)↑**
Declined (n = 36)	11.88	35	(.00)↓*	4.35	35	(.00)↓*	7.75	35	(.00) ↓*	6.35	35	(.00) ↓*

Note: * p < .01 (1-tailed); ** p < .05 (1-tailed); (↑) significant increased; (↓) significant decreased

We also further evaluated changes in students' self-regulated learning strategies on questionnaire-item level between both groups. Students in the improved group significantly improved their planning strategies on items 2, 3, 4, and 5 (see Table 3a); monitoring strategies on items 5, 6, 7, 9, 11, and 12 (see Table 3b); and regulating

strategies on items 3, 4, and 7 (see Table 3c) after using the enhanced guided notes. When we evaluated students in the declined group, the findings revealed a significant decline in planning strategies on items 1, 2, 3, and 4 (see Table 4a); monitoring strategies on items 1, 2, 4, 5, 6, 7, 8, and 12 (see Table 4b); and regulating strategies on items 1, 3, 4, 6, and 7 (see Table 4c).

Moreover, the phenomenological data analysis of identifying relevant statements and forming themes from interview transcripts provided insights regarding how students used their SRL strategies while using the EGN. Overall, students found the EGN to be useful as a resource for understanding new concepts or ideas, as a mechanism for distilling detail from the text, and as a guide to emphasize important points on learning content. In addition, the EGN encouraged the students to ponder what was being asked through the meta-evaluation questions on the notes. This evidence suggested that the students exercised their SRL strategies while using the guided notes. The statements also revealed the excitement of the students regarding their strategies in learning electric circuit concepts. Table 6 gives detailed information about how the author worked with the transcripts and constructed themes. Brackets highlight significant statements.

Table 6. Formation of themes for learning experience based on identification of significant statements

Themes (clusters of meaning)	Significant statements
Understanding the use of EGN in the class	"I [*expected*] to use them to [*emphasize important points*] from the lectures and text." "I was [*expecting*] that the notes would be [*like a summary of the text*] and that [*the alignment with the text would be similar*]. They seemed [*pretty close to the text*], so I didn't have trouble with that."
Learning plans while using the EGN	"It helps you [*know the things you need to study*]." "So, I usually read through the book when I'm doing my homework after class. I [*look at the notes before class*], then we have the class, then I read the book. That is different from other classes." "I read the notes before I come to class, and read the book after class. That is different from what I do in other classes where I read the book before class. [*Reading the notes before class is more efficient*]. The notes don't replace the book, but they are a supplement that helps me focus on what is important." "The professor teaches the big idea in the lecture and with the guided notes, and the book provides the details. The book goes over 10 times what the teacher does, but [*you need the lectures and notes to find out what is most important*]." "I've been in a couple of classes – one where the notes are posted after the lecture, and one where he basically video recorded the lecture. The problem with that was if you had a test coming up, you had to go through 10 hours of lecture materials and pick out what was important. I felt the video recording was particularly useful. [*With the EGNs, the way they were set up was very useful because you always knew where he was*]."
Strategy execution in acquiring information	"It helps me [*filter out the information*] I don't need from the book." "I think they help me learn because in class I tend to be rushing to write down all that the professor is saying, and with the notes I can listen more so I can understand the concept better as it is being taught. Instead of writing it all down, [*it helps me with the process where I didn't have to think about writing*], I could think about understanding what was being said and ask questions." "I agree that trying to write really fast while trying to ask questions and absorb new information. [*It helped me to limit that so I could digest what the professor was saying.*]" "The notes gave me a good reason for being in class, because [*it helped me when I went back over the notes step-by-step when studying for the tests*.]" "They helped me [*focus on important parts of the lectures*]. Instead of going on and not really knowing what to focus on, [*they provided me a way to focus my attention and what to write down*.]" "Having [*these notes helps me winnow out the stuff I don't need from the text.*]" "I felt [*they allowed me to focus on what he (instructor) was saying*.]" "The EGNs changed my study habits, so [*I looked more at the notes than I do in*

	other classes]. [*They made my note taking more organized*].” “I have had the experience where a professor has posted notes from the classes online, which I thought was really helpful because [*it helped to breakdown the lectures.*]”
Reflection on what has been learned	“What I liked were the questions at the end. [*It was interesting to see what was being asked and that helped me a lot to understand the concepts*.]” “[*I liked the meta-evaluation questions because they help me to focus on what I have learned*.]” “[*I like the self-evaluations at the end*]; however, some of them were incomplete.”
Adjustment of learning activity	“Sometimes we had to [*stop our questions because we were getting behind on the notes*] ...”

4.3 Students' Grade Performance between Improved and Declined Groups

We evaluated students' grade performance between the two SRL groups by investigating regular exams and DC/AC conceptual understanding. The findings revealed that, despite the increasing level of difficulty of the learning contents as reflected in the topics of the course, both groups of students were able to show a steady increase of their exam scores, from exam 1 through exam 3. In contrast, students declined in performance on the final compared to the third exam (see Figure 2). From a series of paired *t*-tests, we found that both SRL improved and declined students reported significant improvements between exams 1 and 2, and between exams 2 and 3 (see Table 7).

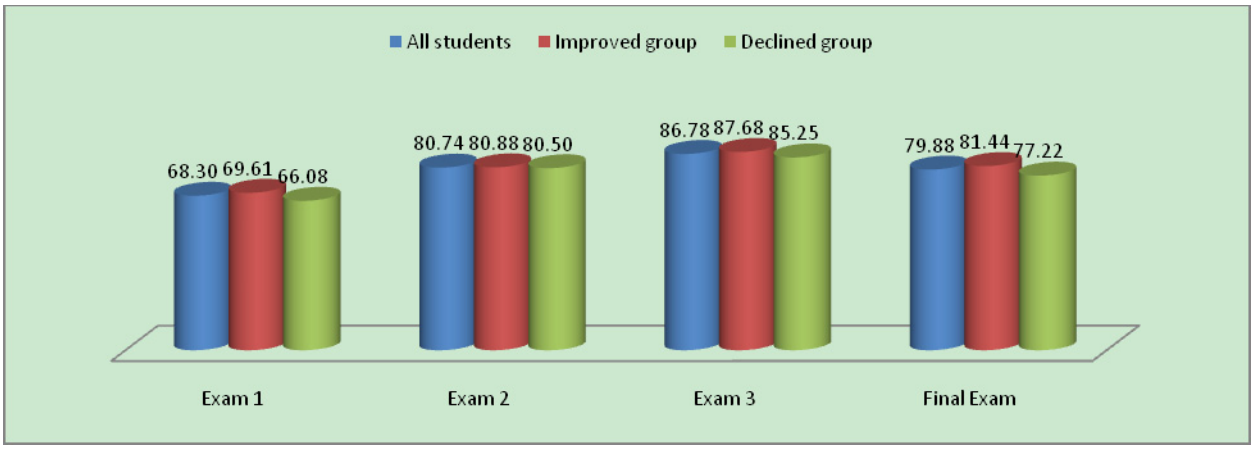


Figure 2. Distribution of exam scores of all students (n = 97), improved (n = 61), and declined groups (n = 36)

Table 7. Differences between exam scores within SRL groups

Regular exam	All students (n = 97)			Improved group (n = 61)			Declined group (n = 36)		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
Exams 1 – 2	-7.97	96	(.00) ↑*	-5.83	60	(.000) ↑*	-5.45	35	(.00) ↑*
Exams 2 – 3	-4.13	96	(.00) ↑*	-3.37	60	(.001) ↑*	-2.39	35	(.01) ↑**
Exam 3 – Final Exam	5.04	96	(.00) ↓*	3.52	60	(.001) ↓*	3.73	35	(.00) ↓*

Note: * p < .01 (1-tailed); ** p < .05 (1-tailed); (↑) significant increased; (↓) significant decreased

When we evaluated DC/AC conceptual understanding of improved and declined groups, the improved group showed significant improvement on the correct answers after using the EGN (M_{before} = 9.61, SD_{before} = 2.46; M_{after} = 11.70, SD_{after} = 3.21; t = -5.45, df = 60, p = .00). Similar to these findings, the declined group reported improvement on their DC/AC conceptual understanding (M_{before} = 9.53, SD_{before} = 2.88; M_{after} = 11.22, SD_{after} = -3.42; t = -2.97, df = 35, p = .003). Furthermore, independent t-tests suggested that the improved outperformed

the declined group in all exams and in DC/AC conceptual understanding (no statistical significant was found). We also evaluated the comparisons of students' grade performance using Mann-Whitney mean ranks tests. The results revealed similar findings with the independent *t*-tests (see Table 8). More specifically, the improved group reported significant higher scores on the final exam compared to the declined group (U = 855.000, p < .05).

Table 8. Mann-Whitney mean ranks tests between Improved and Declined groups on performance assessment

	Improved group (n = 61)	Declined group (n = 36)
Performance assessment	Mean rank (Sum of ranks)	Mean rank (Sum of ranks)
Exam 1	**52.02** (3173.00)	43.89 (1580.00)
Exam 2	**50.02** (3051.50)	47.26 (1701.50)
Exam 3	**50.59** (3086.00)	46.31 (1667.00)
Final Exam**	**52.98** (3232.00)	42.25 (1521.00)
ACDC Concepts test before using EGN	**50.24** (3064.50)	46.90 (1688.50)
ACDC Concepts test after using EGN	**50.52** (3081.50)	46.43 (1671.50)

Note: **p < .05 (1-tailed).

5. Discussion

The findings of this study are important in terms of advancing the understanding of the use of note taking in engineering classrooms. Previous studies reported that students benefitted from the use of guided notes. Research also has shown that note-taking student skills need to be improved further (e.g., Ferris & Tagg, 1996; Tsai, 2009). In the main author's prior work (Lawanto, 2011), we found that the use of EGN improved students' understanding of the course content. However, it was not clear how prompted questions on the EGN improved the way student think or their learning strategies. This study extends that work by examining students' self-regulated learning profiles while learning electric circuit concepts using the EGN.

Our analysis of students' understanding of course content suggested that, in general, students reported improvements from the first to the third exams, and declined in performance on the final exam. In addition, our data analysis on DC/AC concepts inventory found that students' conceptual understanding of DC/AC concepts improved at the end of semester. The results suggest that it may be valuable to identify high and low performers according to exam scores, evaluate the content of their notes, and encourage the students to share their notes with peers. This strategy may trigger the students to learn in a collaborative learning environment. As suggested by other studies, collaborative learning facilitates students to become familiar with different views of interpreting information from other students and improves understanding (e.g., Cabrera et al., 2002; Shibley & Zimmaro, 2002). Cooperative learning will also give students an opportunity to explore other essential information that may not be included in the guided notes. According to the instructor's evaluation, the decline of students' grade performance between the third and final exams might be caused by the increased coverage of course materials that were tested. On the final exam, students needed to master all materials learned in the semester to achieve positive results.

Although most students do take notes in the classroom, the integration of guided notes during lectures is a relatively new experience for them. In this study, some students expressed difficulty in using the EGN, for instance, they were a bit confused with the questions at the end of the EGN (i.e., under the section 'Quick Reflections') and with the format of questions that contained errors that needed to be identified. Another student reported that the fill-in-the-blank activity made him did not think as much. These suggestions will be considered to nuance our prompts in the EGN. Furthermore, it is suggested that it may be helpful to emphasize the objective of the EGN usage and specific tips for students to deal with their guided notes. The instructor and teaching assistant may also need to frequently highlight and remind some steps related to planning before they work on problem solving in the class meeting.

The analysis of the SRL survey data revealed intriguing findings about changes of students' awareness on their SRL strategies. While the improved group significantly improved their SRL on planning, monitoring, and regulating strategies, the declined group significantly declined in those strategies after using the EGN. Specifically, these findings suggested that the use of EGN helped the improved group to practice their SRL

strategies for instance in planning and monitoring their methods for solving problems. The improved group also reported significant improvement on the way they dealt with important concepts. The improvement of SRL strategies might have implication on students' grade performance. We also evaluated the survey data to understand whether both groups of students reported different levels of SRL strategies compared to each other. The findings showed that at the beginning of semester, the declined group outperformed the improved group on planning and monitoring strategies. On the other hand, the improved group showed better planning, monitoring, and regulating strategies after using the enhanced guided notes compared to their peers.

When we evaluated the grade performance between the two groups, our findings suggested that the improved group outperformed the declined group on all regular exams as well as the DC/AC conceptual tests. These findings suggested that a higher percentage of students in the class had the advantage of exercising their SRL while using the EGN than did those students who reported a lower awareness of their SRL; the improved group represented 63 percent of the participants. The demographic composition of each group might provide some insight into this phenomenon. Our data analysis on student demographic information proved that the improved group had a relatively higher percentage of students with a good GPA, and fewer freshmen and sophomores than the declined group. These findings confirmed previous studies regarding the development of self-regulated learning according to class level (e.g., Chung, 2000; Zimmerman & Pons, 1990). These studies reported findings on how self-regulated learning develops across class levels. In addition, Zimmerman (1990) emphasized that the use of "self-regulated learning strategies was strongly associated with superior academic functioning" (p. 8). We concluded that the declined group might have been more apt to misjudge their self-regulated learning before using the EGN. Other studies suggested that there are correlations between overconfidence in judgment and GPA (Hadwin & Webster, 2012), and also between judgment accuracy of metacognition and levels of retention (Dunlosky & Rawson, 2012).

The current study built from prior research to advance the understanding of the strengths and challenges inherent in learning electric circuit concepts using EGN. To build further on these efforts, we offer four recommendations. First, a rigorous mixed-method approach needs to be used to evaluate students' self-regulated learning strategies. A single method is not sufficient to clearly examine the strategies. The method of study can be extended by also evaluating students' notes on their EGN as learning artifacts. Second, an increase in sample size is essential to improve the generalizability of the findings. Third, a longitudinal study is needed to investigate whether the use of enhanced guided notes benefits the students in other classes. Fourth, further study is needed to continue to nuance the SRL prompts on the enhanced guided notes as suggested by the students. Creating self-regulation prompts on enhanced guided notes was not an easy task. Our goal was to avoid repetitive prompts that could result in boredom on the part of the students. Moreover, we suggested that the prompts should be contextual according to the topic presented.

6. Conclusion

The current research successfully developed new types of instructional materials and strategies for use in an electric circuit course for nonelectrical engineering majors. The enhanced guided notes (EGN) were designed to replace traditional note taking practiced in most engineering courses. The objective of the EGN usage both during and after classroom activity was to help students improve their note-taking skills and grade performance.

The first important contribution of this study was to describe students' grade performance specifically on exams and DC/AC conceptual understanding after using the EGN. As we expected before, our findings showed that note-taking activity using the EGN benefits the students in improving their performance on exams and DC/AC conceptual understanding. Phenomenological data analysis from interviews also revealed themes related to learning experience of using the EGN such as: the EGN made learning much easier; the EGN improved test preparation and the availability of course content when classes missed; and the EGN supported the use of other learning resources.

The second important contribution of this study was to describe profiles of students' self-regulated learning (SRL). When looking across the SRL strategies, overall mean comparisons between before and after using the EGN on the SRL survey revealed no statistically reliable differences. However, our findings suggested a trend of improvement in monitoring and regulating strategies in questionnaires. As our early data analysis found that SRL strategies of all participants were relatively similar before and after using the EGN, we decided to run cluster analyses. Cluster analyses were conducted to see whether different SRL profiles existed among students. From the analyses, we identified two groups of students: improved (i.e., students with significant SRL improvements) and declined (i.e., students with significant SRL decline). The improved group scored significantly higher than the declined in the areas of planning, monitoring, and regulating strategies after using the EGN. On the other

hand, the declined group reported significantly higher scores on planning and monitoring strategies before using the EGN. Results of the cluster analysis also triggered us to investigate differences in the grade performance of the two groups. Our findings suggested that the improved group outperformed the declined group on all regular exams as well as the DC/AC conceptual tests. Moreover, five themes were found on phenomenological data analysis for SRL strategies, including understanding about the use of EGN in the class, learning plans while using the EGN, strategy execution in acquiring information, reflection of what was learned, and adjustment of learning activity.

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