THE EFFECTS OF IMMEDIATE FEEDBACK USING A STUDENT RESPONSE SYSTEM ON MATH ACHIEVEMENT OF ELEVENTH GRADE STUDENTS

by

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A Dissertation Submitted to the Faculty in the Curriculum and Instruction Program of Tift College of Education at Mercer University in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

Atlanta, GA

2015
DEDICATION

I dedicate this dissertation to my wife, Seematty Austin, and our daughter, Arshia Clare. Their support, sacrifices, and encouragement were the beacons that guided me towards this accomplishment.
ACKNOWLEDGEMENTS

I would like to thank Dr. Jeffrey Hall, my dissertation committee chair; Dr. Justus Randolph, my methodologist and statistics guide; and Dr. Sherah Carr, my guide for theories for their kindness and generosity to guide me through the entire dissertation process. I admire your passion for lifelong learning and your patience to scaffold and support a learner like me that tremendously encouraged me to reach my goal.

Special thanks to my family, especially my wife, Mrs. Seematty Austin, and our daughter, Arshia Clare, whose immense patience, kind support, and loving sacrifices guided me well to this accomplishment. Thanks also go to my parents in law, Mr. Bosco Malatt and Mrs. Uris Bosco, and my sister and her husband, Mrs. Simi Joseph and Mr. Joseph Jacob, for their unlimited moral and financial support. The prayers and blessings of my sister, Sr. M. Josephine, Missionaries of Charity, also helped me to sail smoothly through this wonderful journey.

I thank the faculty of Tift College of Education, especially Dr. Allison Gilmore, Associate Dean, for your encouragement and support throughout this educational journey. I appreciate and am thankful to Dr. Karen Swanson for your continuous support and guidance that helped me to navigate the doctoral program effectively. My sincere and heartfelt thanks also goes to every Mercer Atlanta faculty member who taught,
encouraged, and inspired me to transform myself into a well-balanced educator, a researcher, and a better person.

I thank you, my friends from Cohort 4, for your support and coherence in every moment of our stride. I appreciate the colorful spectrum of knowledge that you represented and shared to make my transformation fuller than ever. We were a small, yet powerful cohort!
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This quasi-experiment using a pretest-posttest with control group design investigated the effects of providing immediate feedback using an electronic student response system (SRS) to 53 math students enrolled in an accelerated precalculus course during the fall semester of 2014. The students in the experiment group \((n = 25)\) went through a continuous, rigorous, and consistent intervention of receiving immediate feedback for their responses during regular classroom activities and formative assessments using SRS, while the students in the control group \((n = 28)\) were not provided immediate feedback using student response system. The results of the pretest indicated that both groups had statistically significant similar entry-level math skills. The analysis of other covariates in this study, namely giftedness, gender, and economic status of the participating students, were also found to be significantly homogenous. Following an 18-week intervention, after the data were found to meet all the assumptions, an analysis of covariance (ANCOVA) was conducted that revealed a statistically significant difference in the math achievement of students who received immediate feedback using SRS with a medium effect size \(\eta^2 = .11\). Even though the results proved acceptable, various limitations might have incurred in this study. Therefore, recommendations
included further research on the effects of providing immediate feedback with varied samples, longer intervention period, and improved technological devices to provide guidelines for informed decision making regarding the use of SRS as an immediate feedback tool.
CHAPTER 1

INTRODUCTION TO THE STUDY

The millennial generation, born into the world of technology, is dexterous in using modern technological devices as an integral part of their daily life (Wieman & Perkins, 2005). Students communicate effortlessly using technology at a very fast pace that sometimes renders the traditional methods of education primordial. It appears inevitable that educational systems should upgrade technological skills to keep abreast with high-tech abilities of the young generation.

Students in our schools are familiar with faster communication and used to getting immediate feedback for every response they make. It thus becomes imperative that the feedback provided for the responses they make in their learning environment should match with their lifestyle. Student Response Systems (SRS) form a collection of many innovations that are available in educational scenarios to meet the challenge.

SRS could be the special hardware provided by innovative hardware systems including ActivExpressions or could be the software offered through different websites, including ActivEngage (Promethean, 2015a) and Socrative (Socrative.com, 2015). Educators in modern classrooms can choose from a wide range of such hardware and software that enable them to give immediate feedback using the aptly chosen SRS. Some of these innovations are available free of charge. However, free versions usually
have some limitations. The availability of an effective SRS may become expensive, especially if teachers require students to use a common appliance to respond. Hence, it is important for stakeholders of education to make informed decisions about the financial aspect of the use of SRS in classrooms.

Again, Wieman and Perkins (2005) pointed out that technology-rich activities increased student engagement in classrooms. In a study, Blood and Neel (2008) were convinced that the use of SRS increased student engagement. They also observed that the use of SRS enhanced the learning experiences. The effective use of SRS improved student comprehension by supporting and enhancing re-teaching of difficult concepts.

According to a statement released from the U.S. Department of Education ([USDOE], 2015c), “technology-based learning and assessment system” would improve educational proficiency of our students (p. v). Wieman and Perkins (2005) pointed out that teachers could easily integrate SRS as a powerful pedagogical tool into the standard curriculum. Thus, the use of SRS has a potential to affect the learning process in a significant way. Consequently, SRS and the effects of SRS in educational scenarios have been under constant investigation in recent decades (Abode, 2010; Christopherson, 2011; Dunham, 2011; Lynch, 2013; Matus, Summa, & Kuschke, 2011; Rigdon, 2010). The potentially huge spending involved in the purchase, installation, training, and maintenance of SRS would naturally stimulate investigations about the effectiveness of the system and the technological devices to prove the worth of the money involved in the process.
Dunham (2011) researched the statistical significance of clickers, a form of SRS, on the math achievement of seventh grade students. Christopherson (2011), after an investigation on the effects of SRS, came to a conclusion that the use of SRS should be incorporated with the best teaching practices to see the effects of SRS in the desired student achievement. According to Christopherson (2011), the role of teachers in using the technology is very pivotal, since effective implementation of the system plays the key role in the effectiveness of learning achievement.

In addition, developments in technology in recent years have led to significant improvement in the structure and utility of SRS so that the tech-savvy students of our generation can interact with this technology without losing their pace. Educators should incorporate text and numerical responses rather than just multiple-choice questions because it would be difficult to evaluate student responses based only on multiple-choice responses. Truly, “alternatives to test-score performance [should] be considered as the relevant outcomes of education” (Becker, 1998, p. 185). Thus, if properly planned, teachers could use SRS to collect and interpret higher forms of input.

Statement of the Problem

It is imperative that millennial students receive immediate feedback for their academic responses to match their normal ways of communication, and they expect educators to do so. Student Response Systems (SRS) are methods to provide the expected communication (Blood & Neel, 2008; Wieman & Perkins, 2005). Consequently, there has been a large volume of sound, theoretically based research conducted to investigate the effects of implementing effective SRS in classrooms (Black
& Wiliam, 2009; Clark, 2012; Hattie, 2012; Schunk, 2001; Yorke, 2003; Zimmerman, 2001). However, despite the potential of SRS to provide effective feedback and engage tech-savvy students, research regarding the efficacy of SRS is inconclusive or controversial. The reported limitations of these studies included period of implementation of SRS (Matus et al., 2011); frequency and rigor in implementing SRS intervention (Penual, Boscardin, Masyn, & Crawford, 2007); and inadequacies of intervention strategies (Abode, 2010; Christopherson, 2011). The majority of researchers recommended further investigations (Dunham, 2011; Matus et al., 2011; Rigdon, 2010); thus validating additional study of the effects of using SRS as a feedback tool in classrooms.

The Purpose of Study and Research Question

The purpose of this “untreated control group [quasi-experimental] design study with dependent pretest and posttest samples” (Shadish, Cook, & Campbell, 2002, p.136) is to determine whether there is a statistically significant difference in the math achievement of eleventh-grade students who receive immediate feedback using a Student Response System at a suburban high school in Georgia.

The research question for this study is as follows: Will there be a statistically significant difference between the educational-district-generated-benchmark posttest scores of students who receive immediate feedback using SRS and those who would not receive immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school?
Theoretical Framework

The applications of SRS draw inspiration from the main tenets of the majority of the major learning theories. However, I laid my theoretical foundation on the theory of distributed cognition and self-regulated learning theory. Both of the theories are oriented towards the provision of formative feedback to student responses and thus dependent on the theory of formative assessment and the consequent theories on formative feedback (Black & Wiliam, 2009; Hattie, 2012; Zimmerman, 2001).

According to Yorke (2003), “Formative assessment contribute[s] to student learning through the provision of information about performance” (p. 478). There are different types of formative assessments, including informal and formal formative assessments. In all these types of formative assessments, quickness of teacher feedback to student responses plays a vital role in the effectiveness of the formative assessment. Further, Black and Wiliam (2009) confirm that one of the guiding strategies for successful formative assessment is “to provide feedback that moves learners to move forward” (p. 8), illustrating the importance of timely feedback to student responses.

Black and Wiliam (2009) theorize that formative assessment is the backbone of any learning process. Grant (2012) asserts that formative assessment largely depends upon effective timely feedback. Traditional feedback techniques require teachers to engage in exhaustive planning to give immediate feedback to student responses. In contrast, the use of technology to provide immediate feedback can positively influence feedback strategies (Grant, 2012). The ability of technology to manipulate student
responses and monitor feedback enables teachers to gain deeper insights about student responses.


Another theory that supports the use of SRS is the theory of distributed cognition distribution, which purports the distribution of knowledge across individuals and the tools used in the learning process. Propounded by Hutchins (1995), the cognitive distribution theory forms a strong foundation for the use of SRS in the students’ learning process (Zimmerman, 2001). The students find a way to express their opinion using the input devices of SRS. Immediate feedback designed in the software allows them to correct mistakes or to adjust their learning process according to the feedback, as per the norms of the theory of cognitive distribution (Hutchins, 1995).
Thus, the theories of formative assessment, especially the self-regulated learning theory and the cognitive distribution theory, underlie the research question of this study. I wished to investigate whether one of the main tenets of the theory of formative assessment that the immediate feedback given to the students to regulate their learning experiences would have any effect on the academic achievement of the students who are given the intervention of SRS to facilitate immediate feedback for student responses.

Limitations

The following are some of the limitations of this research:

1. The study is limited to the data collected from students of one school only, possibly affecting the external validity of the hypotheses.

2. In this study, the student feedback system is based only on the use of one type of software. The type of software may be different from the software available to students in other educational systems.

3. The students and the teacher who participated in this study were familiar with the devices used in the study, which may result in lack of generalizability of the study results to educational situations in other parts of the country or the world.

4. This study, being a quasi-experimental study, lacks thorough randomization. However, a pretest was administered to verify that the experiment and control groups were not significantly different.
5. The intervention of using ActivExpressions to collect responses and to provide feedback varies among researchers, thus making it difficult to replicate this study in terms of exact research design.

6. Even though I developed the research design based on the recommendations from previous studies, there were chances that construct validities, including novelty, compensatory rivalry, and resentful demoralization, might have influenced the results. These factors, beyond my control, might affect the generalizability of the results of this study.

Assumptions

The following assumptions were made in this study

1. The students who participated in this study had the same learning opportunities.

2. The students in each group were interested to learn the mathematical concepts taught.

3. The students did not cheat on pretest or posttest.

Significance of the Study

The beneficiaries of this study to investigate the effects of SRS include teachers, students, teacher education institutions, and policymakers. The SRS has the potential to provide effective, fast, and less time-consuming feedback for teachers. When teachers use SRS in classrooms, students need not wait for teachers to mark their papers to get the feedback and to correct their comprehension, if needed. Teacher education institutions could make decisions about integrating SRS training as an intuitive tool for upcoming
teachers. Further, policy makers could make informed decisions about purchasing an expensive educational tool that might support education and help to reach the educational goals of the entities they represent.

This study also contributes to the controversial research base surrounding SRS. Using strong theories as their basis, some investigators seeking to verify the effects of using SRS on student achievement instead found a poor correlation of the results; consequently they suggested the need for further research (Dunham, 2011; Matus et al., 2011; Rigdon, 2010). Further, many of the researchers reached a consensus that the use of a student response system would help to improve student engagement and subsequently the learning environment, unanimously recommending further investigation into the effects of using student response systems to improve student achievement (Edgerton, Peter, & Roberts, 2008; Kim et al., 2011; Payne & Biddle, 1999; Thomas & Stockton, 1999; Vega & Travis, 2011). In contrast to these studies, other studies suggested that there were students who did not benefit from the use of SRS (Blood & Neel, 2008).

**Definitions of Key Terms**

*Student Response System (SRS)* is a technological system that includes the software and the hardware typically used to collect student responses and has the ability to provide feedback to student responses.

*Formative assessment*, in this study, comprises practices in classrooms where teachers, learners, or their peers "elicit, interpret, and use the evidence about student
achievement to make decisions” to improve instruction and educational environment (Black & Wiliam, 2009, p. 9).

*Student response* is the response given by the students using the SRS during the learning process throughout the research. Student responses could provide input to formative and summative assessments.

*Immediate feedback* refers to the feedback provided by the teacher for student responses immediately after the student response.

*Summative assessment* is the process of evaluating the students’ academic achievement at a point in time, typically at the end of a unit or a semester. Summative assessments may be teacher created or high-stakes assessments created by educational districts or state departments of education.

*Self-regulated students* are students who “self-generate thoughts, feelings, and actions to attain their learning goals” (Zimmerman, 2001, p. 5).

Summary

According to various studies, the development and application of a suitable SRS could enhance the learning experience of students in mathematics (Black & Wiliam, 2009; Clark, 2012; Hattie, 2012; Schunk, 2001; Yorke, 2003; Zimmerman, 2001). The nature of SRS has strong implications for designing an effective feedback system. The multiple types of responses using the modern SRS make it unique to collect textual, mathematical, or objective responses, thus helping the teachers design and redesign the instruction based on the student feedback and the assessment (Black & Wiliam, 2009; Cormo, 2001).
However, there are limitations to this research. The limitation of this study to a small group of the student population, which was not representative of the entire student community learning mathematics, poses an external validity threat. In addition, the tests used in this research were restricted only to a particular course and could not represent the mathematical achievement for students in other classrooms. However, the research addressed the effectiveness of the use of SRS by designing and redesigning the mathematical learning based on the student responses and may serve as a guideline for any further research on the topic.

Thus, this research provides a systematic insight into the effect of using SRS as a learning strategy to improve student achievement. The theoretical frameworks—theory of distributed cognition and self-regulatory learning theory—ample support the use of SRS in the improvement of student achievement. I employed this study to find out the effect of using SRS as an immediate feedback tool on the participant students’ academic achievement.

To summarize, suggestions for further research (Edgerton, Peter, & Roberts, 2008; Kim et al., 2011; Payne & Biddle, 1999; Thomas & Stockton, 1999; Vega & Travis, 2011); constant development of technology involved with SRS; financial concerns connected with SRS technology; and projected effects of immediate feedback using SRS on students’ academic achievement encouraged me to investigate the effects of SRS on student achievement. In this study, I investigated how immediateness of feedback to student responses using SRS affects concept comprehension, as suggested by theoretical perspectives and studies analyzed in Chapter 2.
Moving forward, in Chapter 2, I explain how I searched for and reviewed existing literature related to my investigation. In Chapter 2, I include a list of criteria for inclusion of the reviewed literature, followed by discussions on the theoretical background of this investigation and research studies of the effects of SRS. In Chapter 3, I discuss the methodology I employed to investigate the effects of SRS as an immediate tool on educational achievement of participant students. In Chapters 4 and 5, I discuss the results of this quasi-experimental study and discuss the results, respectively. Finally, I include a calendar of SRS intervention, a comparison of studies investigating the effects of SRS, and other relevant documents in the appendices section.
CHAPTER 2

REVIEW OF RELATED LITERATURE

In the beginning section of this chapter, I explain the detailed steps of the search I conducted on various databases to find a substantial collection of literature involving investigations and theoretical inspirations related with my study. In the remaining sections of this chapter, I include a description of the theoretical framework of this study. I also relate multiple investigations regarding the effects of using SRS as an immediate feedback tool. In the final summary this chapter, I present an overview of the literature review, which served as a rationale for this study.

Search Strategy

It is very crucial to organize the search for literature to find the most relevant information from the literature review produced from the search. To draw inferences from the accumulated knowledge, gathered through the years of using various types of SRS, and to investigate the underlying principles regarding the effective use of the SRS, I formulated a search strategy to collect literature pertinent to the use of SRS in classrooms. To start with the process, I conducted a search using the terms or combinations of the terms student response system, clickers, technology and clickers, technology and student achievement, handheld device education. I read the abstracts of the most relevant outcomes, gathered peer-reviewed literature, and organized them based on a self-developed data system. I read the whole literature of selected articles and books.
to identify the main tenets of the related concepts. I followed the relevant sources cited by the literature to follow-up the idea of the researchers and searched for further literature. Once my reading reached a saturation point, I started another search thread using the words or phrases that included feedback, formative evaluation, formative assessment, summative evaluation, and summative assessment, following the same process outlined above.

The focus of this study is measuring math achievement of students. Thus, it was important that my search included the words or phrases that involved math achievement, and the search definitely helped me to find a wide variety of literature related to achievement in mathematics. In addition, it was imperative to investigate whether individual student's gender, economic status, or giftedness would affect receiving immediate feedback through SRS. Therefore, my next search focused on the words and phrases that included gifted students, gifted students in mathematics, economic status and academic achievement, gender and academic achievement, characteristics gifted child AND technology, economic status AND technology OR clicker, education AND socio-economic status, and economic status.

I utilized ProQuest Databases, Wilson Omni File: full text mega edition and Google Scholar in my search. I followed similar strategies on the emerging lists of literature related to each search, namely, reading the title, the abstract, and then the entire article to determine whether they met the criteria of inclusion. I labeled, sorted, and arranged the articles obtained from the searches in a folder after avoiding duplications. I used the reference lists of the selected articles to expand my search for relevant articles.
The cycle of searching for the articles in the reference lists provided a saturated list of the pertinent literature.

In addition, dissertations based on the above search terms were included in the literature review list. The use of Microsoft Excel to store information about the articles facilitated the construction of a literature-review matrix to organize the articles systematically. The faculty of Mercer University and the listserves they hosted were very generous in suggesting relevant literature for my study. Classroom discussions with my cohort also helped me to expand my search for literature. I included the articles and books suggested by professors and classmate—either personally advised or obtained from classroom discussion—in the folder and in the matrix.

Criteria for Inclusion

The criteria for inclusion of the articles in the literature review were the following:

1. The article should include topics relevant to my study including SRS, clickers, student responses, feedback, theories of self-regulation and distributed cognition, giftedness, gender, economic status, socio-economic status, and articles that discussed other relevant topics connected with my study.

2. The language of the article was English.

3. The article was published in a peer-reviewed journal, book, or report by a reputable educational organization.

4. Since the topics of this research study addressed current technology and millennial students, it was important to review literature reflective of these
characteristics. Thus, I consulted articles and books published in the last 15 years. However, for theoretical definitions and perspectives, I had to be very lenient with this criterion.

5. The article dealt with education or student population including K-12 and higher education.

Assessments

The National Council of Teachers of Mathematics ([NCTM], 2000) asserted that assessment should be more than just a test to measure learning given at the end of instruction; instead, assessments on topics of mathematics should focus more on the understanding of the concepts and procedural skills. NCTM further asserted that the focus of assessment should indicate the much-needed mathematical knowledge and drive students towards the comprehension of that knowledge, giving priority to mathematical process and thinking involved in the process. In addition, assessment should enable teachers to make instructional decisions to guide students to accomplish mathematical understanding based on their knowledge acquisition according to teacher planning of mathematical concepts and related activities.

Clearly, every stakeholder in education should agree that assessment is one of the most important factors in education. Marzano (2006) stressed that one critical practice that distinguishes effective teachers is their role in administering effective classroom assessment. National policies including the No Child Left Behind Act of 2001 and the Race to the Top of 2009, as well as traditional forms of educational systems, emphasize assessment as an integral part of education at all levels (USDOE, 2015a, 2015b). Surely,
assessment forms an integral part of knowledge acquisition. Without assessment, teachers and students would not be able to identify the extent of knowledge acquisition and determine whether the process of education is keeping pace with the needs of the students.

However, there has been a debate in education about the roles played by summative assessments and formative assessments to enhance student comprehension and motivation. Thus, I move forward to analyze the important roles played by each to improve student achievement. In *Figure 1*, I illustrate the flow of discussion on assessments and feedback associated with the assessments.

*Figure 1. Flow of Discussion on Assessments and Feedback*

**Summative Assessment**

*In an educational system so driven by assessments—including the End of the Course Tests (EOCT), criterion-referenced competency tests (CRCT), and other*
summative assessments to determine student achievement—the role of summative assessment is inevitable. The current Race to the Top (RTT) policy, and the money involved in the policy, have forced the stakeholders of education to ponder different ways to improve students' scores in each of these summative assessments (USDOE, 2015b). In fact, student achievement is highly dependent on the scores the students would make in the corresponding summative assessment.

One of the purposes of the RTT assessment program is to fund states to develop summative assessments to inform educational stakeholders about the college readiness of the students, thus enabling educators and students to plan their educational endeavors to meet the college readiness requirements (USDOE, 2015a). The purpose statement for the RTT further asserts the states should design summative assessments that play a pivotal role in educational systems. Subsequently, educational stakeholders should have access to data obtained from such summative assessments, distributed with the intention of continuously improving educational experiences of the students (USDOE, 2015b).

Marzano (2006) rightly pointed out that the percentile of increase in student achievement is directly proportional to the skills of the classroom teacher. Consequently, one facet of teacher evaluation depends on student summative assessment performance. Thus, summative assessments form a high-stake activity not only for students, but also for teachers. Naturally, educators in school systems tend to focus on improving the test scores that students make in summative assessments.

In addition, Black and Wiliam (2009) suggested that educators could use summative assessments in a formative nature. In their five-item list types of activities
used to define formative assessment, Black and Wiliam identified the fifth type as
"formative use of summative tests" (p. 7). As per Black and Wiliam, summative
assessments are tests designed to serve the summative function of summarizing students’
accumulated learning brought about by their learning experiences.

Clearly, Black and Wiliam (2009) were focusing on the summative assessments
that happen during the course, which differ from the summative assessments of the
widely known tests in Georgia such as EOCT, CRCT, and the like. For these types of
summative assessments, teachers can provide prompt feedback based on the expectations
of the particular summative assessments. The feedback has the potential to lead students
to rectify mistakes in their future attempts of similar summative assessments (Black &
Wiliam, 2009; Yorke, 2003).

Thus, summative assessments play a vital role in measuring the progress of
students’ achievement in mathematics. The current trends in education, including the
RTT initiative, require every stakeholder of educational system to focus on educational
achievement of students in terms of their achievement on summative assessments.
However, researchers indicated that summative assessments did not facilitate the design
of instructional practices or differentiated learning experiences to match students’
learning requirements during a course (Black & Wiliam, 2009; Marzano, 2006).

Formative Assessment

Black and Wiliam (2009) agreed that even though the term formative assessment
lacked a formal definition, it consist of all practices that would improve student
performance. These practices could be the instructional changes that follow the
assessment, based on student responses to the assessment. While summing up these practices, Black and Wiliam collated the following five principles that might determine effectiveness of formative assessments: "sharing success criteria with learners, classroom questioning, comment-only marking, peer- and self-marking, and formative use of summative tests" (p. 7). Black and Wiliam stressed the importance of providing effective feedback in all five circumstances to help the students move forward to reach their educational goals.

Again, according to Black and Wiliam (2009), when targeted to improve student performance and to facilitate educational improvement, formative assessments should consist of classroom practices that would obtain evidences elicited from students’ achievement. Teachers should use such evidences to improve educational experiences of their students. In a study conducted by Black and Wiliam (2009), the researchers denoted that at the beginning of class discourse, teachers could have a general educational goal that might later change to meet the diverse needs of individual students. The formative assessments designed by teachers at different levels of students’ learning experiences, as perceived by individual teachers, decide the level of student autonomy in learning. Teachers should prudently design and execute formative assessments matching the needs of individual students. Results of students’ responses to these formative assessments would determine the design of class environment and the corresponding learning experiences. However, Black and Wiliam assert that the effects of formative assessments largely depend on the quality of feedback provided by teachers.
Yorke (2003) also supported the concept of formative assessments as learning experiences and further suggested that the main role of formative assessments was to provide information about the educational performance of learners. Formative assessments could be series of continuous activities or it might be some occasional stand-alone processes. However, the focus of formative assessments should be to improve student performance based on the evaluation provided by teachers or peers. Based on these thoughts, Yorke distinguished two types of formative assessments. The first type, the formal formative assessment, constituted a part of the formal curriculum. Yorke termed the second type of formal assessment as informal formative assessment. Teachers could administer informal formative assessment using the same entities that would deliver the formal formative assessment, but informal formative assessment and its feedback are so subtle that teachers could not record them in the syllabus. One example of such an informal formative assessment could be reading body language of students during the lesson. In addition, Yorke (2003) mentioned a third type of formative assessment on the borderline of the aforementioned types without assigning a name for it, where peers provide anonymous feedback for student performances that would yield better outcomes.

Yorke (2003) also contended that formative assessments should contribute to student learning. In his review of literature, Yorke found that researchers presented evidence to prove formative assessments were effective determinants to promote student learning across different educational settings, both in school and in higher education. Yorke, however, asserted that the quality of feedback students receive as a part of the
corresponding formative assessment plays a pivotal role in determining the effect of the formative assessment in student achievement.

Typically, a classroom teacher, an entity that Marzano (2006) believes is the most important variable in the educational system that leads to student achievement, gives this feedback. Therefore, it is extremely important to investigate the best practices of highly effective teachers. In addition to management techniques and instructional strategies, Marzano stated that the most effective teachers implement constructive practices of formative assessments to promote better learning outcomes for their students. According to Marzano, formative assessments occur while learning happens and form or alter students' learning experiences to understand the concept. In addition, and more importantly, effective formative assessment activities enable teachers and peers to give feedback to the corresponding student activity that eventually result in improved comprehension of the concepts learned.

Thus, studies and research regarding formative assessment emphasize the importance of providing feedback to the students in order to enhance their learning outcomes (Black & Wiliam, 2009; Marzano, 2006; Yorke, 2003). The next section provides a discussion of the various aspects of feedback that lead to effective formative assessment, which in turn has the potential to enhance student achievement in the summative assessment (namely, posttest) that forms the dependent variable of this study.

Feedback

Wiggins (2012) defined feedback as the information provided to individuals regarding their efforts to reach their goal. According to Wiggins, feedback is an
inevitable component of educational process. Wiggins, referring to a large volume of educational research on feedback, very confidently asserts that less teaching with more feedback produces better results. However, feedback becomes effective only if the process is oriented to make improvement in the learning process of the students. Wiggins cautions that educators should not interpret feedback as advice, even though both share the same intention of improving the learners' performance. According to Wiliam (2012), providing effective feedback to student responses is similar to setting a thermostat that adjusts room temperature.

Hattie's (2009) synthesis of approximately 900 meta-analyses comprised of more than 5000 studies established the importance of the role of feedback in student achievement. After identifying feedback as the most common factor that had the highest effect on student learning, Hattie stresses the importance of using feedback to clarify the educational goals. It is equally important to make sure that students understand the feedback. Teachers also need to receive feedback from their students to modify their teaching strategies. In the following sections, I present an analysis of various tenets of feedback as observed from the related literature review.

Positive and Negative Feedback

In a study investigating the task-motivation processes of feedback intervention theory (FIT) proposed by Kluger and DeNisi (1996), Krenn, Wurth, and Hergovich (2013) used both positive and negative feedback interventions following a performance task with 413 students. The researchers investigated in detail the effects of the positive and negative feedback on the participants' responses. The researchers explained the
standard of performance to the participants in terms of the number of correct responses to the questions they received. Participants who met or exceeded the standard received positive feedback and others received negative feedback. After providing feedback, the participants could respond with three different options, namely, *maintain the standard, raise the standard, or abort*. The participants repeated the process one more time. Thus, every participant received one of the following combinations of feedback, namely, “positive-positive . . . positive-negative . . . negative-positive . . . [or] . . . negative-negative” (pp. 84-85).

In addition, after noting the response choices made by the participants after the type of feedback provided, researchers set out to analyze the effects of the type of feedback provided to them. Discussing the results of the study, Krenn et al. (2013) concluded that when they gave positive feedback, the participants responded by raising their standard \(p = .002, \eta^2 = .033\). The researchers also found that upon receiving negative feedback, the participants either maintained their standard or quit, trying to protect their self-image. Thus, even though their main research specifics aligned with feedback intervention theory, Krenn et al. did not observe several subsequent claims of the theory. The researchers hoped future studies would throw light on these aspects of the theory.

The discussions from this study led me to explore the feedback intervention theory more deeply. In developing the theory, Kluger and DeNisi (1996) focused only on task-performance feedback interventions by external agents and explored what to expect from feedback interventions by external agents. The researchers put forward five basic
arguments related to the feedback intervention theory (FIT). One of the arguments was that providing feedback correlated with goals or standards can regulate behavior. Researchers suggested that people would try to decrease discrepancies that prevent them from attaining their goal through an external feedback. Thus, people who receive negative feedback would strive more than those who get positive feedback in situations where they compare their success with set goals or standards.

Effects of Negative Feedback

Kluger and DeNisi (1996) urged that negative feedback might lead those receiving such feedback to abandon the standard. Sometimes, people might alter the standards to fit their levels of achievement. In educational settings, this situation usually appears in cases where the standards are set very high. In some cases, the researchers suggested that people might even tend to reject the negative feedback. On the other hand, people might set internal standards that differ from the official standards set before them for a particular task-performance or they might not have a clear vision of the standard to compare it with the feedback they received, however clear the feedback may be.

Wiliam (2012) backed up the feedback intervention theory and appropriately used the analogy of comparing negative feedback loop with a thermostat because both operate as part of a self-regulating system designed to regulate a process, the former to initiate the learning process and the latter to initiate the process of keeping the room warm. Wiliam further asserted the importance of implementing feedback as an integral part of the instruction rather than considering feedback as a separate action, disconnected from the process of instruction.
Wiliam (2012), commenting on the work of Kluger and DeNisi (1996), confirmed their finding that the reactions of individual students towards various types of feedback given to them were more important than the nature of feedback itself. Explaining the phenomena, Wiliam asserted that knowing the effect of a particular feedback is very relevant. By organizing and tabulating the different student responses to feedback, Wiliam illustrated only two out of the possible eight outcomes were favorable, namely in cases where students may increase their efforts by changing their behavior and where the students may increase their aspirations for learning by modifying the goal.

According to Wiliam (2012), the first case occurred when the feedback for the performance was negative, indicating that the participants did not meet the goals. The second case happened after a positive feedback, indicating that the performance exceeded the goal. To cater for improving response to the feedback in the first case, it is necessary for teachers to create a classroom environment where making mistakes is acceptable; the best learning happens when learners learn to correct their mistakes. In order to enhance the second case, teachers should emphasize the importance of improving “self” rather than meeting the criteria and encourage achievers to improve themselves; there is always room to improve.

Goals and Standards of Feedback

Kluger and DeNisi (1996) suggested that the primary goal of feedback should be to reach a specific goal. Consequently, a clear feedback intervention would encourage people to attain the desired standard. Secondly, Kluger and DeNisi suggested organizing the goals or standards hierarchically. Researchers cautioned that different people might
consider the same act at different levels of values. Different people would attribute
different levels of importance to the same task. Thus, the hierarchy of goals and
standards would affect intervention feedback. Third, “Attention is limited and only
feedback-standard gaps that receive attention actively participate in behavior regulation”
(p. 259). Fourthly, “Attention is normally directed to a moderate level of the hierarchy”
(p. 259). Finally, “. . . feedback intervention changes the locus of attention and therefore
affects behavior” (p. 259). Integrating these five basic arguments, Kluger and DeNisi
defined a three-level hierarchical process: task-learning process, task-motivation process,
and meta-task process.

These interdependent arguments would investigate and elucidate how feedback
intervention by external agents affects the attention of the participating subject. One of
the major implications of the meta-analytic moderator analyses conducted by researchers
was that feedback intervention affected the performance of the participating subject
involved in different directions, especially in terms of self-related feedback in all the
three processes identified by the theory (Kluger & DeNisi, 1996).

Wiliam (2012) also pointed out that researchers agree that feedback should focus
on the current task and address what students can do about it. An important characteristic
of the feedback, as per Wiliam, is that the learner should have more work to do from the
feedback than what the teacher would have to do. Finally, Wiliam cautioned that
feedback works only in a system, and the design of a successful system depends on a
teacher’s ability to create a student-focused learning environment.
Brookhart (2012) offered additional advice: (a) setting a target should precede feedback and (b) immediate practical opportunity to improve performance should follow feedback. Students need to know the objectives for their learning. It is also important that learning goals should be set in students’ perspective. Teachers should engage students in performance tasks that match the set learning goals. An effective feedback system is applicable only to a performance that students embark on to achieve a predetermined goal.

Brookhart (2012) further suggested designating clear learning outcomes for any given task. Students may have different perspectives in solving a particular problem posed to them that may be entirely different from what teachers want them to do. Establishing clear expectations clarifies the feedback teacher gives to the students. Feedback can take the form of guidelines, directives, or scaffolding that teachers provide students to assist them in reaching their learning goals.

Hattie (2012) delineated the three levels of feedback in formative assessments. Firstly, teachers should give task-feedback focusing on accuracy or building knowledge of the learners’ tasks. When teachers provide feedback on the processes or strategies involved with the students’ work, feedback could be rightly termed as process feedback. More importantly, sometimes, students monitor and regulate their own actions as they move toward the learning objectives. Teachers can provide effective self-regulation feedback to a student at this level that promotes critical thinking skills of the learners. Hattie suggests that effective feedback at these different levels advances students up the ladder of mastery of content, strategies, and conceptual understanding respectively.
However, Hattie urges educators to provide feedback in positive environments where students feel safe to make mistakes.

Wiggins (2012) contends that effective feedback should be “goal-referenced; tangible and transparent; actionable; user-friendly (specific and personalized); timely; ongoing; and consistent” (p. 13). Sometimes, goals in classrooms may not be clear if the teacher does not specifically list them. It becomes imperative that the teachers specify educational goals and give feedback on whether students’ activities were leading to meet the goals.

Characteristics of Feedback

Invariably, feedback is useful only if students get a chance to implement the feedback on the performance task for which they received the feedback. In this sense, Brookhart (2012) advocates for feedback to a summative assessment only if the feedback accompanies an immediate opportunity to modify student responses to the assessment, before finalizing the grades. Thus, Brookhart supports differentiated, clearly worded, and positive feedback that describes and motivates student work while they are still working on the task.

Defending the same line of thought, Chappuis (2012) suggests that effective feedback should have the following characteristics. Firstly, the feedback should direct the students towards the learning goal by accentuating the strengths of the students and providing specific scaffolding as needed. In order to accomplish this goal, teachers should provide detailed information about their expectation beforehand. Secondly, students should receive feedback while they can still apply the feedback provided to
them. Thirdly, teachers should provide feedback only on partial learning. If it is clear from the student’s work that the concept is not understood, Chappuis (2012) advises re-teaching the concept rather than providing feedback.

Next, Chappuis (2012) cautions teachers from giving very explicit directions in the form of feedback, thus taking away their chances of thinking. Finally, Chappuis warns teachers that excessive corrective information hampers the learning outcomes of the students. Students might eventually shut down because of the large number of corrections they need to make. Chappuis concludes that effective feedback leads the students to act upon the feedback and encourages students to attempt difficult tasks without complaint.

Students are not the only stakeholders who profit from feedback. Tovani (2012) perceives feedback as a two way process: it can come not only from teachers, but also from students. According to Tovani, teachers should frequently seek feedback from their students regarding their needs in the learning. Sometimes, student feedback proves to be effectual when planning instruction to meet the students’ learning needs. Tovani offered different strategies to elicit student feedback and include student feedback in daily lessons.

Firstly, Tovani (2012) suggests a workshop model that consists of “opening, work time, and debrief” (p. 50) and provides great opportunities for teachers to give and receive effective feedback. Teachers can use the feedback thus obtained from students to plan lessons to meet the learning requirements for students. During work time sessions, teachers can support struggling students and provided advanced insights for those who
exhibit mastery of concepts. Tovani further advocates the importance of student conferences as an integral part of giving and getting feedback.

Wiggins (2012) also advised educators to be tangible and transparent when they give feedback, so that students clearly understand how to improve their educational activities. The teacher’s feedback will not achieve the desired goal if it does not address the action the student should perform to improve the activity. If the student does not comprehend the indication, specific and accurate feedback is ineffective. However, teachers should avoid too much feedback lest the students get weary of it.

Effects of Timely Feedback

In concurrence with other researchers, Tovani (2012) believes in and advocates for timely feedback. Feedback without an opportunity to correct the mistakes and get the benefit of the newly corrected task is untimely and almost futile (Brookhart, 2012; Chappuis, 2012; Tovani, 2012; Wiliam, 2012). Tovani emphasizes the importance of timely feedback by explaining that late feedback, however great and important it may look like, is irrelevant. If students do not get chances to revisit the work after feedback, then the feedback is pointless and ineffective.

Wiggins (2012) also stresses the importance of giving feedback in a timely manner. Feedback given too late is pointless. It is also important that students receive opportunities to improve their performance based on the feedback they received. Continuous and consistent feedback from teachers and peers helps students to achieve this end.
Further, Marzano, Pickering, and Pollock (2001) advocate for the importance of timely feedback, stressing the significance of providing feedback after the whole test ($effect \ size = .72$). Comparatively, providing feedback after each item of the test had a smaller effective size ($effect \ size = .19$), according to the meta-analysis. However, a delay in providing feedback after the whole test has an adverse effect on the success of the feedback itself ($effect \ size = .57$). A follow-up test, according to Marzano et al., was ideal after one day ($effect \ size = .74$).

Self-Regulation from Feedback

Yorke (2003) adds that educators should view feedback from two perspectives. The assessor, with the intention of improving the student’s development, provides effective feedback in different forms, expecting the student to review the educational product through the lens of assessor’s feedback perspectives. The assessor expects the student to improve educational performance based on feedback. Ideally, the student who receives the feedback understands the feedback perspective of the assessor. However, Yorke (2003) cautions that there is a chance that the student might interpret the feedback in a different perspective and eventually develop “learned dependence” (p. 489), where the student relies on the teacher to explicitly spell out the expectations rather than develop learning skills. Sometimes, students who are more vulnerable to a sense of failure may end up developing this learned helplessness because of the feedback. Yorke urges educators to consider these aspects when providing feedback to student responses. In order to overcome or avoid this dilemma, Yorke suggests providing supportive critical
feedback as part of formative assessment. Such effective feedback helps stimulate self-regulation in learners that eventually results in improved student achievement.

Marzano (2006) addresses the concept of self-regulation in his discussion of classroom assessment. He delineates four important characteristics associated with effective classroom assessment, of which the first two pertain to the process of feedback. The first characteristic is that feedback “should provide students with clear picture of progress and how to improve [the students’ activities]” (p. 5). Next, feedback should “encourage students to improve” (p. 5). Marzano distinguishes between encouraging- and discouraging- feedback using drive theory and attribution theory. Drive theory suggests that success orientation and failure avoidance are the two driving forces that make students positively or negatively receptive to feedback. According to attribution theory, students tend to attribute their success or failure to four factors: ability, effort, luck, and task difficulty.

Marzano (2006) suggests that educators can positively reinforce the effort factor by using effective feedback to motivate students to be successful in their academic endeavors. He advises educators to provide convincing feedback that relays the message that low scores do not mean failure and improved effort leads to higher scores. Marzano further highlights the necessity of frequent formative assessment and corresponding feedback to result in improvement of the learner.

Feedback Models

Black and Wiliam (2009) also maintain that an effective interaction between student responses and teacher feedback results in the learner’s individual internal
production. Teachers, as an integral part of formative assessment, are supposed to provide feedback that leads the learner to the learning goal. Black and Wiliam (2009) stressed that the feedback serves its formative function if, and only if, it results in improved student performance. Thus, it becomes imperative that teachers create or utilize models of student learning that involve feedback in advance, at the start of planning for the lesson. They allege that a teacher’s pedagogical orientations tend to guide the basis of teacher-student interactions that play a very critical role in formative assessment and feedback of their students. Recognizing the differences in the instructional practices of teachers, Black and Wiliam (2009) proffer a variety of feedback models as options for teachers.

In the “initiation-response-evaluation or I-R-E” (Black & Wiliam, 2009, p. 11) model, the teacher assumes the role of evaluative listener or interpretive listener before providing one-to-one or group feedback. Another model recommended by Black and Wiliam is self-regulated learning model, discussed in the section titled Self-Regulated Learning. In another model, the dynamic assessment model, Black and Wiliam discuss how teachers can exploit the full Zone of Proximal Development (ZPD) of students by following up every success step of the student.

When creating their own feedback model, Black and Wiliam (2009) suggest that effective teachers construct their feedback based on the insights they have about the students’ responses. Teachers should carefully analyze student responses because, many times, the responses may not perfectly reflect what they actually wanted to convey, even in mathematical contexts. They emphasize the importance of pondering over the learning
orientation developed in the student because of the teacher’s feedback. Focusing feedback on grades, marks, judgments, or competition may have a negative effect on the student’s learning orientation. Black and Wiliam express concern that such negative orientation might hamper the educational achievement of students. They encourage teachers to make a list of feedback to match different expected student responses. However, teachers should caution themselves that the list may not be exhaustive and that the feedback may not be suitable depending on varying situations, content area, and student behaviors.

Total Participation and Feedback

Himmele and Himmele (2012) address another important aspect of feedback: total participation of students in classrooms. Total participation techniques serve as a great formative assessment strategy to monitor student progress and provide an effective feedback strategy. The researchers point out that any student activity should have the important characteristics of high cognition and high participation to make the learning experience great and memorable. Himmele and Himmele (2012) offer several techniques to achieve total student participation. One such method is “rippling” (p. 59), where quick-write or quick-draw prompts are given to all students in the class as an individual student activity. After a moment, the activity requires students to pair and share their responses. In the next step, students share with a group. Eventually, students share their responses with the entire class. The rippling activity provides opportunities for all students to think and share their responses with classmates. In addition, the process enables students to receive effective peer feedback. Another technique recommended by
Himmele and Himmele (2012) to achieve total class participation is the chalkboard splash, in which each student goes to the board and writes his or her response to the teacher's prompts. Debate team carousel activity, where students develop an argument taking sides on a debate prompt provided by teacher, or picture notes, where students drew pictures representing the main ideas at the prompts from teachers, also encourage effective total student participation. Although the total participation techniques require time to implement, the realization of improved results in the form of effective feedback enhances the learning environment for students (Himmele & Himmele, 2012).

Summary of Feedback

Researchers stressed the importance of providing feedback to student responses in a timely manner, so that students could apply the feedback immediately to the activity. Vital feedback on student performance, if given long after the ultimate completion of the action, would prove useless. Suggestions from various studies imply that the feedback should be immediate and explicit to help the student to correct their shortcomings (Hattie, 2012; Tovani, 2012; Wiggins, 2012). Some researchers pointed out how effective and timely feedback would lead recipients of the feedback to self-regulate their learning activities, to change their learning behaviors, and to improve their learning outcomes (Black & Wiliam, 2009; Kluger & DeNisi, 1996). Himmele and Himmele (2012) proposed total participation techniques to address to provide ways to give effective feedback to the entire class, partially using peer-feedback strategies in addition to teacher feedback. The next section of this chapter elucidates how self-regulated learning theory
and theory of distributed cognition guided the attempts to provide immediate effective feedback to the responses of students in this study.

Theoretical Framework

It is essential for a strong theoretical background to support experiments or studies conducted in educational systems involving young individuals because a lack of existing or emerging learning theories or psychological paradigms would adversely affect students' education and possible well-being. Discussions on student responses and feedback, closely aligned with formative assessment, led me to the parameters of self-regulated learning theory. Several researchers and theorists held the view that self-regulated educational activities and the corresponding feedback are the epitomes of feedback phenomena (Black & Wiliam, 2009; Hattie, 2012). When different cognitive elements, including those involving students, teachers, SRS, and other learning parameters, combine with the corresponding curriculum to become a part of an interactive environment in classrooms, these educational components interact and result in a distributed cognitive learning environment. Use of SRS as an important stimulus to connect different cognitive aspects of classrooms and the concept of distribution of cognition led me to analyze the distributed cognition theory. The following sections provide a discussion of the main tenets of self-regulated learning theory and distributed cognition theory that might influence and direct the use of SRS.

Self-Regulated Learning Theory

Zimmerman (2001) defined self-regulated students as the students who would "self-generate thoughts, feelings, and actions to attain their learning goals" (p. 5).
Importantly, self-regulated students immerse themselves in a self-oriented loop of feedback in their learning process. When teachers supplement the attempts of students with effective formative feedback, self-regulated students generally increase their pace to attain their learning objectives.

Self-regulated learning theorists display differences largely in the various fundamental learning theories they subscribe to, namely “operant theory, phenomenology, information processing theory, social cognitivism, volitional theory, Vygotskian theory, or constructivism” (Zimmerman, 2001, p. 2). In this section, I provide an explanation of how different schools of thought contribute to self-regulation theory to affect the learning outcomes of the students in this study. In Figure 2, I illustrate various perspectives that influence self-regulatory learning.

![Figure 2. Different Perspectives Influencing Self-Regulated Learning](image-url)
According to Zimmerman (2001), each theory depicted in Figure 2 provides a different rationale for promoting the theory of self-regulation in learning. Operant theorists support the use of external stimuli, including teacher feedback, to enhance motivation for the process of self-regulation among students. Immediate or delayed rewards act as positive re-enforcers to trigger the steps that lead to self-regulation. By skillfully controlling the external stimuli, the teacher can control students’ process of self-regulation. Those who possess the perspectives of social cognitivism believe that self-regulated learning develops from social sources and passes through different levels until the learners attain the higher level of self-regulatory learning (Zimmerman, 2001). Those who view learning from a volitional perspective believe teachers should train their students to achieve self-regulation in the learning process. The information processing perspective suggests that the rule systems that develop in students to process information are the root cause of self-regulation in learning. When teachers and community cater to the development of their rule systems, students tend to develop strengths in self-regulated learning in turn. Phenomenologists agree that improvement of self-perceptions enhances self-esteem, which prompts students to self-regulate their learning. Vygotskian principles define self-regulation as the internalization of self-directional models that result from observing social interactions of adults. As per Zimmerman (2001), constructivists suggest that different stages of cognitive development develop the self-regulatory learning capacity of the learner.

In the self-evaluation or self-correction stage, the individual compares his or her behavior with a set of desired or standard behaviors. Mace et al. (2001) emphasize that, in the stage of self-evaluation, the individual might modify their self-monitored behaviors to match with the set standards. In the final stage, self-reinforcement, the individual—after experiencing the steps of self-monitoring, self-instruction, and self-evaluation—adheres to a set of performance standards as a result of effective contact with feedback as invigorating stimuli. Once an individual attains the self-reinforcement stage in a variety of skills related to a specific content area, he or she is able to transfer and generalize the skill to other learning areas, thus enhancing individual learning outcomes in other content areas, too.

Social cognitivism. Those who possess the perspectives of social cognitivism believe that self-regulated learning develops from social sources and passes through different levels until the learners attain the higher level of self-regulatory learning
(Zimmerman, 2001). Schunk (2001) asserts that self-regulation is not a voluntary process because external agents (such as teachers, parents, or computers) may deliberately set up or instigate the environment for the students to achieve self-regulation. Even then, self-regulation does not generalize across all learning situations. Deliberate attempts become necessary to attain the goal of self-regulation in specific situations.

Schunk (2001) observed that the conceptualization of self-regulation involved “self-observation, self-judgment, and self-reaction” (p. 130) of the students. In line with operant thinking, social cognitive theory supports self-observation using the same techniques of tabulation, recording, and the like. Schunk further contends that self-observation motivates students to understand and improve their learning situations. It can also induce changes in behavioral patterns. Schunk describes self-judgment as the process of comparing oneself to set goals. Feedback increases the importance of attaining goals at this stage.

Schunk (2001) expands upon the concept of feedback from a social cognitive perspective, explaining that learners’ self-regulation develop with effective attribution-feedback. In addition, Schunk (2001) notes the importance of utilizing progress feedback until students are able to provide self-evaluation for their learning experiences.

Hattie (2012) agreed with Schunk (2001) regarding the impact of different levels of feedback on the development of student self-regulation. However, the paramount outcome of learning experiences should be the mastery of conceptual understanding. Hattie used the term task feedback to refer to the feedback provided to students based on their performance on tasks. Through task feedback, students understand their mistakes,
strive to correct them, and improve their performance. Similarly, process feedback clarifies and corrects student performance.

However, to improve students' conceptual understanding, it is necessary to orient feedback towards self-regulation. Using self-regulation feedback from teachers, students are able to regulate their learning process to achieve mastery of concepts. At this level, Hattie (2012) recommends that teachers promote their students' effective learning skills through error-detection, peer teaching, and help seeking, and the like.

However, Hattie (2012) suggested that it is improper to give self-regulation feedback right in the beginning. Students should gradually improve their skills to receive task feedback, process feedback, and self-regulation feedback in ascending order corresponding to their levels of responses. If teachers give the correct level of feedback based on the current level of the student's learning, it is probable that students will ascend the ladder of mastery and attain the mastery of conceptual understanding. Even at this level, self-regulation feedback helps students accomplish enhanced mastery of conceptual understanding and thus improve their learning outcomes.

Black and Wiliam (2009) highlight the importance of interpretive listening as an essential part of moments of contingency during formative feedback, for it is imperative that the communication between teacher and student regarding the learning process is on the same cognitive level to give effective feedback. Black and Wiliam state it is also important for teachers planning for effective feedback to be ready to construct their responses based on the insight they possess about student responses. As per Black and Wiliam, teachers should analyze the cognitive intentions of student responses before
providing any feedback. Further, the researchers suggest that in order to achieve this level of clarity, it is necessary that teachers design effective models to plan feedback.

To address this issue, Black and Wiliam (2009) offer a three-fold, self-regulated learning model. Firstly, in the growth model, also known as top-down self-regulation, students build up knowledge based on obtained feedback that centers on “personal interests, values, and expected satisfaction and rewards” (Black & Wiliam, 2009, p. 13). When students are driven by the norms of well-being rather than knowledge build-up—where feedback focuses around rewards or maintenance of positive feelings in the classroom environment—the second process, known as the well-being model or bottom-up self-regulation, commences. The third process in the model, termed “en route phase” (Black & Wiliam, 2009, p. 14), is the switching that occurs between the top-down and bottom-up self-regulation.

According to Como (2001), volitional functioning involves self-management and efficiency in handling personal resources and learning environment. The tenets of volitional strategies play a vital role in education because students are subject to many distractions that prevent their cognitive development even in a well-structured classroom. Black and Wiliam (2009) contend that, if exposed to proper feedback practices, students are encouraged to stay in the growth model by gaining control of their educational environment by utilizing volitional strategies. Como, when explaining the modern theory of volition, supported Black and Wiliam’s recommendation. As per the explanation, learned volitional strategies encourage students to focus on their learning goals by
“control[ling] intentions and impulses” (Corno, 2001, p. 194) that might tempt them to deviate from their learning goals.

Information processing theory. Inspired by tenets of information process theory, Black and Wiliam (2009) suggested that the actions of the students in the process of self-regulation model include identifying the task, planning and executing a strategy or response, and the resulting adaptation, review, or re-cycling. Learners draw resources from typically four different sources.

Firstly, Black and Wiliam (2009) suggested that learners gain resources from (a) conditions that include internal cognitive status of the task in hand and (b) external information about the task. The former includes theoretical/conceptual knowledge about the task, internal motivation to do the task, background knowledge about the task, and knowledge of tactics and strategies for performing the task. The latter includes external resources, time, and teacher-created directions that help learners perform the task.

Secondly, students gather resources from “operations” that include knowledge and the process employed to undertake and complete the task. Operations are comprised of various processes like “searching, assembling, rehearsing, and translating” (Black & Wiliam, 2009, p. 15).

Thirdly, students would base their self-regulation process in comparison with the resource of “standards” available to them. Finally, Black and Wiliam (2009) maintain that students self-regulate themselves based on the evaluations they receive from authorities, including teachers, that form the fourth set of resource. In the resulting model, evaluation—the fourth component of the resources available to students to self-
regulate their learning—plays a key role. When other resources of self-regulation are either internal or set as common, evaluation from authorities or teachers is the only external resource that guides learners individually to achieve learning goals.

Phenomenological perspective. McCombs (2001), from a phenomenological perspective, pointed out that learning, like self-development, is a continuous process influenced by self-system structures and self-system processes, and supplemented “by self-defined conceptualizations of self-attributes” (p. 85). During different developmental stages, individuals receive information received from their own experiences as well as from significant people around them, which directly influence the individual’s self-regulation process. Such self-regulation processes would ultimately result in the development of self-system structures for the learner. McCombs further asserted that when students self-evaluate their learning experiences they endure during a particular learning opportunity would create self-system processes that would help them in maintaining meaningful self-control. Imperatively, McCombs advocated that students, in their developmental stages, should get opportunities to enhance self-regulated learning by focusing on “self-system development . . . understanding of inherent capacities for motivation and learning . . . [and] learner choice and control” (pp. 110-112).

Vygotskian perspective. McCaslin and Hickey (2001) delineated the foundations of co-regulated learning in classrooms. Students have to regulate themselves to learn goal-coordination through their interactions with and among different aspects of their learning environment. Even though co-regulation imply to create shared responsibilities of all the stakeholders of educational environment, McCaslin and Hickey stresses the
importance of students imposing self-regulation as a means to achieve the effects of goal-coordination. From a Vygotskian perspective, McCaslin and Hickey stated that learners, when trained and provided with opportunities to promote self-motivation, self-enactment, and self-evaluation, would strive to achieve goal-coordination as their educational achievement.

Constructivist perspective. Paris, Byrnes, and Paris (2001) suggested that education should enable students to use various learning strategies to guide their educational experiences. From a constructivist perspective, individuals are capable to interpret their successes and failures in educational context and with effective interpretations from different sources can regulate their attitudes, experiences, and actions to better their educational situations. However, it is important that teachers or their individual learning environment should scaffold them in their efforts to self-regulate their learning experiences through various tenets of motivation and creation of meaningful educational environments to match the expected learning experiences.

Distributed Cognition Theory

Hollan, Hutchins, and Kirsh (2000) discussed the fundamental principles that guided the formation of distributed cognition theory. Firstly, the elements and the relationships between the elements participating in the process determine the boundary of the unit of distributed cognition. Secondly, the range of entities that participate in the process of distributed cognition might become wider than what traditional views of cognitive theories could observe or anticipate.
According to the concept of distributed cognition, Schwartz (2008) suggested that in the process of learning, cognition is distributed from "mind to mind, mind to tool and tool to mind" (p. 390). Schwartz also observed that in the process of learning, there develops a strong interconnection of cognition distribution among members of the learning group, objects involved in the learning process, and the period involved in the learning process. Figure 3 illustrates the factors that may influence distributed cognition theory in this study, following the suggestion of Schwartz that the process of learning is distributed across the learner's mind and the learner's social and physical environment.

Figure 3. Factors Influencing Distributed Cognition Theory.

Hollan et al. (2000) asserted that the phenomena of the distributed cognitive process disperse across the participating entities and involve "members of a social group [...] coordination between internal and external...structure [...] could be distributed
across time and events” (p. 176). In modern work environments, where humans accomplish many of their tasks through group efforts, it becomes necessary for us to understand the distribution of cognition not only among human brains, but also between humans and machines, especially computers.

According to Hollan et al. (2000), educators can extend the theoretical perspectives of distribution cognition to modern learning environment where students interact with technology in different forms to build their knowledge structure. Hollan et al. also suggest that the millennial students use various technologies, including SRS, to communicate using technology not only among themselves, but also with teachers and their learning environments, thus enhancing their ability to learn more effectively through distribution of cognition.

Thus, Hollan et al. (2000) posits that the theory of distributed cognition suits well with the use of SRS as an effective feedback tool. Using SRS, the students can communicate, draw feedback inferences, and improve their self-regulatory skills using teacher feedback as a guide. The fact that distribution of cognition may also occur between different events, past or present has the potential to enhance the retention capacity of the students when they continuously use SRS. The human-computer interactions that are quite important in current technology-oriented workspaces or classrooms, thus become an important aspect to consider when students are interacting with SRS.

In an explanation of the nature of distributed cognition, Rogers (1997) describes the theory as focused on the “interactions between the distributed structures of the
phenomena under scrutiny” (p. 2). According to the study, the researcher who uses distributed cognition strategies can focus on different units of analyses. Among them, focusing on the processes of individuals—in this study, on learners using SRS as the feedback tool, in interaction with the tool and among themselves—may prove very informative.

Rogers (1997) suggests that in a cognitive system, there is a pool of resources developed by the individuals who form the system. To accomplish a group task, learners can pull from these resources when needed. In addition, the cognitive system creates a well-developed coordination system of actions. Rogers asserts that in any cognitive system comprised of two or more participants, each participant will have different cognitive characteristics. Thus, when participants work on a group activity or respond to the same activity using the same media, they may indulge themselves in actions that result in sharing knowledge and creating a collective knowledge, thus constituting a cognitive system. Sharing of knowledge and ideas thus creates a new learning environment together with the communicative devices in place, enhancing learning situations.

Wright, Fields, and Harrison (1999) indicate that the distributed cognition theory focuses on a network of participants and technology involved in the activity. Wright et al. contend that, even though teamwork is an outcome of the distributed cognition activity, it is possible to emphasize individual’s problem solving or learning effects using teamwork. Wright et al., commenting on the works of Norman (1988), reiterated Norman’s conclusion that properly planned technological activities would reduce the
cognitive activities of individuals participating in the activity. In contrast, a lack of effective planning of technology and devices used in the activity would demand extraneous efforts from the participants. Thus, the designers of the activity who plan to demonstrate a distributed cognition effect should plan to make the technology and the devices included in the learning activity ready to enhance learning experiences.

Wright et al. (1999) explained the suitability of using the distributed information resource model to demonstrate distributed cognition methodology. According to the model, the abstract information structure includes “plans, goals, affordances, history, action-effect relations, and states” (p. 8). Thus, I designed a sequence of SRS actions, which comprise the planning section of the model. The goal of my intervention was to give the accurate concept perceptions to learners using systematic corrective directions or by the whole class corrective measures using effective group feedback through SRS technology. There are different ways in which students can input their response using SRS. The plan should clearly indicate the types of affordances meant for each occasion. The history of the distributed cognition activities helped me to visualize the steps that the learners had taken, thus, allowing me to analyze and modify further plans in the intervention. The states were the recorded values of different interactions in the activity at given intervals of time. Once the plan was in place, the intervention activity, cyclic in nature, acted upon the cognitive development of the participating learners.

The interaction between the learner and SRS, or among the learners, created a new learning environment that enabled me to evaluate the distributed cognition aspects of the activity. These observations allowed me to plan and implement interaction strategies,
the second level of the model suggested by Wright et al. (1999). It was also imperative to design a follow-up strategy to ensure the proper execution of the plan in place. The follow-up strategy closely observed the abstract resource elements, including goals and states.

Thus, according to Wright et al. (1999), the plan-construction strategy requires investigators to adjust the plan after comparing the current state with the planned goal. Sometimes, investigators construct or reconstruct the plan to meet situations whenever necessary. The goal-matching strategy helps the investigator at this process stage.

Finally, the researchers acknowledge that, based on the current state of activity, strategies including "history based- selection" or "elimination" (Wright et al., 1999, p. 12) may become necessary.

Additionally, Wright et al. (1999) caution that there are chances to have a large probability of operator error while implementing the distributed cognition activities. The educator should carefully describe and utilize the purpose of technological device to elucidate the anticipated goals, as defined in the activity. The educator should also monitor the results of the intervention to decide whether to construct or reconstruct the activities that are vital for the success of the intervention.

Student Response Systems (SRS)

During the lesson planning process, it becomes necessary for teachers to design strategies to measure comprehension levels of their students frequently. The information obtained may lead teachers to make modifications in the lesson, including remediation, rectification of conceptual errors, and the pace of instruction. Traditionally,
communication between students and teachers regarding conceptual comprehension in classrooms, especially in large-sized classrooms, was never easy. Collection of student responses, synthesis of collected responses, and provision of effective feedback based on student responses were tiresome processes. If some teachers accomplished this, it took them a considerable amount of time. Even when using total participation techniques suggested by Himmele and Himmele (2012), the time taken to give the feedback was not feasible. It is almost impossible to provide personalized feedback for every student in the classroom.

Yet, research shows that timely and effective feedback is an important and essential part of the learning experience (Hattie, 2012; Marzano, 2006; Tovani, 2012; Wiggins, 2012). Thus, it is important to ponder on various strategies to provide effective, timely feedback to ensure that our students have every support to reach their maximum potential of achievement. The emergence of different computer programs and websites that enhance the speed and effectiveness of providing feedback are boons to meet this end. It becomes very important for an educator to understand, master, and use these technological devices to improve educational experiences of their students. The role of technology in helping the students to get effective feedback is thus very critical.

Types of SRS

Historically, teachers have used different types of response systems corresponding to their availability. The manual student response systems that include response cards, or using mechanical devices like colored responses, are still used today in many classrooms to elicit student responses. As Randolph (2007) points out, such manual SRS enhances
student achievement more effectively than relying upon student expressions. With the advancement of technology, computer-aided SRS improve the ways in which student responses can be collected and analyzed. Clickers with the capability to collect multiple-choice responses were a breakthrough when introduced. However, modern SRS, even though generally called clickers themselves, where students can respond in texts, numbers, and sentences, has taken the realm of student responses to a higher level. Technology and its applications, especially those designed for use in classrooms, are improving quickly. The clickers have now become so much more functional that it is improper to call them clickers anymore because they do more than just clicking the right answer. The ways to collect student responses and provide feedback have undergone major refinements. The upgraded technology allows students to respond to teacher prompts using text, numbers, and sentences that involve mathematical symbols. In addition, many Web 2.0 programs, which enable students and teachers to connect through any internet capable device, provide avenues to collect student responses and provide feedback.

In the following section, I discuss how various researchers have added to the knowledge of using SRS to improve students’ learning experiences.

Literature Review Involving Student Response Systems

In a meta-analysis, Randolph (2007) reviewed 18 studies that used response cards to record student responses and found that the manual SRS had a higher effect on student achievement when compared to the traditional methods of communications, such as students raising their hands. In contrast, response cards provide teachers with an
immediate response from the students regarding their comprehension. The responses provide enough information to modify the learning plans or to correct the comprehension problems. Randolph noted that write-on cards and printed cards were widely used throughout educational scenarios ranging from small kids to college classes.

In the meta-analysis, Randolph (2007) compared the effects of write-on cards or printed cards on student achievement to more traditional SRS, namely, raising the hand. Randolph suggested that, according to the “active learning theory” (p. 125), students would have benefited from using response cards, irrespective of the type of cards, namely write-on cards or pre-printed cards with a small effect size, Cohen’s $d = .26$. However, Randolph noted some disadvantages in using response cards, as widely reported, which include waste of instructional time, students’ noncooperation, and messiness in handling the write-on cards. In spite of the drawbacks, Randolph recommended educators use response systems because of improvement in test scores, student participation, and on-task behaviors of students.

In an investigation of the implementation of student response systems, Nicolle and Lou (2008) conducted a mixed methodology study comprised of surveys and interviews of tertiary-level faculty. One research question in the study addressed the “role [played by] instructional design and delivery [in technology] on the learning process and student learning outcomes” (p. 241). Nicolle and Lou claim that the faculty in the tertiary educational institutions used technology integration to increase their students’ learning potential. In addition, they note that interpersonal interactions increased with the use of technology in the classroom. Only when the faculty was unable
to find the relevance of using technology and learning outcomes did the faculty decide not to use technology integration in their classroom activities. The researchers recommended the need for further studies to investigate how technology might help to improve students' learning outcomes, especially when the faculty encourages their students to use effective technological devices and apparatus in or out of their classrooms and learning environments.

Blood and Neel (2008) investigated the effects of SRS in a lecture class in a study involving 35 graduate students. For the intervention group, Blood and Neel used a *Turning Point* device to collect student responses at the end of each week of the 10-week lecture classes, a Likert-scale engagement measure, and a weekly content quiz. Investigators also provided feedback for the quiz responses using a poll facility available with the SRS. The feedback, displayed using PowerPoint slides, was in terms of graphics corresponding to the student response. On the occasions during the intervention when student responses revealed poor conceptual comprehension, the investigators provided remediation activities and subsequently repeated the quiz.

Blood and Neel (2008) reported a statistically significant increase in the posttest scores of students when they provided immediate feedback using SRS. The measures used for the study were a weekly content quiz, weekly engagement Likert scale, and the overall course evaluation questionnaire. All the while, the non-SRS group received the same quiz every week. Blood and Neel compared the groups for achievement and engagement of the learners using independent *t* test. The researchers claim that the results of the study demonstrated a statistically significant difference between the
engagement and achievement scores of the groups who used SRS and who did not use SRS in their learning environment. In addition, Blood and Neel (2008) suggest that the learners who used SRS developed more confidence in their learning process. The immediate feedback led to timely correction of learning errors and increased the quiz scores of learners in the intervention group. However, Blood and Neel (2008) concluded that the values of dispersion in the scores of intervention group was high, indicating that improvement in the learning was more individualized and the effect size in general was very low. There were students who did not benefit from the use of SRS.

Blood and Neel (2008) further pointed out that the limited learning environment of the study and student-lecturer relationships might have influenced the results of the study. In addition, the novelty concept of using SRS might have increased the engagement level of the participating learners. In spite of these limitations, the statistically significant differences in the achievement and engagement prompted Blood and Neel to conclude that SRS definitely improve the achievement and engagement of the students in similar learning environments.

Christopherson (2011) stresses the importance of testing the effectiveness of using SRS in classrooms before implementing the technology across the entire educational system. Christopherson sought to discover whether simply adding the technology to the class environment would increase engagement and achievement of the learners involved in the process of learning. Indeed, Christopherson pondered whether the use of SRS changed the pedagogy of the teacher and thus led to previously mentioned improvements, so she designed a study with a control group consisting of 19 psychology students and an
SRS group consisting of 21 students who selected two courses through the normal college admission processes. Using the Beyond Question SRS system, Christopherson collected and manipulated student responses in the study. The students in SRS groups used clickers to answer the questions displayed on PowerPoint slides. The same instructor for both the courses utilized identical instructional materials. Different forms of interactive responses used in the experiment group consisted of "reading questions, concept checks, opinion polls, personal experiences, and discussion starters" (Christopherson, 2011, p. 2). The investigator compared students’ ACT scores using a t test to establish that the scores between the two groups did not show a statistically significant difference.

Christopherson (2011) implemented the scale created by Morling, McAuliffe, Cohen, and DiLorenzo (as cited in Christopherson, 2011) to establish that there was no statistically significant difference in student engagement between the two groups. At the end of the course, Christopherson analyzed the results of five exams and overall grade of the students in both groups using analysis of covariance procedure, with average F values 0.25 (Cohen’s $d = .49$) and 1.53 (Cohen’s $d = 3.06$) respectively. Morling et al.’s engagement measure scale served to measure the engagement level of the students at the end of the course. Christopherson claimed that the results of the study, in contrast with general assumptions, did not show any statistically significant difference in student achievement. The claim implied that merely using SRS in the classrooms did not have any effect on students’ learning outcomes.
However, Christopherson (2011) delineated how SRS could address students’ misunderstanding of the concepts, engage passive learners, and provide real-time feedback to student responses. These benefits of SRS, as per corresponding learning theories, might enhance learning experiences of the students. Yet, the benefits of using SRS manifest only when an effective teacher executes well-designed instructional plans that include the effective application of SRS.

Thus, Christopherson (2011) concludes that the use of SRS implements the expected changes that results in learning gains only if an effective teacher with a well-designed instructional plan uses SRS. Christopherson accurately identifies SRS as only a tool. The success and the effectiveness of the tool depend on the effectiveness of the design used to collect student response and provide feedback. It is not the tool but the user of the tool that makes the difference.

In contrast, Jones, Antonenko, and Greenwood (2012) suggested that implementation of formative feedback requires the use of modern technology to meet the challenges of giving the feedback continuously to every student in large classrooms. Jones et al. noted that the usual SRS implementation process includes devices that collect student responses corresponding to teacher stimuli, a software that analyzes the student responses and devices that give a teacher planned or software-provided feedback for the student response, either personally or as a group. The software usually comes with different options of providing feedback. Depending on the different types of student responses, teachers can change the pattern of instruction to facilitate better learning outcomes.
Jones et al. (2012) noted that when peer instruction is included as a part of the teacher feedback, the rate of concept learning increases exponentially. Jones et al. studied the effects of using formative feedback using student responses with a convenience sample including 194 undergraduate students enrolled in a 16-week class. The investigators planned to find whether SRS-based instruction would enhance “motivation, metacognition, transfer of knowledge” when feedback was provided using either “individualized or collaborative SRS strategy” (Jones et al., 2012, p. 480). The investigators gave the right answer to the members of the Individualized Response (IR) group immediately after collecting their responses using SRS. After displaying the right answer, investigators gave an additional chance to the members of the Peer Instruction (PI) group to correct their answer after discussing the question with their self-selected pair.

Jones et al. (2012) employed “a split-factorial multivariate analysis of variance (MANOVA) . . . for attention, relevance, confidence, and satisfaction with [the two] sections and gender” (p. 482). Jones et al. claimed that the results of their study indicate that the use of SRS proved effective for both individualized and group strategies to enhance achievement and motivation in the students’ educational endeavors. However, the maximum effect size, partial $\eta^2$, of all the results in this study was .08; hence, the researchers advise further investigation on the impacts of SRS in educational achievements, including developing measures to assess learning outcomes using SRS. In addition, Jones et al. contend that further research is necessary to identify the proper integration of SRS into other content areas.
Liu, Gettig, and Fjortoft (2010) studied how SRS would influence the short- and long-term learning in pharmacy science using the Turning Point Response System. Students purchased the system and used the system in their classes. Both the control group and the intervention group attended identical lectures, where the students in the former group did not use SRS and the students in the latter group used SRS. The researchers administered unannounced quizzes at the end of both the lectures and a similar quiz to both groups after one month without announcement. According to Liu et al. (2010), "The quiz scores were not included in students' final grades" (p. 2) even though their participation in the quiz activity gave them bonus points for another class not related with the study. Results of paired $t$ tests determined the homogeneity of the two sample groups.

Liu et al. (2010) used chi-squared tests to identify the differences in categorical values. According to Liu et al., the results of the first quiz indicated that the students who used SRS performed significantly better. However, the students did not successfully retain their superiority in terms of long-term memory. There was not a statistically significant difference in the scores of the second quiz when compared with the students in the control group. Consequently, Liu et al. argued that even though SRS improved comprehension of the students at the time of their learning, SRS did not prove to be very helpful in retaining educational gains.

Dunham (2011) conducted an experiment to discover how SRS would affect the academic performance of 106 seventh grade mathematics students. The sample population consisted of students from four classes. Dunham stated that two classes were
assigned classroom activities involving the use of SRS (experiment group) and the other two classes (control group) did not have any activity involving the use of SRS.

Dunham (2011) used ActivPoll to collect student responses. The performances in end of unit tests and in seventh grade CRCT tests helped Dunham to evaluate the students. Dunham used two-factorial repeated measures analysis of variance to evaluate the effects of performances in the tests, one-way ANOVA to compare CRCT scores, and t test to analyze the difference of CRCT scores. Dunham claims the study indicated no statistically significant difference in achievement, either in teacher-generated tests or in CRCT, with the use of SRS. However, Dunham recommends the use of SRS since the use of the system helped improve the learning environment by enhancing student engagement. Yet, the researcher advocated for further research to explore the full potential of the tool to elicit better learning outcomes.

Abode (2010) also investigated how instructional activities involving SRS experienced by the students and the three teachers in the treatment group improved the learning outcomes of the students. In a mixed method study, Abode chose three, third grade classes for the treatment group and the control group each. The non-randomized pretest/posttest quasi-experimental study took place in an inner city elementary school. Abode obtained the quantitative results of learning outcomes for students in both the groups from the Online Assessment Reporting System, already in place in the school as part of California Standards Test. After determining the reliability of a 5-point survey, Abode used the School Achievement Motivation Rating Scale (SAMRS) and the survey to measure students’ achievement motivation and student engagement level. The results
of the 2 x 2 analysis of variance (ANOVA) revealed no statistically significant difference between the achievement of students in the treatment and control groups.

However, there was a significant increase for both groups with respect to time, indicating that both the groups, whether they were using the intervention or not, gained almost identical achievement in due course of time (Abode, 2010). Still, the qualitative analysis, which included interviewing teachers and students who consistently used SRS and the analysis of the modified SAMRS, led Abode to suggest that the use of SRS increased student engagement and motivation. Abode contended that the implementation problems and the limitations of the study, which included sampling issues, student participation criteria, unfamiliarity of the teachers to use SRS, affected the performance of SRS in the classroom and impeded the accuracy of the measurement of accurate achievement level of the students.

There were limitations in Lynch’s (2013) pretest/posttest quasi-experimental between-subject study to determine the effects of using clickers in eleventh grade students’ math achievement. Lynch used one-way analysis of covariance (ANCOVA) to determine the increase in achievement levels of students who used clickers to support their learning activities. There were 28 students in the intervention group and 33 students in the control group. During the intervention, Lynch used elnstruction’s Classroom Performance System (CPS) to give feedback to students by displaying histograms representing student responses for formative multiple-choice questions provided to them. The class then remediated any misconceptions that occurred as represented by the histogram. The intervention group used the clickers on a daily basis. Lynch stated that
the ANCOVA test provided no evidence that the intervention of using clickers improved mathematics achievement of the students in the intervention group. Lynch suggested that further investigations overcoming the limitations of this study (i.e. variation of math ability levels, poor student motivation, student effort, and limited time) might reveal the true nature of the effects of using SRS in the realm of student achievement.

Rigdon’s (2010) mixed method study also sought to determine the effects of using SRS in middle school mathematics classes. The study focused on finding the achievement and attitude differences among students using SRS in their learning environment. Rigdon maintains that it is important to change instructional strategies in millennial classrooms containing students born into the technological era, for these students are easily disengaged if teachers’ instructional strategies do not involve modern modes of communication. Typically, the current student population uses modern technologies including SRS with ease because the process matches perfectly with their interactions with technology. Rigdon’s study included interviews and observation in real time settings from 425 middle school students; it also included a pretest and a posttest to measure students’ learning achievement. Rigdon doubted the generalizability of the study since teachers’ exposure to SRS technology varies across educational systems and the effectiveness of using SRS largely relies on teachers’ experience in planning and implementing SRS learning.

Rigdon (2010) documented an increase in participation in classroom activities when students used SRS to give their responses. The quasi-experimental study used ANCOVA to compare the pretest and posttest scores of the two groups of students, one
that used SRS in their learning process, and the other that did not use SRS in their classroom activities. For the purpose of quantitative study, the control group consisted of 25 students; the treatment group consisted of 56 students.

Analysis of the qualitative data indicated that the use of SRS helped to inculcate a positive learning attitude among students about learning middle school mathematics, leading Rigdon (2010) to conclude that improvement in the learning environment, where students feel safe to respond without any fear of wrong responses, generates a positive attitude. Again, the students started to enjoy using SRS because it was “fun” (Rigdon, 2010, p. 51).

However, when controlling pretest scores, the quantitative data analysis comparing the posttest results between the control and treatment group did not show a statistically significant difference. In spite of the results from the quantitative analysis, Rigdon (2010) concluded that the use of SRS enhances the learning environment and, as a result, enhances the learning outcomes of the students. Rigdon also recommended extending research to determine the effects in the learning outcomes of students using SRS in different content areas and grade levels.

Edens (2006) stressed the importance of considering whether teachers are ready to teach classes with SRS. It is true that some teachers are not skillful in transferring the knowledge to daily classroom challenges, including the effective use of SRS. The quasi-experimental study conducted by Edens included 120 students in two groups, each group exposed to different pedagogical implementations of SRS. One group of 60 students, the Operant Conditioning group, used SRS for quizzes that counted for 25% of their grades;
the other group, the Metacognitive group consisting of 60 students, used SRS as a tool to
self-monitor and self-assess their comprehension. The weekly quizzes and the results
associated with SRS were mandatory for the Operant Conditioning group and
informational, but not mandatory for Metacognitive group.

Edens (2006) investigated student-related behaviors including attendance,
preparation for class, “self-regulatory and motivational characteristics, instructional
approaches, and achievement” (p. 163) of students exposed to both instructional
strategies. Edens used an end of course survey and posttest to collect data at the end of
the course for both groups. In contrast to the expectation regarding student achievement,
the results of the MANOVA indicated that neither method proved to be more successful.
However, the results obtained from data analysis supported the positive association
between achievement and self-regulation purported by prior research. The interaction
between gender and self-regulation was significant, and low-self-regulated male students
had greater achievement than high-self-regulated male students did, which was in
contrast with literature review. As a secondary finding, Edens reported that the students
in the Metacognitive group enjoyed using SRS to learn from their mistakes.

In an investigation of a different content area, Matus, Summa, and Kuschke
(2011) selected three classes of students enrolled in a business strategy course. After
conducting ANOVA on Class Participation Summary scores of the students, researchers
found that the classroom participation attitudes of the students in all three classes were
homogenous. Matus et al. used scores from the Business Field Exam (BFE), a
standardized test conducted by Educational Testing Service (ETS), as an indicator for the
students' pretest. Matus et al. stated that the results from ANOVA showed no significant difference in the students' BFE scores across the three groups. As part of the study, in the first month of the experiment, one group underwent instruction in traditional format, the second group received online instruction, and an SRS supported the third group.

A monthly test in each class served as additional evaluation of student achievement (Matus et al., 2011). The researchers cycled the methods of instruction for each group in a one-month interval. Thus, at the end of three months, all three groups had experienced all three methods of instruction, and investigators recorded their academic achievements in three monthly exams. Students engaged in a quiz review and administration on a weekly basis. A correct answer and three distracters accompanied each question in the quiz. In the traditional group, the students responded orally, whereas the students in the SRS group responded using clickers. Finally, the students in the online group obtained online feedback with a restriction that the online students knew only their final score since, to encourage students to put an earnest effort, the online system did not reveal the correct answer for each question.

Matus et al. (2011) conducted a 3 x 3 mixed factorial ANOVA and suggested there was no significant difference across the different pedagogical methods: traditional methodology, SRS methodology, and online methodology. Matus et al. cautioned readers of the study that the small sample size, duration of the study, exam used to determine the academic achievement, and investigator bias might have influenced the results of the investigation. Matus et al. recommended further investigations to determine the effects of different pedagogical strategies on academic achievement.
Penual, Boscardin, Mason, and Crawford (2007) also conducted an investigation of pedagogy. The researchers stated that one of the techniques advocated by research to improve math and science education across the nation is to encourage teachers to combine instructional strategies with technology. Penual et al. suggested that making the student thinking visible for their peers and to their teachers assists teachers to modify the thought processes of the students and occasionally helps peers to check and guide their thought process. Penual et al. strongly advocated using SRS to make the process of student thinking effortlessly visible to the class. The large-scale survey study included 584 elementary and secondary educators across the United States who used elnstruction's Classroom Performance system as their SRS (Penual et al., 2007).

Penual et al. (2007) collected data using a six-section questionnaire. The first section focused on the educators' instructional knowledge of using SRS. The second section collected data regarding the specific use of SRS. The third section focused on teachers' purpose in using the SRS. The fourth section was regarding teachers' pedagogical beliefs. The fifth section explored the perceived results of using SRS in their classroom. The sixth section, excluded from the analysis, sought to determine the science topics taught by science teachers. Penual et al. motivated the participants by offering a prize and monetary compensation for completing the survey.

Penual et al. (2007) found that K-12 teachers used SRS for instruction and for assessment. The visual display of student thinking helped to stimulate discussion in the classroom. Penual et al. ventured that frequent and continuous use of SRS undoubtedly enhances learning outcomes. In addition, Penual et al. found that personal pedagogical
orientations influenced teachers who used SRS. Teachers who favored constructivist pedagogical practices tended to utilize SRS more frequently when compared to teachers who favored behaviorist pedagogical practices. Furthermore, teachers who participated in the survey also tended to believe that effective professional development regarding the use of any new technology would result in teachers adopting the novel concepts in the classroom to enhance student participation, student engagement, and student achievement. Penual et al. hoped that further investigations and research would enable the educational system to reap the benefits of this useful technological device in the near future, as the system would become more structured and viable to use in K-12 environment.

Summary of Research on the Effects of SRS

Table E1, located in Appendix E, and Figure 4 present a summary of the implications and recommendations obtained from the studies discussed in the Literature Review Involving Student Response Systems section of this chapter. The majority of the studies represented a mixed methodology design, which gave me the impression that the researchers were not satisfied with the quantitative results they found. However, there were not many qualitative studies related with the effects of SRS satisfying the criteria for inclusion of my search.
**Figure 4.** The Effects of SRS According to Selected Studies

Only a few studies suggested that SRS had a strong and direct impact on academic achievement of students. However, the investigators were doubtful of the results, because the results were not in correlation with theories pertaining to formative assessment and feedback. However, the investigators generally agreed that implementation of SRS increased student engagement in classroom activities. The quantitative studies that I examined had limitations that would have directly affected the results of SRS effects. It is noteworthy that all the investigators recommended further investigations that probe into the effects SRS.

Evidently, more investigation will enlighten the effects of integrating SRS in classrooms in the realm of student achievement. The development of intervention instrumentation will also draw from the concepts of using systematic immediate feedback for error analysis that will lead to early correction of misconception. I also employed anonymous, immediate feedback using the anonymous poll feature of SRS that enabled me to design the less pervasive intervention to give feedback. Thus, the literature review on SRS helped me to plan a detailed intervention procedure. It is also noteworthy that
there are limitations for my investigations, as delineated in Chapter 1 and in Chapter 5.

In addition, I delineated the assumptions for this study in Chapter 1.

Other Factors That Could Affect Student Achievement

Although the millennial generation has a strong affinity toward modern technology in general, attitudes of individual students might vary in the ways they utilize technology in their educational life. Apart from individual differences, there are different factors that determine how they analyze and consume technology available to them so abundantly. I wished to study three factors that would be very crucial in determining how each student would interact with SRS in math class and how these interactions would result in educational achievement in mathematics, namely, giftedness, economic status, and gender. The following sections include the insights I received when reading the relevant literature related to each of these important factors.

Giftedness

Identifying giftedness and providing gifted services to students identified as gifted learners has been a major educational development in the nation after the induction of laws and regulations for the same. I tried to collect evidences and practices that led me to put effort into knowing how using SRS as an immediate feedback tool would prove effective to the students identified as gifted learners. Figure 5 illustrates the characteristics of giftedness that had the potential to affect my investigation.
Theoretically, after reading literature related with giftedness, I found that the definition for giftedness is very vague. Definitions range from the top 1% of the population identified using the Stanford-Binet Intelligence scale advocated by Terman (1926) to the multiple giftedness eligibility criteria in Georgia (Georgia Department of Education [GaDOE], 2015d). The National Association for Gifted Children ([NAGC], 2015a) defined gifted children as those individuals who “demonstrate outstanding levels of aptitude or competence in one or more domains [, including]... structured area of study with its own symbol system and / or set of sensorimotor skills” (para. 4). GaDOE (2015d), in tune with the definition of NAGC, defines a gifted student as follows:

A gifted education student is defined as one who demonstrates a high degree of intellectual and/or creative ability (ies), exhibits an exceptionally high degree of motivation, and/or excels in specific academic fields, and who needs special instruction and/or special ancillary services to achieve at levels commensurate with his or her ability (ies). (GaDOE, 2015d, para. 1)
Terman (1926), who conducted a longitudinal study of gifted students with a sample of 1,500 gifted students, concluded that gifted students differed from other students with respect to their academic performance and emotional stability. The five-volume study spanning nearly 40 years presented the characteristics of gifted children and advocated for treating the gifted students differently. Many researchers followed suit, including Hollingsworth, who started the Special Opportunity Class in New York for gifted students in 1922 and wrote *Gifted Children: Their Nature and Nurture* (Hollingsworth, 1926), which is regarded as the first textbook on gifted education. He examined how to identify a gifted child and contradicted popular myths and superstitions related to the physique and structure of gifted children that purport their brains compensate for what they miss in their physique. Hollingsworth also held gifted children to be the epitome of character. More importantly, Hollingsworth (1926) detailed how gifted students could transfer their giftedness across many facilities, thus indicating that they would be more ready to self-regulate themselves when compared with their counterparts.

According to the standards in gifted and talented education, NAGC (2015a) suggested that classroom teachers are the primary agents who are supposed to identify and serve gifted children in the classrooms. Consequently, it becomes imperative that only gifted-trained and gifted-endorsed teachers should teach gifted students. NAGC (2015b), in propagating its standards for teacher preparation for teaching gifted and talented students, advocated that professionals should create safe, yet rigorous learning environment to promote the giftedness and talents of the gifted students. The standards
stress the importance of differentiation of learning activities according to the giftedness of the students. Since most gifted and talented students use their abilities to self-pace themselves, teachers should find ways to cater to their diverse learning abilities and learning progress.

The features provided by SRS, including self-paced learning responses and corresponding feedback, help teachers to provide a variety of learning environments for differentiated and self-paced learning to gifted students very effectively. The NAGC (2015b) standards further required teachers of gifted students to design learning models to enhance acceleration, creativity, and conceptual comprehension of academic contents. In addition, the standards emphasize multiple methods of assessment, both formative and summative, to measure the progress of the gifted students differentiated to meet their learning needs and styles. Clearly, the requirements according to the standards encourage teachers who teach gifted children to adopt modern technology, especially SRS to assess student responses and to provide differentiated feedback to enhance learning process of the gifted students.

Shaunessy (2007) noted that technology is one of the appropriate tools to challenge gifted students. Definitely, the next generation leaders should have a sharp edge on how to handle technology. Consequently, education of gifted students should include modern technological tools. When teachers of gifted students recognize the advanced needs of their students, technological tools become one of the natural tools in their instruction and assessment. According to Shaunessy, technology, due to its ability to collect, analyze, and synthesize data, is a great tool in the hands of the gifted learners.
Shaunessy argued that teachers of the gifted students should find ways to train themselves to make good use of technology in their classrooms, especially when trying to enhance the learning abilities of their gifted students. Some of the obstacles to the attainment of technological proficiency for teachers are the lack of professional development, access to technology, and pedagogical beliefs.

In a study of teacher attitudes toward technology, Shaunessy (2007) sought to understand how much access to technology teachers have and how much training was available for teachers to perform well with technology. Shaunessy also studied how accessibility to available training for teachers affected their attitude toward information technology. The participants of the study, 418 gifted certified teachers who taught intellectually gifted students across grades 2 through 6, responded to the survey, a 101-question “Teachers Attitude toward Information Technology Questionnaire (TAT),” where teachers responded to questions that self-reported their attitudes toward technology.

Shaunessy (2007) claimed that the results of the study indicated that professional development was a significant factor in determining positive attitude toward providing technology in the classroom. It is thus very important to provide sufficient professional development to teachers who teach gifted students to help teachers have a positive attitude toward technology and incorporate more technology in their daily lessons. Shaunessy hoped that when teachers are more efficient in incorporating technology in the classroom, gifted students would be able to utilize technology in their learning and develop their learning-giftedness to suit their learning needs. In this context, it is
imperative to provide professional development to teachers regarding the use of SRS to enhance the learning outcomes of gifted students.

Nugent (2001) asserted that technology is essential in gifted students' education. The reasons Nugent delineated—"student centeredness, independent student learning, better attitude towards innovations, complexity involved in using technology, differentiated grouping opportunities, and flexibility in learning structure" (p. 38)—were very convincing. Technology supports the characteristics of gifted students, especially their independent learning abilities with personal learning pace. I deem that the use of SRS is helpful in the situation because of the immediateness of the feedback the gifted students receive for their self-paced learning. The use of technology, especially the immediate feedback feature of SRS, can elicit the capability of gifted students to incorporate complex learning situations. Nugent cautioned teachers that technology should remain as a tool to help learning and not become the focus of the learning. I agree with Nugent that the learning curve involved with technology use, should not impede the content learning process, for both teachers and the students. However, teacher training in using technology to match the content learning would largely solve this problem.

Nugent (2001) further stated that differentiation of the four different uses of technology as a learner, namely, "acquirer of information, retriever of information, constructor of information, and presenter of information," (p. 40) across the use of technology in the classroom would cater well to the needs of the gifted students. Nugent also suggested that gifted at-risk students would benefit from the use of technology in the classroom, especially the activities that involve interactive activities. In this context too,
SRS should prove very helpful since it provides immediate interactive feedback to the students.

In addition, Nugent (2001) recommended providing professional training for teachers to apply educational technology as an integral part of gifted students’ educational endeavors. Nugent, when recommending further research, suggested there should be more research toward finding the effectiveness of incorporating technology in the classroom, which encouraged me to investigate the effectiveness of using SRS incorporated into the content learning of the gifted students.

Rotigel and Fello (2004) delineated the characteristics of mathematically gifted students and possible solutions to the common challenges for teachers to help mathematically gifted students to reach their full potential. Mathematically gifted students focus more on the conceptual understanding rather than the mathematical process and can demonstrate their intuitive understanding with accuracy. In many instances, they tend to skip the steps because of their intuitive perspective of mathematical situations. The students who belong in this category sometimes demonstrate the ultimate conceptual understanding, yet make computational errors. The spiral nature of the usual mathematical curricula might be boring to mathematically talented students. Rotigel and Fello suggested that a linear math curriculum, modified by the teacher, would prove helpful to these students. This modification of curricula would involve providing opportunities for mathematically talented students to investigate further into the topic. Mathematically gifted students usually see the relationship of mathematics to patterns and structures early in their educational life.
Rotigel and Fello (2004) suggested providing open-ended inquiries to engage mathematically talented students. Rotigel and Fello supported the use of formative assessments to help mathematically talented students in the classroom. It is important to evaluate the depth of their mathematical talent to provide a suitable learning environment for mathematically gifted students. Providing immediate and effective feedback plays a critical role in identification and enhancement of the depth of mathematical understanding of the mathematically talented students. Rotigel and Fello also favored the use of technology to assist the learning styles of mathematically gifted students. The researchers recommended further investigations on the influences of technology in the education of mathematically talented students.

Duan, Shi, and Zhou (2010) conducted a study involving 94 gifted students of different age levels to identify how accelerated learning strategies affect the information processing capability of the students. The control group consisted of gifted students who did not receive accelerated learning, and the gifted students in the experiment group had many opportunities to accelerate their learning. According to Duan et al., the tasks allotted to the students did not require intelligent strategic variations and hence the performance results depended only on the time taken for the student responses. The researchers stated that the students who had accelerated learning were able to respond to the questions quicker than the students who did not get accelerated learning opportunities. In addition, the ages of the participants highly influenced their academic performance.
Duan et al. (2010) concluded that accelerated learning environment helps gifted students because of the additional learning stimuli they received from their learning environment, thus highlighting the importance of providing as many learning stimuli as possible to increase student performances. Thus, it becomes imperative to understand how immediate feedback through SRS provides the extra stimuli needed to inspire the gifted students to perform better in their learning situations, especially in their accelerated learning situations.

Hong and Aqui (2004), in agreement with modern trends in gifted education, suggested that giftedness is a multidimensional concept. The researchers argued that academic achievement, intellectual ability, and creativity might not be highly correlated. In their study, Hong and Aqui administered self-assessment questionnaire (SAQ) and an Activity and Accomplishment Inventory to 90 ninth and tenth grade Algebra 2 students from three high schools. Math achievement scores used for the study were scores from the math midterm exam provided by the participating teachers.

Hong and Aqui (2004) grouped the students into three groups. The first group was comprised of students who were “academically gifted, but not creatively talented in mathematics,” while the second group consisted of students who were “creatively talented, but not academically gifted in mathematics” and finally, the third group of students comprised of students who were “neither academically gifted not creatively talented” (Hong & Aqui, 2004, p. 195). The researchers used multivariate analysis of variance (MANOVA) tests and follow-up tests, namely, univariate analysis of variance
test (ANOVA), to determine the statistical significance of the differences among the scores of SAQ.

Hong and Aqui (2004) applied Bonferroni correction, made alpha small (.0125), and performed posthoc tests using the Tukey method. The results of the study indicated that the three grouping and gender difference influenced the individual results. The researchers further claimed that the students in Groups 1 and 2 that contained gifted students did well compared to their peers in the last group. Thus, the gifted categorization of students played a large effect on the results of student achievement.

Economic Status

Implementing an effective SRS system in classrooms depends on the economic situation of the educational community. Students belonging to a financially well-supported school get more opportunities to use SRS regularly. I wanted to investigate whether economic situation of students would affect their achievement when they receive immediate feedback using SRS. In the following paragraphs, I try to collect evidences from previous studies regarding whether the economic status of students might influence their ability to receive immediate feedback using SRS.

Ritzhaupt, Liu, Dawson, and Barron (2013) conducted an experiment to find out the depth of digital divide, especially in terms of Information and Communication Technology (ICT) among different subgroups of middle school students, characterized by socio economic status, gender, and ethnicity. The sample of the study consisted of 5,990 participants enrolled across various districts of Florida. With equal distribution of gender, the majority of the students had access to free or reduced lunch program and
practical knowledge in using computers. ST2L, the measurement system used in the research, required teachers to collect data on five domains: “technology operations and concepts, constructing and demonstrating knowledge, communication and collaboration, independent learning, and digital citizenship” (Ritzhaupt et al., 2013, p. 4). The descriptive statistics and the inferential statistical results illustrated the existence of a significant divide between various subgroups of students with respect to their dexterity in information and communication technology applications, with “high [socio economic], female, or white outperforming their counterparts” (p. 4) in their ICT abilities. Ritzhaupt et al. used Bonferroni correction to have a stringent value of alpha for the inferential statistical procedures.

However, comparatively small values of statistical effectiveness ($\eta^2 = .034, .024, \text{and} .028$) demonstrated that Ritzhaupt et al. (2013) could not fully explain the observed digital divide using the variables of socio-economic status, gender, and ethnicity alone. Ritzhaupt et al. suggested that other factors involving parental involvement, effects of languages, and the like had decisive roles in determining the digital divide. Researchers also suggested that using free and reduced lunch as a criterion for determining socio-economic status might be erroneous.

In a study conducted by Vega and Travis (2011), the investigators defined reformed math curricula to include technology-based or hands-on oriented, collaborative learning practices with an integration of various mathematical concepts, including but not limited to algebra, geometry, statistics, and discrete mathematics. Researchers
investigated the effectiveness of reformed math curricula on students controlled by ethnicity, socio-economic status, and limited English language proficiency.

The researchers sent questionnaires to math supervisors of 17 districts in Texas to determine whether the districts were following traditional method or reform method to teach their mathematics curricula. Using the scores of students from these districts on Texas Assessments of Knowledge and Skills (TAKS), Vega and Travis (2011) compared math achievement across districts. “All Students, African American, Hispanic, White, Economically Disadvantaged, and Limited English Proficiency” served as categories to organize the data obtained from the results of TAKS (Vega & Travis, 2011, p. 12).

Vega and Travis (2011) analyzed data using one-tailed Z statistic, $\alpha = .05$ and $Z_a = 1.65$. On interpreting the results of the test, the researchers found that in the years 2003-2004, economically disadvantaged and limited English proficiency students in ninth grade and African American students in eleventh grade outperformed their corresponding peers when taught using reformed math strategies. Reformed math strategies did not lead to significant students’ mathematics achievement for any other category for both years. However, the researchers pointed out that they did not investigate certain aspects that would affect the math performance of students, including teacher practices and student perceptions in using reformed practices. The important result that this study brought out was that reformed methods of teaching mathematics might not improve mathematical achievement of any particular group of students (Vega & Travis, 2011).

Interestingly, one of the drawbacks of this particular study conducted by Vega and Travis (2011) is that the researchers overlooked the differences in the implementation
of various reformed methodologies at different sites. The investigators did not investigate how well individual schools in the study utilized the reformed methods. In addition, according to Vega and Travis (2011), opinions of the supervisors employed in this study—based on just a Likert-scale—would not be a sufficient data source to rely upon for the effects of a system. In spite of these defects, the investigation clearly showed that in general, reformed math strategies did not affect the academic achievement of the subgroup of economically disadvantaged students.

Kim et al. (2011) conducted a mixed method study in primary schools to find whether socio-economic factors would affect the adaptation of mobile technology in educational systems. The first school was located in a thickly populated area with an urban population. The second school was located in a rural area. Both of the schools, located in Baja California, a town at the border of the US and Mexico, lacked a technological infrastructure. Acting on the research-based premise that mobile technology positively influences educational outcomes, the researchers attempted to implement the technology in both of the schools and subsequently determine which socio-economic structure benefitted the most from it.

Kim et al. (2011) were able to isolate the social setup from economic status in their investigation involving 160 primary students because of the similarity in the economic status of the two regions of their investigation. The study design provided a control group and an intervention group with 40 students in each at both locations and a "nonrandomized control-group pretest posttest design" (Kim et al., 2011, p. 470) was adapted for the investigation. Each of the Teacher Mate mobile devices were loaded with
short story e-books with text-to-audio features, including the capabilities to record narrations. For the purpose of the study, researchers used the mobile units for "individualized remedial and self-directed personal literacy enrichment opportunities" (Kim et al., 2011, p. 471). Data collected included the results of pretest, posttest, surveys completed by parents, and educator interviews. The design of the investigation focused on individualized learning and did not allow students to interact using the mobile devices.

The results of the 2 x 2 x 2 ANOVA test in the study conducted by Kim et al. (2011) indicated that students in the rural district made better progress when compared with their urban counterparts. The students in the intervention group made a statistically significant improvement in their educational achievement according to the results portrayed in the study. Four independent $t$ tests with Bonferroni correction of alpha revealed no statistically significant difference between the control group and the intervention group in both of the socio-economic set ups, indicating that the improvement depicted in the ANOVA test may have been because of their social setup, rather than the technological intervention.

There was a significant difference in performance only between the intervention groups. However, in this study, maximum effect size illustrated by the values of $\eta^2$ was .08, indicative of the small effects of the intervention. In contrast, when the effects of the locations were analyzed, there was a significant improvement in the literacy achievement for rural schools with a high effect size ($Cohen's \ d = 0.72$ equivalent to $partial \ \eta^2 = .11$). In addition, Kim et al. (2011) suggested that that there was no significant difference between the rural and urban control groups provided grounds for determining that the
difference between the achievements was only because of the effects of mobile technology.

The results of the interview analysis conducted as part of the mixed methodology of the investigation consolidate the results of the test (Kim et al., 2011). The parental involvement and expectations were very high in the rural school when compared with the same in urban school. The survey results also indicated that the average income of the rural parents were higher than that of the urban parents, even though both of the incomes belonged to the economically disadvantaged category. The awareness of technology was slightly higher among the urban population. Kim et al. (2011) suggested that a combination of increased parental interest, use of mobile technology, and teacher motivation might result in better student achievement. It is also very important to note that there was a threat to the internal validity of the investigation in the form of experimental mortality because several students dropped out during the experiment. However, these dropouts were a common phenomenon in the region (Kim et al., 2011).

Edgerton, Peter, and Roberts (2008) used data published by Organisation for Economic Co-operation and Development (OECD)'s 2003 Programme for International Student Assessment ([PISA], 2003) to study the extension of the "effects of socio-economic background, gender, and region" (p. 1) on the academic achievement of students in Canada. The sample involved 28,000 students who took the test in 2003 and their corresponding demographic information. After explaining the process of data collection and analysis employed by PISA, Edgerton et al. (2008) added that the investigators performed three regressions on the academic areas of math, science, and
reading using Statistical Package for the Social Sciences (SPSS). The researchers discovered that in accordance with earlier investigations and general assumptions, educational achievement largely varied across Canada in terms of socio-economic factors, gender, and regional differences. In fact, according to the results of the study, investigators suggested that economic status had a direct impact on educational performance in all three categories. In addition, Edgerton et al. (2008) suggested that economic status would control high scores in mathematics.

In the study conducted by Thomas and Stockton (1999) on the effects of socio-economic status, race, gender, and retention on student achievement, the investigators referenced innumerous articles and studies to emphasize how the socio-economic status of the students drives their educational achievement. Payne and Biddle (1999) criticized the disparities existing in educational funds across the nation, within states, and among districts. Commenting on the Coleman Report of 1966, Payne and Biddle (1999) argued against the conclusion made in the report that schools do not play a vital role in student achievement and that achievement is more dependent on home environments and peer influences than school activities. According to Payne and Biddle (1999), the publication of the Coleman Report initiated a debate over spending on schools across the nation, and the divide among the people from different parts of the country might have resulted in the disparity.

In the article, Payne and Biddle (1999) delineated flaws in the studies that did not tie achievement with funding and argued that such studies did not look into the direct effects that money could or would have in schools. Taking data from the Second
International Mathematics Study (SIMS), Payne and Biddle (1999) conducted a study in which a dependent variable, ACHIEVE, defined as the average mathematics achievement in the classroom SIMS test items the students answered in the test. Another variable, CURLEVEL, which determined the level or type of math curriculum used in the classroom, was also constructed.

The sample of the study included 205 public school senior classrooms from different parts of the country (Payne & Biddle, 1999). The school district data book (SDDB) provided information for other variables of the investigation, including measures of funding. The correlation analysis of data clearly illustrated that available funding and poverty significantly and substantially correlated with student achievement. Payne and Biddle depicted how the economic status or funding provided to districts affected mathematical achievement in a figure comparing the math performance of students from different funding levels in the U.S. with the SIMS test results indicating the math performance of students from other nations. The figure showed that economically disadvantaged districts of the U.S. equated with underdeveloped or developing nations of the world in terms of the math performance.

The results portrayed in various studies and the suggestions of Kim et al. (2011), in particular, provided understanding of the correlation between socio-economic status and the depth of parent involvement, which can be a detrimental factor in discovering the effect of using technological devices in the classroom. The findings of Edgerton et al. (2008) indicated that the socio-economic factor is a crucial driver of academic achievement. Payne and Biddle (1999) strongly suggested that the availability of funding
to educational district is another crucial factor that determines student math achievement. Thus, it becomes imperative to address the socio-economic status of the participants in this study. However, Vega and Travis (2011) cautioned the use of better-stratified information regarding socio-economic status in comparison with free and reduced lunch.

Gender of the Students

Most of the classrooms that I had taught mathematics had an equal proportion of male and female students. Yet, throughout my educational career, I noticed that gender disparity in math comprehension had been a prominent topic in educational discussions. I decided to add gender as a covariate in this study to investigate the effects gender would make in receiving immediate feedback using SRS. In the following paragraphs, I tried to collect evidences that might help me to understand this questionable gender disparity in education.

Using the National Center for Education Statistics 1998 Reading Report Card for the Nations and States as reference, Thomas and Stockton (1999) reported that females outperformed males in reading successively in 1992, 1994, and in 1998 in fourth, eighth, and twelfth grade (as cited in Thomas & Stockton, 1999). Thomas and Stockton suggested that the lead the females obtained in these scores were due to their affective nature and the value females naturally give to reading, as per research. Thomas and Stockton further commented that gender did not qualify as a predictor for math achievement in any of the grade levels. Yet, the percentage of male students above or at proficient level was significantly large when compared with the percentage of female students who were at or above the proficient level. In addition, Thomas and Stockton
(1999) surmised that the strategies used by females might be different from those employed by males, resulting in diversified gender effect in math achievement.

In their investigation of gender and math achievement, Fennema, Carpenter, Jacobs, Franke, and Levi (1998) conducted a three-year longitudinal study of 82 first grade students, selected from 11 different classrooms in three schools, included 44 males and 38 females. The researchers trained teachers in the classrooms to implement a system of teaching mathematics that included exposing their students to various strategies in solving math problems suiting the different learning styles of students in their classrooms. As part of the intervention, teachers illustrated and explained the algorithms to solve problems to all the students and provided opportunities to practice and use them in their math activities. Assessment of all of the students occurred in three interviews during the course of longitudinal study. The tasks in the interview consisted of numerical problems and word problems that required the students to use mathematical strategies to solve them.

Routine problems and extension problems were also included in the assessment interviews. Researchers used $t$ tests to perform data analyses with varying alpha values to accommodate the difficulty levels of the problems in assessment interviews. The results illustrated no significant differences between males and females in doing numerical problems, whereas males in the third year tended to be more efficient in solving extended problems. Fennema et al. (1998) concluded that, based on the results of the data analysis, females used more problem modeling and algorithms, whereas males tended to solve problems using abstract strategies.
Hong and Aqui (2004) found a significant gender difference among the students in the academically gifted students in their study of 90 students, grouped into “academically gifted students, mathematically talented gifted students, and neither academically gifted nor mathematically talented students” (p. 191). Although there were gender differences in achievement between students in the academically gifted group, the results did not indicate any significant gender difference among the students in other groups. The interviews with the students of this group revealed to the researchers that the academically gifted females tended to look more critically at their work, checking them for accuracy, whereas their male counterparts did not. Hong and Aqui (2004) ventured that both the genders in the mathematically talented group illustrated their capability of math skills by, perhaps, putting up more effort. The effort put forward by the male students was higher for those who belonged to the second group than the other males in the other groups, supporting the researchers’ claim for greater effort of the male students in the second category (Hong & Aqui, 2004).

Due to the conflicting results found in this study and several previous studies, Hong and Aqui (2004) stressed the necessity for further investigations to determine whether gender differences observed in this study were transferable. However, the performance of students in both the gifted groups exceeded the performance of their counterparts in non-gifted groups, regardless of their gender. The findings in the study and the recommendations of the researchers necessitated the addition of the covariate of gender in this study to determine the difference, if any, in the effects of using SRS as an effective tool to provide effective feedback to their students.
In congruence with earlier studies, Edgerton et al. (2008) noted that females outperformed males in their reading skills, but males of age 15 scored better in math and science than their female counterparts. Acker and Oatley (1993) stated that further research is necessary to comprehend the causes for underrepresentation of women in math, science, and technology in schools and workplaces and to find a solution for the plight. In addition, Nugent (2001) suggested that gifted females tend to drop out from the use of technology as they grow. Teachers of gifted females should promote and sustain the students' interest in using technology in their daily life. In this scenario, the use of SRS that serves as a feedback tool will definitely help to encourage and sustain the gifted female interest in technology.

However, the study conducted by Ritzhaupt et al. (2013) illustrated that females outperformed males in their ability in Information and Communication Technology (ICT) skills, in contrast with the results of previous studies. The researchers recommended further investigation to understand the statistically significant divide in the technological abilities between females and males. Even though the study results showed a statistically significant difference in technological abilities, the effect sizes ($\eta^2$ values) were very low, indicating the presence and influence of unaccounted for extraneous factors.

Clearly, research indicates that gender difference affects math achievement (Acker & Oatley, 1993; Edgerton et al., 2008; Fennema et al., 1998; Ritzhaupt et al., 2013; Thomas & Stockton, 1999) in favor of males as well as females. Moreover, the gender difference is highly reflected in the learning habits of gifted students (Hong & Aqui, 2004; Nugent, 2001). Thus, it becomes very important to include gender as a
covariate in this study to examine the role played by the characteristic in math achievement.

Math Achievement and Accelerated Precalculus Course

In its vision for implementing Common Core curriculum in mathematics, the GaDOE (2015a) organized math standards to meet the challenging requirements for college readiness and continuing education. The accelerated math course designed for eleventh grade, namely accelerated precalculus, aims to prepare students to meet the requirements of taking advanced math courses in calculus. Furthermore, the standards and rigor of the course reflect the demands of deep conceptualization and application of mathematics to novel situations. It is rightly said in the GaDOE (2015a) course description for accelerated precalculus that students should “experience mathematics as a coherent, useful, and logical subject that makes use of [students’] ability to make sense of problem situations” (p. 3) through their learning experiences in this rigorous course.

The description of mathematics modeling in the GaDOE (2015a) standards is as integral part of getting ready for calculus course; hence, it forms a requirement throughout accelerated precalculus course. Constant student responses and effective feedback are imperative to make mathematics modeling a success, especially when modeling situations call for “expertise and creativity” (p. 9) of teachers as well as students. Thus, the use of SRS as an immediate feedback tool merits investigation of their effect in improving student achievement.

NCTM (2000) also acknowledged that there is room to improve math education in the nation. Many students do not get the opportunity to engage themselves in meaningful
math curricula related to their interests. The quality of mathematical engagement that students get in their school life varies due to many aspects of the educational system. Thus, NCTM suggested that every stakeholder of mathematics adhere to effective standards of teaching and learning mathematics that involve high mathematical engagement based on effective practices of assessment to enhance high student achievement in mathematics.

In their 2000 publication, *Principles and Standards for School Mathematics*, the National Council of Teachers of Mathematics (NCTM) envisioned classrooms rich in technology, equipped with resources that teachers could use effectively in classrooms, and curricula rich in activities that would lead students to enhance their math achievement. NCTM challenged the stakeholders of education to make this vision practical for every student in the nation, thus contradicting the general idea that math is only for a selected few. NCTM further asserted that math education is very important for establishing a successful life in modern society. The achievement of math skills is not only essential for maintaining an informed daily life, but also critical for modern workplaces. Being efficient in mathematics, one of the most heralded intellectual achievements of human kind, allows every student in the nation to benefit as a part of the scientific and technological development in the nation.

To accomplish this, the NCTM (2000) recommended the use of technology as an important tool to enhance comprehension of abstract concepts. In addition, technology, including graphing calculators and computer applications, would help students to view, practice, and apply the concepts they learned. Using technology to visualize abstract
concepts would help teachers to make the concepts more concrete for struggling students. Technology facilitates in-depth understanding of math concepts and the ability to remember the concepts. Teachers could use “spreadsheets, dynamic geometry software, and computer microworlds” (NCTM, 2000, p. 26) to enhance students’ learning situations. However, development of technology and the fact that students could engage themselves in mathematical endeavors using technology should not lead to the wrong idea that technology could replace math teachers.

It is also important to note the potential to use SRS technology as immediate feedback tool to encourage higher-order thinking and promote self-regulation skills (Hattie, 2012). It is essential teachers plan to select efficient technology to support the mathematical concepts. To attain improved student math achievement, it is imperative that teachers introduce their students to the right technology and keep them engaged in it.

Summary

The theoretical framework of this investigation, comprised of the theories of self-regulatory learning and distributed cognition, led me to analyze relevant studies and experiments that used SRS to affect student achievement. A concept of the self-regulated learning theory is that immediate, continuous, and consistent feedback on student activities promotes self-regulated learning, which in turn, results in improved student achievement. The theory of distributed cognition validates the importance of planning to integrate cognitive sharing among peers in the class as well as cognitive sharing between technology and humans to enhance social and cognitive improvements.
Several studies were unable to prove the positive effects of SRS on student achievement due to various reasons (Abode, 2010; Christopherson, 2011; Dunham, 2011; Liu et al., 2010; Lynch, 2013; Matus et al., 2011; Rigdon, 2010). Some investigators claimed to find little effect for SRS on student achievement, but admitted that threats to validity and reliability (both internal and external) possibly influenced the results of their studies (Abode, 2010; Matus et al., 2011; Rigdon, 2010). Some mixed method studies proved that SRS did not seem to have a direct impact on student achievement quantitatively (Abode, 2010; Rigdon, 2010). However, the participants in those studies unanimously acknowledged the higher levels of student engagement that SRS brought along with it. Because of study limitations, all the researchers encouraged further investigations to determine how SRS affects student achievement. In addition, most of the studies agreed that proper implementation of the intervention, namely the use of SRS, plays a major role in elucidating the correct effects of SRS on student achievement.

To sum up, only a few of the researchers investigating the effects of SRS suggested that SRS had a strong and direct impact on academic achievement of students. However, the investigators were doubtful of the results, because the results were not in correlation with theories pertaining to formative assessment and feedback. In addition, the investigators generally agreed that implementation of SRS increased student engagement in classroom activities. The researchers of the studies admitted to serious limitations that directly affected the results of SRS effects (Dunham, 2011; Matus, et al., 2011; Rigdon, 2010). It is noteworthy that all the investigators recommended further investigations that probe into the effects SRS.
Studies conducted regarding giftedness gave the impression that there are students who tend to look at their education from a different perspective (Duan et al., 2010; Hong & Aqui, 2004; Nugent, 2001; Rotigél & Fello, 2004; Shaunessy, 2007). The underlying theories of my investigation aligned with the nature of gifted students. The students enrolled as gifted students through the state’s selection process mostly include individuals who apply self-regulated learning skills in learning mathematics (GaDOE, 2015d; Hollingsworth, 1926; NAGC, 2015a, 2015c; Shaunessy, 2007; Terman, 1926). In addition, classrooms that include several gifted students constitute a suitable environment to observe various tenets of distributed cognition theory. However, this literature review did not provide enough information regarding the effects that giftedness might have in the implementation of SRS as feedback tools, even though, in theory, both the technology and giftedness are an appropriate fit.

The literature review regarding the effects of economic status and gender on academic achievement provided conflicting perspectives. The results mentioned in various studies recommended further investigation into the effects by extending the parameters of the studies (Edgerton et al., 2008; Kim et al., 2011; Payne & Biddle, 1999; Thomas & Stockton, 1999; Vega & Travis, 2011). Many of the researchers agreed theoretically how technology facilitates improvement in learning conditions, but the level of success was not high enough to prove the significance of technology inclusion.

It is clear from the literature review that formative assessment and prompt feedback associated with student responses combine to form one of the strong pillars of effective learning experiences. This literature review provided results from various
studies indicating the necessity of incorporating SRS in the learning environment of modern education. Even the studies that did not prove the effectiveness of SRS attributed the lesser influence of the SRS to the improper application of systems and/or limitations. In addition, researchers urged for more research on the contribution of SRS toward student achievement.

Thus, to conclude, it became imperative to conduct a study to find out how SRS would affect student achievement when the technology provides systematic, immediate feedback to student responses. In addition, it was necessary to determine whether giftedness, economic status, or gender of the students would affect the achievement of students when they use SRS in their learning environment. It was inevitable that the content-driven design of the study focuses on systematic and specific feedback provided for students' responses. Thus, an investigation on the immediate feedback effects of SRS on students' math achievement, considering the factors of giftedness, economic status, and gender, observed through the lenses of the theories of self-regulatory learning and distributed cognition was warranted.

*Figure 6* is a pictorial representation of my argument. After a detailed discussion on the effects of using SRS as projected by different studies obtained from the search, I include summaries, suggestions, and recommendations from the literature in addition to adhering to the illustrated plan. *Figure 6* also illustrates how theoretical perspectives of distributed cognition and self-regulation led my investigation, along with tenets of various types of feedback, to analyze quantitative, qualitative, and mixed method studies, together with doctoral dissertations. When the impacts of giftedness, gender, and
economic status of students to the analysis are added, pictorial representation of my study culminates into the purpose of literature review: to delineate the known and unknown elements assimilated from the analysis of drawbacks, limitations, and recommendations from the related literature and to formulate the research question of this study.
Figure 6. Pictorial Representation of the Investigation
CHAPTER 3
METHODOLOGY

In previous chapters, I reviewed the literature related with the effects of using Student Response System (SRS) as an immediate feedback tool. Research and theoretical discussions revealed the importance of providing formative assessments in classrooms to enhance learning outcomes (Black & Wiliam, 2009; Marzano, 2006; Yorke, 2003). Giving effective feedback to student responses is a vital part of providing formative assessment. It is important to integrate the practice of effective feedback continuously and consistently in classroom activities to provide relevant learning environment that promote learning process (Brookhart, 2012; Wiliam, 2012).

As a part of their feedback intervention theory (FIT), Kluger and DeNisi (1996), asserted that the highest level of feedback intervention should generate self-related feedback among students. Zimmerman (2001) discussed the impacts of self-regulated learning theory from the perspectives of different learning theories. Informed by a review of the literature of the above theories, I devised learning activities for intervention using the tenets of self-regulated learning theory.

The proponents of distributed cognition theory suggest that the use of SRS to leads to the integration of the resources developed by the students and teacher and supplied by the computer and communication-device combination to enhance learning outcomes (Hollan et al., 2000; Rogers, 1997). As suggested by Wright et al. (1999),
I attempted to create an effective learning environment through a proper intervention design by integrating SRS to provide immediate feedback to the students.

As delineated and discussed in Chapter 2, multiple studies have been conducted to investigate long term and short term effects of SRS, student engagement, student achievement, and retention of information (Abode, 2010; Blood & Neel, 2008; Christopherson, 2011; Dunham, 2011; Lynch, 2013; Nicolle & Lou, 2008; Randolph, 2007; Rigdon, 2010). According to the literature review of the use of SRS in instruction, there was little evidence that the use of SRS positively affected student achievement (Abode, 2010; Christopherson, 2011; Dunham, 2011; Liu et al., 2010; Lynch, 2013; Matus et al., 2011; Rigdon, 2010).

However, there were indications from the distributed cognition theory and tenets of theories of feedback that SRS could potentially serve as an effective tool to improve academic achievement (Edgerton et al., 2008; Kim et al., 2011; Payne & Biddle, 1999; Thomas & Stockton, 1999; Vega & Travis, 2011). Thus, I planned to investigate whether the provision of immediate feedback using SRS would promote student achievement as the result of the intervention strategies that would involve the implications of the aforementioned theories.

In this chapter, I describe in detail how I conducted this experimental study. The explanation includes the participant selection process and criteria for inclusion in the study. Also presented is a description of the design of this “untreated control group [quasi-experimental] design [study] with dependent pretest and posttest samples” (Shadish, Cook, & Campbell, 2002, p. 136). I present the variables and the predictors
used in the study to explain how the variables make meaning to this study. Data collection methods are delineated as well as the steps taken to safeguard privacy of the participants who have confided in me. This chapter also contains a detailed description of the statistical data analyses used to interpret the collected data in this study. The chapter culminates with a summary of the various methodological strategies implemented in this study.

Research Question

The following was the research question that I investigated in this study: Will there be a statistically significant difference between the educational-district-generated-benchmark posttest scores of students who received immediate feedback using SRS and those who did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school?

Research Hypothesis and Criteria of Rejection of Hypothesis

In order to establish a relevant conclusion for my inquiry, the following statement served as my research null hypothesis corresponding to the research question:

There will not be a statistically significant difference between the educational-district-generated-benchmark posttest scores of students who received immediate feedback using SRS and those did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a
suburban high school. The $p$ value for the intervention parameter is set to be less than or equal to .050 for the rejection of the null hypothesis.

Sample Population

The sample population consisted of 53 students in a suburban high school in Georgia, enrolled in an eleventh grade accelerated precalculus course. The student population in this public school in a middle class area of the city was similar to other schools in the district. The student population in the entire school district was 51% African American, 39% White, 5% Hispanic, 1% Asian, and 4% mixed races. The study school population was 51% African American, 41% White, 4% Hispanic, 1% Asian, and 3% mixed races. Of the entire school population, 62% of the school’s students were eligible for free or reduced lunch. Of the 53 students who participated in the study, 25 students received the intervention of receiving immediate feedback using SRS during instruction (experiment group), while 28 students did not receive immediate feedback using SRS (control group). Table 1, Table 2, and Table 3 provide the corresponding number and percentages for the gender, race, and socio-economic status of the student participants in the control and experiment groups respectively.

Table 1

*Gender Breakdown of Sample Groups*

<table>
<thead>
<tr>
<th>Group</th>
<th>Male #(%)</th>
<th>Female #(%)</th>
<th>Total #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>13(46%)</td>
<td>12(54%)</td>
<td>28</td>
</tr>
<tr>
<td>Experiment</td>
<td>13(52%)</td>
<td>15(48%)</td>
<td>25</td>
</tr>
</tbody>
</table>
The control group in this experiment consisted of 28 students enrolled in an eleventh grade accelerated precalculus course. The experiment group of the study, selected randomly between the two classes using the application from RANDOM.ORG (2015), was comprised of approximately 25 students enrolled in one class of eleventh grade accelerated precalculus course. The accelerated precalculus course was designed for junior students who successfully completed accelerated analytic geometry coursework. Consequently, the stakes are high for students who enroll in this advanced
math course. The students enrolled in the course held similar educational experiences. In addition, the population of the students enrolled in the course shared similar demographical characteristics of the school population, as displayed in Table 4.

Table 4

<table>
<thead>
<tr>
<th>Group</th>
<th>Gifted #(%)</th>
<th>Non-gifted #(%)</th>
<th>Total #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>15 [54%]</td>
<td>13 [46%]</td>
<td>28</td>
</tr>
<tr>
<td>Experiment</td>
<td>15 [60%]</td>
<td>10 [40%]</td>
<td>25</td>
</tr>
</tbody>
</table>

In addition, Field (2009) suggested that there should be “10 cases of data for each predictor in the model” to “obtain a reliable regression model” (p. 222). There were 53 cases in this study, 25 in the experiment group and 28 in the control group. In addition, I had no control over the determination of student enrollment in both the classes. Thus, I categorized my experiment as untreated control group quasi-experimental design study with dependent pretest and posttest samples, which was sufficient to meet Field’s suggestion to conduct a reliable analysis of covariance.

Research Design

In the “untreated control group [quasi-experimental] design study with dependent pretest and posttest samples,” (Shadish et al., 2002, p. 136), I investigated math achievement using a posttest, which was actually a midterm assessment designed for the course, successfully used for a couple of years as midterm-summative-assessment for
precalculus course in the educational district. The posttest comprised of 30 multiple-
choice questions that conform to current format and calculator use policies of accelerated
precalculus course as prescribed by GaDOE (2015a). I used the scores of the test as the
dependent variable, namely, the posttest scores.

The independent variable of the study was the immediate feedback provided to
the learning responses of the students in the experiment group of the study. The control
group received feedback without using SRS. In addition, I investigated how giftedness,
economic status, and gender of the students in both the groups influenced student
achievement as measured by the posttest. The study included the corresponding
covariates as summarized in Table 5.

Table 5

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Type</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Score</td>
<td>covariate</td>
<td>continuous</td>
</tr>
<tr>
<td>Giftedness</td>
<td>covariate</td>
<td>dichotomous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(gifted - 1/not gifted - 0)</td>
</tr>
<tr>
<td>Economic Status</td>
<td>covariate</td>
<td>dichotomous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(disadvantaged - 0/not disadvantaged - 1)</td>
</tr>
<tr>
<td>Gender</td>
<td>covariate</td>
<td>dichotomous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(male - 1/female - 0)</td>
</tr>
<tr>
<td>Posttest Score</td>
<td>dependent variable</td>
<td>continuous</td>
</tr>
<tr>
<td>Intervention</td>
<td>independent variable</td>
<td>dichotomous</td>
</tr>
</tbody>
</table>
|                       |                 | (immediate feedback with SRS—
|                       |                 | experiment - 1/                      |
|                       |                 | no immediate feedback with SRS—       |
|                       |                 | control - 0)                           |
Measures and Covariates

I administered the pretest, the first covariate, at the beginning of the study. One of the requirements of eleventh grade accelerated precalculus course was that the students enrolling in the course should have successfully completed either accelerated analytic geometry course. Consequently, I selected the End of Course Test (EOCT) test form for analytic geometry, released by GaDOE (2015b) for pretest at the beginning of the course to determine the readiness of students in the control group and in the experiment group.

I obtained data for the second covariate, giftedness, directly from the teacher portal of the educational district. Every gifted student enrolled in the class was designated “gifted” in the rolls. Therefore, I marked the dichotomous categorical variable as either “Gifted (1)” or “NotGifted (0).” The educational district had already identified and enrolled the gifted students in the classes that I investigated according to the criteria prescribed by the state department. Again, both gifted and non-gifted students completed the requirements to join eleventh grade accelerated precalculus course.

The student population of this experimental study had a large number of economically disadvantaged students. The student population also included students from middle-class or affluent families. Thus, the third covariate, economic status, played a key role in the successful implementation of student response system as an effective and immediate feedback tool. I categorized the economically disadvantaged students as (Disadvantaged—0) and all other students as (Not Disadvantaged—1). After acquiring the corresponding Institutional Review Board (IRB), I used Georgia’s Statewide
Longitudinal Data System (GaDOE, 2014), a statewide data system provided by the educational district, to determine the economic status of students in my study.

I surmised that controlling the outcome with the fourth covariate, gender, would enable me to understand the influence that gender might have on the use of SRS as an immediate feedback tool. Therefore, I assigned the category, Male – 1 for all male students and the category Female – 0 for all female students participating in my investigation.

The dependent variable, the posttest, consisted of a district-designed benchmark containing 30 multiple-choice questions. The educational district produces valid and reliable tests to evaluate the students, incorporating standards of the course, as per the guidelines of GaDOE (2015e). I used the midterm assessment previously used in the precalculus classes of the educational district where the study took place.

Validity of Pretest and Posttest

American Educational Research Association ([AERA], 1999) strongly suggested, “Validity . . . is the most fundamental consideration in developing and evaluating tests” (p. 9). The pretest used in this quasi-experimental study consisted of released items in the Georgia End of Course Test (EOCT) for analytic geometry (GaDOE, 2015c). In this study, the pretest served to measure the math achievement level of students admitted the accelerated precalculus course. The test was created based on the “current state-mandated standards in mathematics” after “educator input and State Board of Education approval” (GaDOE, 2015c, p. 1). Further, the performance standards were the basis of the contents of the test. According to the Georgia Department of Education (2015c), the
performance standards were grouped into content domains to ensure the "provision" of reliable measures of student achievement" (p. 3).

The posttest used in this quasi-experimental study was developed by the educational district where I conducted the study. It was imperative to uphold the terms that I agreed to when obtaining IRB from the educational district, especially the term that I should, under no circumstance, reveal the identity of the educational district or the school where I conducted the experiment. Consequently, I did not get discrete permission to reprint the actual posttest in the appendix.

However, according to the phone calls I conducted with teachers who developed the test, the test was created as a collective effort of educators experienced in teaching accelerated precalculus course. It is important to note that the posttest contained elements to test students' knowledge in terms of comprehension and application for all the standards relevant to the course in the fall semester. The posttest contained 30 multiple choice questions that tested students on conic sections (3 questions); evaluating trigonometric values from angles represented in degrees and radians (5 questions); evaluating inverse trigonometric values in angles and radians (3 questions); trigonometric identities and applications (5 questions); solving trigonometric equations and applications (3 questions); applying laws of sine and cosine (6 questions); converting units of angles between degrees and radians (1 question); and graphing trigonometric functions with all possible transformations (4 questions).

In addition, authorities from the department for assessment in the educational district confirmed through phone calls that the test had been in use for several years in the
course of accelerated precalculus course. However, there were no data indicating whether the test had gone through any pilot stage.

Reliability of Pretest and Posttest

It is important to test the reliability of the tests used in this study because reliability measures the consistency of construct of the test (Field, 2009). The pretest of this study consisted of released test items from Georgia Department of Education (GADOE, 2015a). Even after several attempts to contact the test makers, I was not successful in finding the reliability measures of these items. However, I conducted a post hoc analysis on the pretest data to determine the reliability of the test to measure the comprehension levels of students in both experiment group and control group. A report of the reliability results is in Chapter 4, under the section Post-Hoc Reliability Analysis of Pretest and Posttest.

The posttest in this quasi-experimental study played a vital role in determining student achievement to compare the effects of providing immediate feedback to student responses. The posttest, developed in educational district of this study, did not have any previous reliability measures associated with it, despite its consistent use to test students enrolled in the accelerated precalculus course. To ensure the reliability of the posttest, I used Cronbach’s alpha to conduct a post-hoc reliability analysis, reported in Chapter 4.

Data Collection Procedure

At the beginning of this a quasi-experiment using a pretest-posttest with control group design, I received consents from the Mercer Internal Review Board (IRB), students’ parents, and informed assents from students to participate in the study,
according to the guidelines of Mercer University and the educational district. A copy of these consent forms and informed assent forms are located in Appendix A, B, and C respectively. Next, after acquiring related IRBs, I used the educational district’s website and teacher portal to find information about the participants in the study. I noted the gender and giftedness status from the student roster. Economically disadvantaged students were marked as such in the State Longitudinal Data System (GaDOE, 2014), a statewide data portal, accessed through the educational district’s teacher-portal.

Following this, I used the website RANDOM.ORG (2015) to randomize the selection of one of the two eleventh grade accelerated precalculus classes to be the experiment group. I assigned the other class to represent the control group for this experimental study. Then, I administered the pretest for all the participating students in the two classes. It is important to note that the test was used to determine retention of the students in accelerated geometry class and thus is a criterion for admission to eleventh grade accelerated precalculus course. In addition, the test is prepared and executed statewide. These facts served to establish the validity and reliability of the test.

I was able to conduct the untreated control group quasi-experimental design study with dependent pretest and posttest samples during the fall semester of 2014, with the administration of the 50 minutes posttest. I explain the intervention used during the experimental period in the following section.

Intervention Procedures

The dependent variable of this quasi-experiment using a pretest-posttest with control group design was the intervention of using student response system (SRS) as an
immediate feedback tool. To accomplish this, I used ActivExpression, a student response
device developed by Promethean (2015b), and the ActivInspire software, developed by
the same company as the student response system in this study. Promethean, in their
website, envisioned that a combination of ActivExpression product and its software
would help teachers to invite all the students into classroom discussions—individually,
yet as a group—through the system. Promethean advertised that using the
ActivExpression system would help teachers to understand and monitor their teaching
effectiveness and predicted that the system would help teachers to balance their
instruction based on student responses collected through the system. According to
Promethean, teachers can also save a large amount of time when the system evaluates
student responses for teachers according to the evaluation plan provided by the teacher. I
planned to use the system because of the power and ease of giving immediate feedback to
students. By utilizing the appropriate design, I was able to provide immediate feedback
to student responses almost on a daily basis to students in the experiment group that used
SRS as an immediate feedback tool in different format.

Anonymous Feedback

After explaining in detail about informal formative assessment that would include
body language expressions like satisfactory smile, shoulder shrug, or verbal expression of
satisfaction, Yorke (2003) described how formal formative assessments, including
quizzes, can affect the learning outcomes of the students. According to Yorke, a third
type of formative assessment is anonymous feedback, which, though uncategorizable as
formal formative assessment or informal formative assessment, has the potential to be very effective by creating a large impact on the student learning process.

Taking Yorke’s (2003) suggestion, I used immediate group feedback to the students in the experiment group using the anonymous feedback feature of ActivExpression. Many times, I required students to provide a short rationale for their answers together with their responses. For example, in the precalculus curriculum, I wanted to know whether my students understood the difference between using Laws of Sine and Laws of Cosine. I posed the open-ended question as illustrated in Figure 7 and asked students to vote. In addition to giving the answer, I required the students to tell which law they used and why. Students could type in the rationale for this particular question using the SRS keypad in a few words or in complete sentence. Thus, if they erred, they could identify why they erred. If they were right, the anonymous feedback provided by the system would confirm their thought process. Consequently, students could self-regulate their learning process based on the immediate feedback obtained through SRS.

Figure 7. An Example of Open-Ended Question
After familiarizing the students with the anonymous feedback, students realized that their opinion, expressed using SRS, counted toward the results of the class, but being anonymous, no one else in the class knew what they answered. For instance, there was an instance when only person answered wrong and the display on ActivBoard clearly indicated so. Only the person who answered it wrong recognized who made the mistake. Everyone else wondered who committed the mistake, but no one knew the person who made it, contributing to the anonymity of the situation. The theory of distributed cognition played a lead role at this instance. When the whole class viewed the results of their individual responses as a histogram, the students saw that the histogram reflected the collective distributed cognition of the class. Individual students assessed themselves and checked whether they needed to self-regulate themselves to understand the concept. I checked the concept comprehension of the treatment group on a daily basis using the anonymous feedback feature of ActivExpression as evident in Appendix D.

Anonymous feedback was an extra SRS feature provided only to the experiment group during this study, which means that the participants in the control group did not receive immediate anonymous feedback using SRS. However, I tried to provide personal feedback to students in the control group, which remained anonymous to their classmates, even though there was a time factor involved in the process.

Self-Paced Quizzes or Warm-Up Activities

I created self-paced quizzes or warm-up activities using the software, ActivInspire (ActivInspire, Version 1.8.64351). It was possible to arrange questions to appear on the screen of the ActivExpression one after the other at a student's own pace. Marzano,
Pickering, and Pollock (2001) contended that providing feedback after the whole test had larger significance with higher effect size when compared with providing feedback after every question. The idea of self-paced questions, followed by a feedback at the end of the test, is consistent with the recommendation of Marzano et al. (2001).

There were provisions in the software to change how an individual student received feedback for each response. First, I gave correct or incorrect feedback, followed by further opportunities to revisit the question and reattempt it. This form of feedback worked effectively with open-ended questions. Figure 7 serves as an example of how to construct an open-ended question using the software. Secondly, I gave the correct answer for every wrong student response. The screenshots to plan for the same are displayed in Figure 9 and Figure 10. In both these cases, the feedback told an individual student that the response was incorrect. The display of the anonymous student responses helped students to understand why they erred, thus enabling them to reteach themselves in most cases. In addition, the display of the correct answers and a short explanation for the same helped the students who responded with a wrong answer to realize their mistake and promoted self-regulatory learning. There were occasions where students might need scaffolding from teacher to rectify their mistakes. However, the use of the type of question helped them to initiate the process of comprehension correction.

The second plan was to provide different follow-up questions after the student got it wrong or right in order to provide students opportunities to learn from the system formative feedback. The second type of feedback was more appropriate for multiple-choice questions. Figures 8 through 12 illustrate the steps to accomplish this option.
Find the value of angle $A$ in nearest degree, given that $AB = 12$ inches, $BC = 8$ inches, and $AC = 14$ inches.

A) $82^0$  B) $55^0$  C) $35^0$  D) $60^0$

Figure 8. An Example of Multiple-Choice Question

Figure 9. Screen Shot of Assigning Correct Answer to Multiple-Choice Question
Figure 10. Screen Shot on How to Include a Follow-Up Question

Figure 11. Screen Shot on Assigning an Open-Ended Question
Students in the control group had opportunities to solve the same questions, for both warm-up and formative quizzes, without using SRS. In the case of warm-up, we discussed the problems, and clarifications if needed, in the class. Students in the control group received feedback for their formative quizzes after I graded their paper quiz. The main difference in obtaining the feedback for quizzes between the control group and the experiment group was that the former had to wait until I manually graded their papers and the latter received their feedback instantaneously.

SRS Experiences of Students in Different Groups

Throughout the intervention period, I provided both anonymous feedback and self-paced student response feedback to students in the experiment group on a daily basis. At the end of every other week, students used SRS to take a short quiz. The rigor and syllabus of the eleventh grade accelerated precalculus course required all the students, in the control group and the intervention group, to participate in summative tests. I utilized the summative testing capability of ActivExpression to collect students' test responses for both the groups.
SRS Experiences of Students in the Control Group

The fact that students in the control group regularly used ActivExpression for summative evaluation enabled me to reduce the threats of compensatory rivalry and resentful demoralization (Shadish et al., 2002). Furthermore, whenever the biweekly quizzes were summative in nature, for example, when I rigorously graded the quizzes with no opportunity to correct them later, I preferred to use ActivExpression for both groups. Thus, the continuous use of ActivExpression helped participants to liberate themselves from the novelty threat of the situation. Again, I investigated the effects of immediate feedback given using the student response system.

The students in the control group used the technology only for summative evaluation. Whenever I used ActivExpression to conduct a summative evaluation for students in the control group, they did not receive any feedback through SRS. However, students in the control group were able to know their scores at the end of the summative test using SRS. When the students needed feedback for summative tests, in both the control and the experiment group, they received the feedback after I analyzed their mistakes. This helped me to prevent the threat of treatment diffusion because the students in the control group did not get feedback using student response system (Shadish et al., 2002).

In addition, students in both the experiment and the control groups did not get chances to make up their grades for summative assessments and hence did not benefit from any feedback other than their final grade. It is important to note that the students in the control group did not get immediate feedback using SRS and that the students in the
experiment group always received immediate feedback using SRS for all their formative assessments. However, students in both the control and the experiment group did not receive immediate feedback using SRS for any summative tests.

Table 6 provides a summary of the students’ feedback experiences. I also provide a calendar delineating the warm ups, formative assessments, summative assessments, and the nature of the corresponding feedback given to both the control group and the experiment group in Appendix D, Table D1.
<table>
<thead>
<tr>
<th>Experiences of Control Group</th>
<th>Experiences of Experiment Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anonymous group feedback without using SRS, which may not be immediate</td>
<td>Immediate anonymous group feedback using SRS (daily)</td>
</tr>
<tr>
<td>Warm-up activities without using SRS, involving open-ended questions.</td>
<td>Warm-up activities using SRS with immediate feedback for each student response with opportunity to revise the wrong answers (open-ended questions). Students were required to type in the rationale for their answers, which when displayed, helped students who gave wrong answers to rectify their conceptual comprehension.</td>
</tr>
<tr>
<td>Paper based quizzes without using SRS</td>
<td>Self-paced quizzes using SRS with immediate feedback of the expected correct answer, with a scaffolding follow-up question that allowed each student to learn from the feedback (multiple-choice format)</td>
</tr>
<tr>
<td>Short quiz (formative) every alternate week without using SRS</td>
<td>Short quiz (formative) every alternate week using SRS</td>
</tr>
<tr>
<td>Short quiz (summative) every alternate week using SRS (feedback will not be provided through SRS. However, students will be able to know their score)</td>
<td>Short quiz (summative) every alternate week using SRS (feedback will not be provided through SRS. However, students will be able to know their score)</td>
</tr>
<tr>
<td>Summative tests using SRS (multiple-choice questions) and paper based free-response-questions (Students will know the scores of multiple-choice questions immediately and will have to wait for me to grade the free-response-questions)</td>
<td>Summative tests using SRS (multiple-choice questions) and paper based free-response-questions (Students will know the scores of multiple-choice questions immediately and will have to wait for me to grade the free-response-questions)</td>
</tr>
</tbody>
</table>
Data Analysis

The entire design of the quasi-experiment using a pretest-posttest with control group design led me to use Analysis of Covariance (ANCOVA). I used Statistical Package for Social Sciences (SPSS, Version 22.0.0.0.) to perform ANCOVA. Field (2009) asserted that the data should meet the following assumptions to perform ANCOVA on it.

According to Field (2009), because the \( p \) value corresponding to pretest*group integration is greater than .05, I determined that there is homogeneity of regression slopes. The propensity matching performed earlier helped me to predict that the two groups are homogenous in their pretest scores. To make sure of the assumption, I checked if the result of the independent samples \( t \) test is greater than .05 for determining the assumption that there is no statistically significant difference between the two groups on pretest.

In addition, I assumed the homogeneity of variances if the result of Levene’s test of standardized residuals is greater than .050. The nature of collecting the data assured that data are independent. The histogram of standardized residuals helped me to decide normality. I also relied upon Kolmogorov-Smirnov test to assess normality because the sample size of each group was not greater than 30. Lastly, the data corresponding to all variables were either continuous or categorical.

As discussed in Chapter 4, the data set met the assumptions, so I performed ANCOVA using SPSS and made the decision whether to reject the null hypothesis or not, based on the criteria for rejection of null hypothesis.
Ethical Safeguards

I used pseudonyms to protect the identity of the students who participated in this a quasi-experiment using a pretest-posttest with control group design. The collected data is stored under strong security to protect the privacy of the students. The report of the study did not include personal information of the participants nor did it contain other information that would lead to the participants. I obtained approval to conduct the study from the Internal Review Board (IRB) of Mercer University and from the educational district where I conducted the study. Thus, the permissions that I obtained from the university and the educational district, informed assents signed by the students, and informed consents from the parents of the student participants enabled me to collect information about gender, economic status, and giftedness of the students without any breach to the ethical safeguards deemed necessary for this study. Copies of these permission forms are located in Appendices A, B, and C.

Role of the Researcher

I am a mathematics teacher with several years of experience in teaching mathematics. I taught a significant number of those years in a school that did not use any technology in classrooms because of the lack of infrastructure and funding. For the remaining years, including the year of this study, I had ample access to technology in my mathematics classrooms. Being enthusiastic about the application of technology in classrooms and receiving help from my resourceful colleagues, I soon became inclined towards using updated classroom technology for the benefit of my students. The continuous and effective professional training provided by the educational district
equipped me to use the most current technology including SRS in my classes. These experiences gave me an opportunity to see both sides of the issue— with technology and without it—objectively. Therefore, I doubt that having technology in the classroom has given me a preconceived bias that technology, especially the use of SRS as an immediate feedback tool, would enhance the learning outcomes of students who are exposed to the technology.

Concurrently, review of the research literature and personal experiences have proven that the mere existence of the technology is of no use unless the teacher properly implements the intended design. From an axiological perspective, providing immediate feedback is an art. The aesthetic value embedded in giving positive, constructive feedback enables students to achieve gains in the learning process. The role of timely, positive feedback is of immense value in every learner's life. This personal, philosophical perspective has led me to take the side of implementing the technology with rigor and passion. Nevertheless, I acknowledge the importance of not influencing the characteristics of the untreated control group quasi-experimental design study that I conducted, which definitely prompted me to take an unbiased stand throughout the experiment.

Summary

To sum up, I conducted the quasi-experiment using a pretest-posttest with control group design to determine the effects of using student response system (SRS) as an immediate feedback tool on student achievement in a school situated in a suburban educational district in Georgia. The school demographics were representative of the
school district demographics. The sample for the study consisted of a control group of 28 students and an experiment group of 25 students.

The variables consisted of a continuous pretest score, categorical gender, economic status, and giftedness. I investigated whether the intervention of giving immediate feedback using student response system when controlling the covariates influenced the continuous dependent variable, the posttest score. In Chapter 4, I explain the use of the analysis of covariance, after ensuring that the data met the assumptions suggested for the analysis according to Field (2009), to determine the effect of the intervention as represented by posttest scores.
CHAPTER 4
RESULTS OF STATISTICAL ANALYSES OF DATA

In previous chapters, in addition to reviewing the literature related with the effects of using Student Response System (SRS) as an immediate feedback tool, I described the methodology used in collecting data to understand the effects of SRS on student achievement. It is very important to provide feedback on formative assessments to improve student learning outcomes (Black & Wiliam, 2009; Marzano, 2006; Yorke, 2003), and it is critical that teachers participate in the practice of providing effective feedback continuously and consistently to students for their educational experiences (Brookhart, 2012; Wiliam, 2012). Moreover, in Chapter 2, I discussed in detail how, despite limitations and inconclusive results, researchers in multiple studies supported the use of SRS to improve student achievement, enhance engagement, and increase information retention (Abode, 2010; Blood & Neel, 2008; Christopherson, 2011; Dunham, 2011; Lynch, 2013; Nicolle & Lou, 2008; Randolph, 2007; Rigdon, 2010).

The literature review presented in Chapter 2 revealed little statistically significant evidence that the use of SRS improves student achievement (Abode, 2010; Christopherson, 2011; Dunham, 2011; Liu, Gettig, & Fjortoft, 2010; Lynch, 2013; Matus et al., 2011; Rigdon, 2010). However, the theories of distributed cognition and feedback anticipated such a change (Edgerton et al., 2008; Kim et al., 2011; Payne & Biddle, 1999; Thomas & Stockton, 1999; Vega & Travis, 2011). Thus, I planned to investigate the
effects of using SRS as a feedback tool when used effectively, continuously, and consistently in the learning environment of students enrolled in a particular mathematics class.

I detailed the plan and the intensity of using the intervention in Chapter 3. Further, in Chapter 3, I explained how I collected data from the experiment group and the control group. After gathering data in the prescribed period of 18 weeks, I conducted a detailed data analysis to determine whether there was a statistically significant difference between mathematical achievements of students in both the groups.

This chapter presents the results of the quasi-experiment using a pretest-posttest with control group design, designed to determine the effects of using student response system (SRS) as an immediate feedback tool on student achievement in a suburban Georgia school. First, I delineate the organization of data analysis and present a description of characteristics of the participants in the study. Next, I explain the research question, hypothesis, and statistical analysis of data. Following that, the statistical analysis section provides an explanation of how the dataset met the assumptions of the test and the actual analysis using the test. I conclude this chapter with a summary of the findings from the statistical analysis of data obtained from the control and experiment groups.

Organization of Data Analysis

In this chapter, I explain how I tested the research question and the corresponding hypothesis using inferential statistics. First, I present the characteristics of students in both the control group and the experiment group that formed the sample for this study.
Secondly, I reiterate the research question and the corresponding hypothesis. Next, I explain how the data set met the assumptions for the analysis of covariance (ANCOVA). Finally, I report the results of the ANCOVA for the sample data, corresponding to the research question and the null hypothesis.

Descriptive Characteristics of Participants

Data collected for testing inferential statistical analysis, including various characteristics of demographic constitution of the data derived from a participant sample consisting of 53 students enrolled in eleventh grade accelerated precalculus in a suburban high school in Georgia. The control group in this experiment contained 28 students enrolled in a class of eleventh grade accelerated precalculus course. The experiment group of the study, selected randomly between the two classes using the application from RANDOM.ORG (2015), consisted of 25 students enrolled in one class of eleventh grade accelerated precalculus course. One student transferred to another class after the selection of the groups, and I did not include the data corresponding to this student. In addition, I did not include the data corresponding to the two students who enrolled in the classes before the selection of groups, but transferred to another class.

There were 13 male students and 15 female students in the experiment group; whereas the control group was comprised of 13 male students and 12 female students. Breakdown of the sample population based on the covariate, economic status of the students was determined by examining whether the student received free or reduced lunch. According to the information provided by Georgia’s Statewide Longitudinal Data System (GaDOE, 2014), 12 students in the control group and 8 students in the experiment
group were economically disadvantaged. In both the control group and the experiment
group, 15 students each qualified as gifted students.

Research Questions and Associated Hypotheses

The following was the research question that I investigated in this study: Will there be a statistically significant difference between the educational-district-generated-
benchmark posttest scores of students who received immediate feedback using SRS and those who did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school?

In order to establish a relevant conclusion for my inquiry, the following statement served as my research null hypothesis corresponding to the research question: There will not be a statistically significant difference between the educational-district-generated-
benchmark posttest scores of students who received immediate feedback using SRS and those who did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school. The $p$ value for the intervention parameter was set to be less than or equal to .050 for the rejection of the null hypothesis.

Post-Hoc Reliability Analysis of Pretest and Posttest

I did not find any official data regarding the reliability of either posttest or pretest as mentioned in Chapter 3. Consequently, I decided to conduct a post-hoc reliability
analysis. Field (2009) recommended Cronbach's alpha as the most common measure of reliability. As stated in Chapter 3, it was important to use Cronbach's alpha to test the internal reliability of both pretest and posttest scores in this study. The pretest scores exhibited sufficient reliability value with Cronbach's $\alpha = .75$. In addition, the posttest scores exhibited medium reliability with Cronbach's $\alpha = .71$. The relatively medium values of Cronbach's $\alpha$ for both the pretest and the posttest utilized in this quasi-experimental study supports the reliability of the two instruments used to measure the math achievement levels of students in this study.

Analysis of Data

Field (2009) suggested that Analysis of Covariance (ANCOVA) is a great inferential statistical test to investigate situations when more than one covariate influences the outcome variable. If the data met all the assumptions, especially if there is no significance interrelation among the covariates, ANCOVA could suggest the effect of intervention on the outcome variable effectively. I used ANCOVA to test the effects of immediate feedback on student achievement for this study.

Assumptions for the Analysis

Field (2009) cautioned that analysis of covariance (ANCOVA) would not yield accurate results if a significant difference between the control group and the experiment group on the covariates used in the test exist. Miller and Chapman (2001) pointed out that, although ANCOVA improve the power of statistical inference test, the results of the test are invalid if the groups differ in covariates. According to Field, non-significant difference among covariates can be established by homogeneity of regression slopes of
the interactions among the covariates. I used independent samples $t$ test to check whether the two groups differ in the corresponding covariates, to ensure that the results of ANCOVA could predict the effect of the hypothesis. In addition, it is important to check whether the dependent variable—in this study, the posttest scores—is continuous in nature. It is thus important to check whether all the assumptions for the validity of ANCOVA are met to determine the effect of intervention on the outcome variable. I report the results of checking the assumptions for meeting the pre-requisites of conducting ANCOVA on the data I collected for this study.

The posttest data, the dependent variable, were continuous in nature and all the data were independent to each other. The interactions of the groups and covariates, namely, pretest, $F(1,43) = 0.03, p = .863$, Gender, $F(1,43) = 2.26, p = .140$, Economical status, $F(1,43) = 0.01, p = .905$, and Giftedness, $F(1,43) = 0.73, p = .398$ were not statistically significant, thus meeting the assumption of homogeneity of regression slopes as illustrated in Table 7.
Table 7

Tests of Between-Subjects Effects

Dependent Variable: Posttest

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1457.38a</td>
<td>9</td>
<td>161.93</td>
<td>1.87</td>
<td>.082</td>
</tr>
<tr>
<td>Intercept</td>
<td>13471.49</td>
<td>1</td>
<td>13471.49</td>
<td>156.15</td>
<td>.000</td>
</tr>
<tr>
<td>Group</td>
<td>112.29</td>
<td>1</td>
<td>112.29</td>
<td>1.30</td>
<td>.260</td>
</tr>
<tr>
<td>Pretest</td>
<td>153.60</td>
<td>1</td>
<td>153.60</td>
<td>1.78</td>
<td>.189</td>
</tr>
<tr>
<td>Gender</td>
<td>28.78</td>
<td>1</td>
<td>28.78</td>
<td>.33</td>
<td>.567</td>
</tr>
<tr>
<td>EconStatus</td>
<td>146.89</td>
<td>1</td>
<td>146.89</td>
<td>1.70</td>
<td>.199</td>
</tr>
<tr>
<td>Giftedness</td>
<td>217.70</td>
<td>1</td>
<td>217.70</td>
<td>2.52</td>
<td>.119</td>
</tr>
<tr>
<td>Group * Pretest</td>
<td>2.60</td>
<td>1</td>
<td>2.60</td>
<td>.03</td>
<td>.863</td>
</tr>
<tr>
<td>Group * Gender</td>
<td>195.08</td>
<td>1</td>
<td>195.08</td>
<td>2.26</td>
<td>.140</td>
</tr>
<tr>
<td>Group * EconStatus</td>
<td>1.24</td>
<td>1</td>
<td>1.24</td>
<td>.01</td>
<td>.905</td>
</tr>
<tr>
<td>Group * Giftedness</td>
<td>62.79</td>
<td>1</td>
<td>62.79</td>
<td>.73</td>
<td>.398</td>
</tr>
<tr>
<td>Error</td>
<td>3709.76</td>
<td>43</td>
<td>86.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>291854.00</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>5167.13</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*R2 = .282 (Adjusted R2 = .132)

The results obtained from the independent samples t tests indicated that there were no statistically significant differences for pretest scores, t(51) = 0.09, p = .929, Gender, t(51) = 1.24, p = .220, Economic Status, t(51) = -0.80, p = .425, and Giftedness, t(51) = -0.46, p = .645 between the values of the control and the experiment groups. I included Table 8, as well as Figure 13, Figure 14, Figure 15, and Figure 16, to demonstrate the results of t tests for covariate interdependency.
Table 8

Independent Samples t-Test Results for Covariates

<table>
<thead>
<tr>
<th></th>
<th>Levene's Test for Equality of Variances</th>
<th>t-Test Results for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
<td>$p$</td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>1.67</td>
<td>.202</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>.09</td>
<td>50.63</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.17</td>
<td>.682</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.24</td>
<td>50.42</td>
</tr>
<tr>
<td>EconStat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>2.38</td>
<td>.129</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-.80</td>
<td>50.83</td>
</tr>
<tr>
<td>Giftedness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.74</td>
<td>.392</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-.464</td>
<td>50.50</td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>.02</td>
<td>.899</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>-2.73</td>
<td>50.33</td>
</tr>
</tbody>
</table>

132
Figure 13. Error Plot Corresponding to Pretest

Figure 14. Error Plot Corresponding to Gender
Figure 15. Error Plot Corresponding to Economic Status

Figure 16. Error Plot Corresponding to Giftedness
The homogeneity of variances was established by the Levene’s test of standardized residuals, $F(1, 51) = 0.06, p = .803$, as illustrated in Table 9. The histogram of standardized residuals, in Figure 17, illustrated normality. In addition, the results of Kolmogorov-Smirnov test, which used Lilliefors significance correction, $D(53) = 0.10, p \geq .200$, established normality of standardized residuals, as illustrated in Table 10. Thus, all the assumptions for the ANCOVA test were met.

Table 9

Levene’s Test of Equality of Error Variances$^a$

<table>
<thead>
<tr>
<th>Dependent Variable: Posttest</th>
<th>$F$</th>
<th>df1</th>
<th>df2</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.063</td>
<td>1</td>
<td>51</td>
<td>.803</td>
</tr>
</tbody>
</table>

*Note.* Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

*aDesign: Intercept + Pretest + Gender + EconStat + Giftedness + Group*
Figure 17. Standardized Residual Histogram for Posttest

Table 10

Tests of Normality

<table>
<thead>
<tr>
<th></th>
<th>Kolmogorov-Smirnov&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistic</td>
<td>df</td>
<td>p</td>
</tr>
<tr>
<td>Standardized Residual for posttest</td>
<td>.104</td>
<td>53</td>
</tr>
</tbody>
</table>

*Note.* This is a lower bound of the true significance.

<sup>a</sup> Lilliefors Significance Correction
The data collected for this study, after successfully meeting all the assumptions, was an ideal situation to conduct ANCOVA. The existence of a statistically significant difference in the values of dependent variable, the posttest, would indicate that the intervention, namely the immediate feedback for student responses had an effect on student achievement. In Figure 18, I illustrate the statistical significance of the intervention as the graph of percentages of posttest scores of students in the control and the experiment groups after adjusting the means for the effects of the covariates in the study. In the next section, I report the results of analysis of covariance on the data set.

\[ \text{Figure 18. Error Plot for Adjusted Means of Posttest} \]
Report of ANCOVA

There was a statistically significant difference in the posttest scores of students who received immediate feedback through SRS and the students who did not receive immediate feedback through SRS, $F(1,47) = 5.99$, $p = .018$, $partial \eta^2 = .11$, when controlling pretest scores, gender, giftedness, and economic status of the students.

However, none of the covariates, namely, pretest, $F(1,47) = 2.19$, $p = .146$, $partial \eta^2 = .04$; Gender, $F(1,47) = 0.17$, $p = .681$, $partial \eta^2 = .00$; Economic Status, $F(1,47) = 1.10$, $p = .300$, $partial \eta^2 = .02$, or Giftedness, $F(1,47) = 3.43$, $p = .070$, $partial \eta^2 = .07$, had any statistically significant effect on the posttest scores, as tabulated in Table 11.

Further, students in the experiment group scored better in posttest, $M = 76.89$, $SE = 1.75$, 95% CIs $[73.15, 80.63]$, when compared to the posttest scores of students in the control group, $M = 70.57$, $SE = 1.74$, 95% CI $[67.04, 74.09]$, when controlling for their pretest scores, gender, giftedness, and economic status, as illustrated in Table 12. In addition, Tables 13, 14, and 15 represent the estimated marginal means of all the covariates, namely, Gender, Economical Status, and Giftedness, respectively.
Table 11

*Tests of Between-Subjects Effects*

Dependent variable: Posttest

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1200.16$^a$</td>
<td>5</td>
<td>240.03</td>
<td>2.84</td>
<td>.025</td>
<td>.23</td>
</tr>
<tr>
<td>Intercept</td>
<td>15139.08</td>
<td>1</td>
<td>15139.07</td>
<td>179.37</td>
<td>.000</td>
<td>.79</td>
</tr>
<tr>
<td>Pretest</td>
<td>184.56</td>
<td>1</td>
<td>184.56</td>
<td>2.19</td>
<td>.146</td>
<td>.04</td>
</tr>
<tr>
<td>Gender</td>
<td>14.49</td>
<td>1</td>
<td>14.49</td>
<td>.17</td>
<td>.681</td>
<td>.00</td>
</tr>
<tr>
<td>EconStat</td>
<td>92.58</td>
<td>1</td>
<td>92.58</td>
<td>1.10</td>
<td>.300</td>
<td>.02</td>
</tr>
<tr>
<td>Giftedness</td>
<td>289.17</td>
<td>1</td>
<td>289.17</td>
<td>3.43</td>
<td>.070</td>
<td>.07</td>
</tr>
<tr>
<td>Group</td>
<td>505.30</td>
<td>1</td>
<td>505.30</td>
<td>5.99</td>
<td>.018</td>
<td>.11</td>
</tr>
<tr>
<td>Error</td>
<td>3966.98</td>
<td>47</td>
<td>84.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>291854.00</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>5167.13</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^aR^2 = .232$ (Adjusted $R^2 = .151$)

Table 12

*Estimated Marginal Means of the Groups*

Dependent Variable: Posttest

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Control</td>
<td>69.90$^a$</td>
<td>1.76</td>
<td>66.36</td>
</tr>
<tr>
<td>Experiment</td>
<td>76.22$^a$</td>
<td>1.93</td>
<td>72.34</td>
</tr>
</tbody>
</table>

$^a$Covariate appearing in the model is evaluated at the following value: Pretest = 37.2642.
Table 13

*Estimated Marginal Means of the Covariate: Gender*

Dependent Variable: Posttest

<table>
<thead>
<tr>
<th>Gender</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Female</td>
<td>73.60a</td>
<td>1.85</td>
<td>69.87</td>
</tr>
<tr>
<td>Male</td>
<td>72.53a</td>
<td>1.85</td>
<td>68.80</td>
</tr>
</tbody>
</table>

*a Covariate appearing in the model is evaluated at the following value: Pretest = 37.2642.

Table 14

*Estimated Marginal Means of the Covariate: Economic Status*

Dependent Variable: Posttest

<table>
<thead>
<tr>
<th>EconStat</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Disadvantaged</td>
<td>71.68a</td>
<td>2.09</td>
<td>67.48</td>
</tr>
<tr>
<td>NotDisadvantaged</td>
<td>74.44a</td>
<td>1.61</td>
<td>71.21</td>
</tr>
</tbody>
</table>

*a Covariate appearing in the model is evaluated at the following value: Pretest = 37.2642.*
Table 15

*Estimated Marginal Means of the Covariate: Giftedness*

<table>
<thead>
<tr>
<th>Giftedness</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>NotGifted</td>
<td>70.68a</td>
<td>1.98</td>
<td>66.70</td>
</tr>
<tr>
<td>Gifted</td>
<td>75.45a</td>
<td>1.70</td>
<td>72.02</td>
</tr>
</tbody>
</table>

^aCovariate appearing in the model is evaluated at the following value: Pretest = 37.2642.

Summary

To conclude, in this chapter I explained how the “untreated control group [quasi-experimental] design study with dependent pretest and posttest samples” (Shadish, Cook, & Campbell, 2002, p. 136) and the data analysis on the collected data from the sample of 53 participants successfully met the assumptions for conducting analysis of covariance. It is important to note that the experiment group received immediate feedback for their responses using SRS and the control group did not get immediate feedback using SRS. Again, both the groups were exposed evenly to every other learning experience prescribed in the accelerated precalculus course. Further, in this chapter, I presented how the covariates and the dependent variable, the posttest scores of the students in both the control group and the experiment group, related to each other.

Moreover, in this chapter, I explained how an analysis of covariance (ANCOVA) was conducted. I reported both the assumptions for the test and the results of the
ANCOVA. I also explained how the results delineated in this chapter led me to reject the null hypothesis (there will not be a statistically significant difference between the posttest scores of students who received immediate feedback using SRS and those who did not receive the intervention of immediate feedback using SRS). The covariates of giftedness, gender, and economic status of the participant students did not have any significant effect in student achievement as measured by the dependent variable, the posttest. Chapter 5 contains a discussion of the implications of the results that this study might bring forth in application of immediate feedback into educational scenarios. In Chapter 5, I also discuss the various limitations and shortcomings of this study, as well as recommendations for further investigations related to applications of immediate feedback.
CHAPTER 5
FINDINGS, DISCUSSIONS, AND RECOMMENDATIONS

Advocates of distributed cognition theory and self-regulatory learning theory support the provision of immediate feedback during the learning process—either as part of the learning or as part of their formative assessments—to improve educational achievement. In Chapter 2, I reviewed the literature related to the theories and available relevant research, accumulated by an almost self-saturated search strategy that included quantitative, qualitative, and mixed method studies and the related peer-reviewed articles. Chapter 3 delineated the quantitative methodology used in this study to inquire the effects of immediate feedback using SRS on student achievement. Chapter 4 contained the reported results of the data analysis obtained from the quasi-experimental study.

In this chapter, I provide an overview of the findings from the quasi-experimental study, followed by an analysis of the limitations of this study and its research design. In the next section, I attempt to examine the implications this study might bring forth, related to distributed cognition theory and self-regulatory learning theory. Next, I compare the results of this study with other studies discussed in Chapter 2, from the perspective of the results and recommendations of previous studies. Then, I discuss how the implications of the results from this quasi-experimental study might affect instructional practices, especially the feedback aspects of formative assessments, in
various educational situations. Finally, in the last section of this chapter, I provide recommendations and suggestions for further research.

Summary of the Study

In this quasi-experimental study, I investigated whether immediate feedback using SRS would significantly affect student achievement. There were two randomly selected groups of students enrolled in two classes of accelerated precalculus courses in a suburban high school in Georgia. While the experiment group continuously received immediate feedback through a SRS, the control group did not receive immediate feedback using the devices. Student achievement, the dependent variable, was collected and measured using an educational-district generated posttest that matched the curricular standards prescribed for the course. The covariates used in this study were the pretest (state-released, standardized EOCT test), gender, giftedness, and economic status of the participant students.

Research Question

The following was the research question that I investigated in this study: Will there be a statistically significant difference between the educational-district-generated-benchmark posttest scores of students who received immediate feedback using SRS and those who did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school?
Research Hypothesis and Criteria of Rejection of Hypothesis

In order to establish a relevant conclusion for my inquiry, the following statement served as my research null hypothesis corresponding to the research question. It is to be noted that if the $p$ value for the intervention parameter is less than or equal to .050, the null hypothesis will be rejected. The null hypothesis is as follows: There will not be a statistically significant difference between the educational-district-generated-benchmark posttest scores of students who received immediate feedback using SRS and those did not receive the intervention of immediate feedback using SRS, when controlling for state-generated-pretest scores, giftedness, gender, and economic status of students enrolled in eleventh grade accelerated precalculus course in a suburban high school.

Results and Literature Review

Analysis of covariance (ANCOVA), with pretest scores, gender, giftedness, and economic status of participant students as covariates, illustrated statistically significant difference between the posttest scores of the experiment group and the control group, thus suggesting that immediate feedback provided to student responses through SRS for the experiment group was effective. The results of this study were consistent with various, prominent theories of feedback, including the Feedback Intervention Theory (FIT) developed by Kluger and DeNisi (1996), and the results of subsequent studies (Brookhart, 2012; Chappuis, 2012; Krenn et al., 2013; Wiliam 2012). It is to be noted that the effect sizes of these quantitative studies, denoted using $\eta^2$, were less than .033, which indicated that this study had a better effect size ($\eta^2 = .11$), indicating better effect size.

Proponents of the theory of distributed cognition advocate for the use of SRS as an effective feedback tool (Hollan, Hutchins, & Krish, 2000). The network of participants and technology involved in the design of the intervention, as suggested by Wright et al. (1999), positively affected the result of this study, especially when the students in the experiment group experienced anonymous feedback characteristics of implementing SRS to provide immediate feedback with a medium effect size ($\eta^2 = .11$).

Several studies indicated statistically significant effects of using SRS to improve student achievement. Even though the use of SRS improved student achievement and motivation significantly in the study conducted by Jones, Antonenko, and Greenwood (2012), the effect sizes of various results of the split-factorial multivariate analysis of variance (MANOVA) were small (maximum $\eta^2$ was .08). The results obtained from the current study surpassed the findings of the aforementioned studies, with an
improved effect size \( (partial \eta^2 = .11) \), which might be due to an improved design of intervention. When unable to establish statistical significance on student achievement, the researchers investigating SRS and its effect on student achievement invariably recommended amendments of intervention strategies and increased period of investigation (Christopherson, 2011; Dunham, 2011; Lynch, 2013; Penual et al., 2007; Rigdon, 2010).

It was interesting to note that researchers reported a significant improvement in the effects of SRS on student achievement from a qualitative perspective in qualitative and mixed method investigations (Abode, 2010; Dunham, 2011; Edens, 2006; Rigdon, 2010). Dunham (2011) reported improvement in learning environment with the implementation of SRS strategies. Abode (2010) confirmed an improvement in student engagement and motivation when SRS was included in learning strategies.

In Chapter 2, I included several studies on the covariates of this study, namely, giftedness, economic status, and gender of the participant students. Gifted students, equipped with technological tools, were well equipped to improve their learning experiences, especially when using SRS as immediate feedback tool (Duan, Shi, & Zhou, 2010; Hong & Aqui, 2004; Rotigel & Fello, 2004). Ritzhaupt, Liu, Dawson, and Barron (2013), with small values of effect size \( (partial \eta^2 = .034, .024, \text{ and } .028) \), could not explain an observed digital divide using socio-economic status, gender, and ethnicity. Ritzhaupt et al. (2013) suggested that other factors might have influenced student achievement in the study. The study conducted by Kim et al. (2011) to identify the effect of socio-economic set up was able to establish a significant difference in academic
performance of students between the intervention groups, with a small effect size
\((partial \eta^2 = .08)\). In the case of the covariate of gender, literature analysis did not
unanimously suggest any significant gender effect on academic achievement in general,
favoring either male or female students, even though individual studies reached their own
questionable conclusions. Thus, it was not a surprise to see that in the current study, the
covariate, gender, did not make a statistically significant effect on student achievement.
Further, the covariates of giftedness and economic status did not significantly affect the
posttest scores of the participating students in both the groups.

Conclusions

The fact that I rejected the null hypothesis implied that there was a statistically
significant difference between student-achievement when I provided immediate feedback
to students in the experiment group using SRS. It is important to note that none of the
covariates influenced student achievement because there was no statistically significant
difference in each of the covariates.

One reason that the intervention of providing immediate feedback using SRS had
a significant effect on student achievement might be attributed to the design of the
intervention, where I tried to imbibe the suggestions and recommendations of studies
delineated in the literature review (Abode, 2010; Christopherson, 2011; Dunham, 2011;
Jones et al., 2012; Rigdon, 2010). Even though there could have been more
improvisations, I tried to implement the suggestions and recommendations of the
researchers in the literature review, which included using SRS for a greater span of time
and focusing on the immediate feedback aspect of using SRS to improve student
engagement and comprehension (Matus et al., 2011; Penual et al., 2007). Probably, better design of the intervention might have been the reason for the medium effect size observed in this study ($\text{partial } \eta^2 = .11$). It is interesting that there was a seven-percentage gain in posttest scores of students in the experiment group. There were 30 items in the posttest, which implied that there was a two-point increase in achievement scores between the two groups.

It is interesting to note that the design of the intervention in this study matched with the requirements suggested by feedback intervention theory suggested and discussed in Chapter 2 (Kluger & Denise, 1996; Krenn et al., 2013; Wiliam, 2012). The student response and the consequent feedback were anonymous in most cases, thus allowing a safe educational environment where it was all right for individual students to make conceptual mistakes and receive healthy negative feedback. The positive feedback the students received after making a correct response also provided the opportunity for individual students to improve his or her “self” (Wiliam, 2012, p. 32). The provision of powerful immediate feedback as part of the intervention might have been a strong catalyst for the statistically significant math achievement with a medium effect size.

Another attribute for the intervention, implemented as per the recommendations from previous studies, was to apply the tenets of feedback very closely organized with the learning habits of students (Hattie, 2012). Students in the experiment group received continuous and consistent immediate feedback almost every day, so receiving immediate feedback became a second nature to them as suggested in the literature review. I heeded Hattie’s advice that teachers could use SRS technology to impart self-regulation feedback
that would definitely stimulate higher-order thinking among students by promoting their self-regulation skills. The organization and implementation of the intervention revolved around the suggestions and recommendations put forth by the researchers of the effectiveness of SRS.

One of the reasons that there was a significant student achievement with a medium effect size would have been the rigor of the intervention, where students were engaged in the process of providing responses and receiving immediate feedback through the medium of SRS. Christopherson (2011), in the conclusion of the study, noted that it requires a well-designed instructional plan implemented by an effective teacher could result in learning gains. Thus, teachers who plan to use SRS as an immediate feedback tool should receive training to use the tool effectively, especially in terms of providing effective and immediate feedback.

It was also interesting to observe how the process of self-monitoring, enhanced by the provision of immediate feedback through SRS, helped students to take responsibility of self-monitoring their learning procedure, correcting their misconceptions about the topic they were learning, thus establishing the tenets of the theory of self-regulation (Mace et al., 2001). In addition, I heeded the advice of Wright et al. (1999) that educators should plan to elucidate the anticipated goals and to monitor the results of intervention to alter the SRS activities, vital for the intervention. After implementing such an intervention, the results of data analysis were significant enough to prove the effects of distributed cognition theory, where the interaction between the learner and SRS
and among other learners created an effective environment conducive to enhanced learning experiences.

Limitations of Research Design

Even though great care was taken to design immediate feedback activities based on the tenets of feedback, distributed cognition, and self-regulation theories, and suggestions and recommendations from previous studies and the corresponding literature review, there were many observable and yet uncontrollable limitations to the research design. Obviously, in a classroom situation, it was not possible to apply exclusive randomness in the selection of participants because there are district and school procedures to enroll students in different classes. There were only two accelerated precalculus classes in the high school where I conducted the experiment, and I taught both the classes. The only randomization that I attained was the designation of a particular class as the experiment group or the control group.

Shadish, Cook, and Campbell (2002) suggested that “the untreated control group design with dependent pretest and posttest samples” (p. 136), which I employed in this investigation, enables researchers to probe different threats to validity more efficiently. The tests of assumptions of the pretest data illustrated the absence of differences between the groups. However, Shadish et al. (2002) cautioned that the “absence of pretest differences in a quasi-experiment is never proof that selection bias is absent” (p. 138). In addition, the design of the quasi-experiment for this study was not able to measure selection-maturation threat, as pointed out by Shadish et al. The only consolation was that both groups of students had similar educational backgrounds of belonging to the
same accelerated math tracking for at least three years, since the beginning of their high school education. Again, in Georgia public schools, students are eligible for enrollment in accelerated precalculus only if they were enrolled in accelerated math courses starting from their ninth grade year.

Another limitation for the design was the use of different pretest and posttest to measure math achievement. Precalculus course and its curricular activities consist of introducing a large amount of new mathematical concepts, which the enrolled students might not have been exposed to in their previous mathematics courses. At the same time, it is important to check whether they were ready to learn the novel concepts of precalculus topics. Thus, I selected the standardized end-of-course test approved by the Georgia Department of Education to test readiness for enrollment in the precalculus course as the pretest.

After the end of intervention and at the fall semester, I administered the posttest, designed to include the precalculus standards prescribed for the course for the semester. I selected the semester final exam that the educational district had used in previous years for the precalculus course to be the posttest, with a few changes. The posttest aligned well with the required standards assigned to precalculus class.

Another limitation to the design for the test might have been the time of the day the classes were in session. After the random selection of the groups using the application from RANDOM.ORG (2015), the experiment group had the class in the morning and the control group had the class after lunch. In addition, the effect size of this study represented by partial $\eta^2$ was medium, $F(1,47) = 5.99, p = .018, \text{ partial } \eta^2 = .11$. 
Effect size of this study was above the effect sizes of most the studies that had a positive effect on student achievement as the result of SRS intervention. I attribute the improvement in effect size to the improved design of intervention, influenced by the suggestions and the recommendations provided in the aforementioned studies as well as other studies that did not exhibit SRS influence on student achievement.

I was certain that the other construct validity threats that Shadish et al. (2002) delineated, including novelty, compensatory rivalry, and resentful demoralization, were not problematic because the participants were acquainted with SRS technology, including the type used in this investigation. Students in both the experiment group and the control group had multiple opportunities in my class, as well as in other classes, to use the same technology, although not necessarily for immediate feedback. However, there are chances that the students in both groups might have noticed the differences in the ways they were getting feedback when they talked to each other outside class. These discussions might have possibly affected their morale, even though they did not raise any concern.

As mentioned earlier, the participants in both the groups and the teacher had previously used SRS, thus, the technology was not a novelty to any of them. Yet, there were some learning curves included with the implementation of the SRS in the classroom, especially with the special intention of providing immediate feedback. It was also necessary that I should not provide immediate feedback using SRS to the participants in the control group. Christopherson (2011) suggested that the teachers, as
well as the students, should acquaint themselves with the SRS tools they chose to use before providing the intervention for the successful implementation of the intervention.

To sum up, even though I intended to plan this research design flawlessly, there are factors beyond my control as a researcher that might have affected the generalizability of the study results. However, the medium effect size of this study was an encouraging factor and helpful to generalize the implications of this study, as delineated in the next section.

Implications

Increased use of technology in classrooms, as well as outside of school, by our tech-savvy, millennial generation of students requires educators to implement learning experiences matching the students' life experiences. However, one of the important factors that would lead students to enhance their learning experiences would be the implementation of effective use of available technology. This study, focused on imparting immediate feedback using SRS, required a well-planned intervention strategy to affect significant student achievement. Recommendations and suggestions outlined in previous investigations of SRS in classrooms guided the intervention design (Abode, 2010; Christopherson, 2011; Dunham, 2011; Jones et al., 2012; Rigdon, 2010). Even though there were some limitations to this study and the effect size of the significance of difference in posttest scores was only medium, I foresee several implications that this study might suggest.

Firstly, providing effective, continuous, and immediate feedback to students responses would improve their self-regulatory learning habits. There was no significant
difference between giftedness of the students in this study. Yet, giftedness does not define self-regulation. Zimmerman (2001) stated that self-regulated students would “self-generate [their] thoughts, feelings, and actions to attain their learning goals” (p. 5). Immediate feedback provided to them would assist them to attain this goal. Suggestions for the necessary, deliberate attempts on the part of educators and educational system to enhance self-regulation for students, as per Schunk (2001), could be easily implied by effective use of SRS to provide immediate feedback.

It is also important for educators to decide the type of immediate feedback they plan to provide for student responses. Hattie (2012) suggested providing conceptual feedback to improve self-regulation of the students, after making them ready to receive it. Anonymous, yet immediate, feedback would undoubtedly enhance self-regulation through error-detection without the stress of peer pressure among socially concerned teenage students. In this study, the requirement that students should provide a rationale for open-ended question helped students to rectify their mistakes, if they had any.

During the intervention period, I noticed among the participants in the experiment group, that, in agreement with Corno (2001), students improved their self-management and efficiency in managing learning environment through continuous use of SRS as an immediate feedback tool. This occurrence supports the veracity of Black and Wiliam’s (2009) growth model controlled by volitional strategies.

It was also interesting to observe that the students used teacher feedback to guide their self-regulatory skills, as suggested by Hollan et al. (2000). I saw suggestions from Wright et al. (1999) in action when students’ learning outcome emerged from the
distributed cognition activities. This was especially obvious when students made a mistake while responding anonymously, then realized that they made the mistake after seeing the displayed correct responses, and corrected their mistake accordingly.

Another implication of this study is the necessity to prepare educators to provide effective feedback using SRS. It is imperative that educators and other stakeholders in education understand that technology by itself is not sufficient to improve the learning experiences of the students entrusted to them. It requires conscious efforts from all the stakeholders of education and teacher training institutes and universities to take a lead in providing training to current educators, as well as the future generations of educators, to provide effective immediate feedback to student responses in every learning environment. The encouraging results obtained from this study should promote investigations and research into different methodologies that could help to improve effective, immediate feedback using SRS, thus promoting students’ conceptual comprehension, early detection and correction of conceptual misunderstandings, and self-regulatory practices of learning, which would, consequently, lead to improve student achievement—not only in mathematics, but also in other subjects.

Thus, the major implication of this study is that it is necessary to design a feedback system to suit student responses to affect learning outcomes of the students. Exploring and implementing rigorous activities to generate student responses that enable the educator to identify the conceptual flaws in students’ understanding of the topic are very critical for an effective immediate feedback system design. Even though the effect size of the statistically significant difference between posttest scores was medium, this
study largely exposes the importance of a well-designed immediate feedback system to be in place to enhance the learning outcomes, and eventually student achievement.

Other implications of this study include the necessity and worthiness of spending resources to implement an effective feedback system in classrooms and providing the necessary training and ongoing support to educators who are willing to implement immediate feedback using SRS or similar technological systems. It is fitting and crucial that we start to communicate with students in their favored mode of information acquisition. Thus, providing effective, immediate feedback to student responses is not an option, but a necessary component of current educational practices.

Future Research

One of the limitations for this study was its period of implementation. Consequently, I suggest that future researchers aim at observing and providing feedback for longer terms. Even though it is important to probe students’ conceptual understanding, it is equally important to investigate how students who used SRS retain their learning outcomes. Long-term research is necessary to investigate such a query.

The millennial generation students live in an era of immediate gratification of their searches. They usually prefer to get feedback for almost all their responses faster and do not tend to wait for the same; therefore, getting immediate feedback is a second nature to them. It is interesting to see that various online programs are readily available for educators and students to utilize the tenets of immediate feedback, so that receiving immediate effective feedback becomes a way of student life and not a unique phenomenon that occurs on special occasions. I imagine that there is a large scope of
research in this direction. Improving the intervention strategies to provide immediate feedback more frequently and more effectively might result in determining more about the effects of using immediate feedback.

In addition, I suggest that further studies should involve more students and include more subject areas simultaneously. It is also important to see students from different grade levels are also included in the study. Throughout the intervention period, I observed that the students in the experiment group were highly engaged in providing their responses and reacted positively to the feedback they received. Consequently, I recommend well-designed, mixed method studies of the qualitative aspects of receiving immediate feedback through SRS. Teacher preparation and the consequent teacher proficiency in designing, managing, and analyzing student data from SRS are inevitable in the successful implementation of immediate feedback using SRS. Hence, I recommend further studies that investigate the role of teachers in providing immediate feedback using SRS.

Summary

Providing immediate feedback to student responses using SRS in classrooms to meet the learning styles of students belonging to the millennial generation is a social necessity (Wieman & Perkins, 2005). The use of feedback technology and SRS could be used to improve student engagement and enable effective comprehension of difficult concepts among students of this generation (Blood, & Neel, 2008; NCTM, 2000; Wieman & Perkins, 2005). In addition, it is important to make financial decisions to use SRS as an immediate feedback tool in classrooms, to ensure the provision of
infrastructure and professional development for educators necessary to effective implementation of the tool.

In this study, I investigated the effects of immediate feedback using SRS on the mathematics achievement of 53 students enrolled in an eleventh grade precalculus course in a suburban school in Georgia. The majority of investigators of effective feedback unanimously agreed that effective, timely feedback is a primary requisite for formative assessments. Student responses followed by teacher feedback could form an effective scaffold for conceptual comprehension and self-regulated learning (Black & Wiliam, 2009; Mace et al., 2001; Zimmerman, 2001). Proponents of distributed cognition theory suggested that immediate feedback enhances students’ self-regulatory skills and consequently enriches their learning experiences.

Using SRS and teacher feedback from SRS activities as guide, students can communicate, draw feedback inferences, and improve self-regulatory skills. The fact that distribution of cognition may also occur between different events, past or present, enhances the retention capacity of the students when they continuously use SRS. The human-computer interactions that are vital in current technology-oriented workspaces or classrooms thus become an important aspect to consider when students are interacting with SRS (Hollan et al., 2000; Rogers, 1997; Wright et al., 1999).

Several studies that probed the effectiveness of using SRS to affect student achievement were not able to establish significant student achievement, leading the researchers to issue multiple recommendations and suggestions to improve the impact of intervention-designs (Abode, 2010; Christopherson, 2011; Dunham, 2011; Jones et al.,
2012; Rigdon, 2010). Currently, the importance of collecting student responses and providing immediate feedback has increased exponentially due to the emergence of various new applications and programs, which are readily and abundantly available as classroom resources. Thus, there was justification for further investigation on the effects of immediate feedback, with improved research design that would include continuous and consistent use of immediate feedback is inevitable.

In order to improve upon previous research designs, other factors needed consideration. One factor was the role played by gender in receiving immediate feedback because several studies suggested that immediate feedback and the use of technology had varied effects across gender. There was also strong evidence that the characteristics of giftedness had an impact on the educational achievement of students, in spite of different levels of definitions that existed for giftedness and its implications. Finally, studies conducted on the effects of economic status prompted me to add the economic status of students as a covariate for the analysis of this study, to identify if economic status affects the effectiveness of the use of SRS as an immediate feedback tool.

I used analysis of covariance (ANCOVA) to test hypothesis in this experimental study, after making sure that the data did not violate the assumptions of this highly robust statistical inferential test (Field, 2009). Interactions of each covariate, namely, pretest scores, gender, economic status, and giftedness with the experiment group and the control group were not statistically significant. Independent samples t tests illustrated that there were no statistically significant differences between the groups on each covariate. After successfully meeting the criteria for assumptions, an analysis of covariance (ANCOVA)
conducted on the data demonstrated that there was a statistically significant difference between the posttest scores of students enrolled in both the groups, proving that immediate feedback affected student achievement significantly. The effect size of the significance \( \text{partial } \eta^2 = .11 \) was medium and considerably larger than the studies from literature review. I attribute the improvement in effect size to improved research design, mainly inspired by recommendations and suggestions from the researchers of previous studies.

The results of this study indicated that effective intervention of providing immediate feedback through careful design of learning experiences using SRS had a statistically significant effect on the mathematics achievement of this sample. The medium effect size \( \text{partial } \eta^2 = .11 \) should encourage researchers to generalize the effectiveness of SRS as an immediate feedback tool. Further research on the topic, with changes in the research design, increased number of participants, and longer terms of intervention are some suggestions that might influence the effects of this study. I suggest that future researchers should maintain the following characteristics of research design, or should improve them. Firstly, the intervention of providing immediate feedback was continuous and consistent. Secondly, the use of immediate feedback was fun and promoted student engagement. Finally, I used the same SRS throughout the intervention because of the availability of the SRS in the educational settings of this investigation.

The use of SRS to provide immediate feedback requires further investigation. The design of learning experiences provided using SRS and the consequent feedback strategies need improvisations. The availability of different SRS tools, namely, online,
offline, machines, and virtual machines provide sufficient opportunities to improve the learning experiences of students who receive immediate feedback through them. Further, it is inevitable to train educators to use immediate feedback and the associated technology to provide the students with better learning experiences that use the strategies of immediate feedback. I also recommend further investigation towards the effective use of SRS as an immediate feedback tool to help educators determine the need for re-teaching the missed concepts. With further authentic research and consequent development of learning experiences using immediate feedback strategies, coupled with successful implementations of SRS, the current millennial generation of students will definitely benefit from the best practices of educational experiences, matching their dexterity in using technological devices.
REFERENCES


APPENDIX A

MERCER UNIVERSITY IRB APPROVAL
Mr. Austin Kureethara Manuel
Mercer University
Tift College of Education
3001 Mercer University
Atlanta, GA 30341

RE: Effects of Immediate Feedback using Student Response System on Math Achievement (H1406189)

Dear Mr. Manuel:

Your application entitled: Effects of Immediate Feedback using Student Response System on Math Achievement (H1406189) was reviewed by this Institutional Review Board for Human Subjects Research in accordance with Federal Regulations 21 CFR 56.110(b) and 45 CFR 46.110(b) (for expedited review) and was approved under Category 7 per 63 FR 60364.

Your application was approved for one year of study on 25-Jun-2014. The protocol expires 25-Jun-2015. If the study continues beyond one year, it must be re-evaluated by the IRB Committee.

Item(s) Approved:
New Application

Please complete the survey for the IRB and the Office of Research Compliance. To access the survey, click on the following link: [Survey Link]

Respectfully,

Ava Chambliss-Richardson, M.Ed., CIP, CIM
Associate Director of Human Research Protection Programs (HRPP)
Member
Institutional Review Board
Mercer University IRB & Office of Research Compliance
Phone (478) 301-4101
Fax (478) 301-2329
ORC_Mercer@Mercer.Edu
173

Tift College of Education

*Quantitative Research*

**Informed Assent for Participants Ages 14-21**

**Effects of Immediate Feedback using Student Response System on Math Achievement**

You are being asked to participate in a research study. Before you give your consent to volunteer, it is important that you read the following information and ask as many questions as necessary to be sure you understand what you will be asked to do.

Investigators at Mercer University are doing a research study where we are trying to learn about the effects of immediate feedback using student response system on math achievement.

**Procedures**

You will be asked to participate in the pretest and posttest designed to measure the effects of using student response system to provide immediate feedback. Demographic information including whether you are enrolled as a gifted student or not, your gender, and your free or reduced lunch status will be collected from relevant teacher portal. The research will involve instances where your child will respond to classroom activities using student response system. You have the right to refuse to have your information included in the research. Refusing to include your information will not jeopardize you receiving any services related to your coursework.

**Questionnaires.** No questionnaires will be used in this quantitative experimental study.

**Videotaping.** No videotaping will be used in this quantitative experimental study.

**Interviews.** No interviews will be used in this quantitative experimental study.

**Potential Risk and Discomforts**

There are no foreseeable risks associated with this quantitative experimental study.

**Potential Benefits of the Research**

The research would add to the body of knowledge about the use of student response system to increase student achievement and would be a guideline for any further research on the topic.

**Confidentiality and Data Storage**

The documents collected for this research study from the student will be the pretest scores and the posttest scores. Your child's name will not be associated with your child's responses and will be identified only by an assigned coded number. Demographic information, collected from relevant teacher portal during the study including whether you are enrolled as a gifted student or not, your gender, and your free or reduced lunch status will also be included in the study using coded number, taking care that the data will be without any identifying information. At no time will your name be associated with the results of the research. At the end of the research, the results obtained from the analysis of the data will
be published without any identifying information.

Your test scores and demographic information will be stored in a locked location and will only be used for research purposes by Mercer University School.

Your parent(s) have said that it is okay for you to be in this research study. You do not have to be in this study if you do not want. You can change your mind at any time by telling your Mom, Dad, or your teacher, Mr. Manuel.

______ No, I do not want to be in this study. ____ Yes, I want to be in this study.

Signature of Participant __________________________ Date ____________

Signature of Person Obtaining Assent __________________________ Date ____________

Rev. 5.17.2010
APPENDIX C

PARENTAL INFORMED CONSENT FORM
Effects of Immediate Feedback using Student Response System on Math Achievement

Parent or Guardian Informed Consent Form

Your child has been asked to participate in a research study entitled Effects of Immediate Feedback using Student Response System on Math Achievement. The study is being conducted by Austin Kureethara Manuel. Ph. No: (678)428-7919. Email: Austin.Kureethara.Manuel@mercer.edu and Jeffrey Hall, Ed.D. (678)547-6520. Email: hall_j@mercer.edu. The results will be used to further my understanding on the effects of using SRS to provide immediate feedback to student responses. Your son’s/daughter’s participation is voluntary. A decision to participate in the research will not affect his/her relationship with Alcovy High School, his/her relationship with other teachers, or his/her academic standing.

I. The purpose of my study:
This research study is designed to assess the effects of using student response system to provide immediate feedback to students enrolled in accelerated math course. The data from this research will be used to analyze the effects that student response system would have on students’ math achievement when used to provide immediate feedback for student responses during formative assessments. The results of the study will contribute to my graduate studies in Mercer University.

II. Procedures:
If you allow your child to volunteer for this study, your child will be asked to participate in the pretest and posttest designed to measure the effects of using student response system to provide immediate feedback. Demographic information including whether your child is enrolled as a gifted student or not, your child’s gender, and your child’s free or reduced lunch status will be collected from relevant teacher portal during the study. The research will involve instances where your child will respond to classroom activities using student response system. Your child’s participation will take approximately 55 minutes a day for 16 weeks during their normal mathematics period in school, while they undergo the class activities related to their math course as prescribed by the school.

Your child will be asked to assent to participate in this research. (Assent means that your child will be asked to voluntarily participate in this research.) Your child will tell the teacher they want to participate by answering yes or no after the teacher verbally reads to your child what the research is about and what he/she will be asked to do.
Parent/guardians who allow student to participate must read and complete this consent form. Please sign the form to indicate that you give permission to your son/daughter to participate in the pretest and posttest assessments and to receive immediate feedback using student response system. Please return this form to Mr. Manuel as early as possible.

III. Potential benefits to students and/or society
The research would add to the body of knowledge about the use of student response system to increase student achievement and would be a guideline for any further research on the topic.

IV. Potential Risks/Discomfort
There are no foreseeable risks associated with this quantitative experimental study.

V. Withdrawal of Participation
Your child’s participation is voluntary. Your child will not be penalized or lose any benefits that he/she are otherwise entitled to if you decide that your child will not participate in this research project.

If your child decides to participate in this project, he/she may discontinue participation at any time without penalty or loss of benefits. You have the right to inspect any instrument or materials related to the proposal. Your request will be honored within a reasonable period after the request is received.

VI. Payment for Participation
Students will not be paid for their participation. There is no financial obligation for participants.

VII. Confidentiality
The documents collected for this research study from the student will be the pretest scores and the posttest scores. Your child’s name will not be associated with your child’s responses and will be identified only by an assigned coded number. Demographic information including whether your child is enrolled as a gifted student or not, your child’s gender, and your child’s free or reduced lunch status will be collected from relevant teacher portal during the study and will be included in the study using coded number, taking care that the data will be without any identifying information. At no time will your child’s name be associated with the results of the research. At the end of the research, results obtained from the analysis of data will be published without any identifying information of your child.

Your child’s test scores and demographic information will be stored in a locked drawer in Dr. Hall’s office at Mercer University for three years after the study ends. Only the investigator, Mr. Manuel, and advisor, Dr. Hall will have access to the data. The list connecting participant numbers and names will also be kept in separate locked cabinets. The collected data will only be used for research purposes by Mercer University School.

08/19/2010
Questions about the Research
If you have any questions about the research, please speak with Mr. Manuel or Dr. Hall. If you have questions later, you may contact Jeffrey Hall, Ed.D., (678)547-6520, Email: hall@jsg.mercer.edu.

You have been given the opportunity to ask questions and these have been answered to your satisfaction. If you do agree to allow your child to participate in this research, please complete the information below:

1. __________________________________________________________________________ do want __________________________________________________________________________ to participate in this research study.

Participant's Name (Print) ______________ Date ______________

Parent Guardian's Name ______________ Parent Guardian's Signature ______________ Date ______________

Please return to Mr. Manuel as soon as possible.

In order to conduct this research, this project has been reviewed and approved by Mercer University’s Institutional Review Board (IRB). If you believe there is any infringement upon your child’s rights as a research subject, please contact the IRB Chair at (478) 301-1101. The IRBs are the governing bodies that are set in place to ensure responsible and safe conduct of research investigations.
APPENDIX D

CALENDAR OF SRS INTERVENTIONS
Table D1

*Calendar of SRS Interventions*

<table>
<thead>
<tr>
<th>Day</th>
<th>Experiment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pretest</td>
<td>Pretest</td>
</tr>
<tr>
<td>2</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
</tr>
<tr>
<td>3</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
</tr>
<tr>
<td>4</td>
<td>Quiz using SRS</td>
<td>Quiz without using SRS</td>
</tr>
<tr>
<td>5</td>
<td>Class Activities using SRS.</td>
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</tr>
<tr>
<td>6</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
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<tr>
<td>7</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
</tr>
<tr>
<td>8</td>
<td>Class Activities using SRS.</td>
<td>Class Activities without using SRS.</td>
</tr>
<tr>
<td>9</td>
<td>Warm Up using SRS</td>
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</tr>
<tr>
<td>10</td>
<td>No Activities involving SRS.</td>
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</tr>
<tr>
<td>11</td>
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</tr>
<tr>
<td>12</td>
<td>Class Activities using SRS.</td>
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</tr>
<tr>
<td>13</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
</tr>
<tr>
<td>14</td>
<td>Quiz using SRS</td>
<td>Quiz without using SRS</td>
</tr>
<tr>
<td>15</td>
<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
</tr>
<tr>
<td>16</td>
<td>Unit 1 Test - Used SRS without any feedback.</td>
<td>Unit 1 Test - Used SRS without any feedback.</td>
</tr>
<tr>
<td>17</td>
<td>Class Activities using SRS.</td>
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</tr>
<tr>
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<td>Warm Up without using SRS.</td>
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<tr>
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<td>Class Activities using SRS.</td>
<td>Class Activities without using SRS.</td>
</tr>
<tr>
<td>21</td>
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</tr>
<tr>
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<td>Warm Up using SRS</td>
<td>Warm Up without using SRS.</td>
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<tr>
<td>23</td>
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</tr>
<tr>
<td>24</td>
<td>Class Activities using SRS.</td>
<td>Class Activities without using SRS.</td>
</tr>
<tr>
<td>Day</td>
<td>Experiment Group</td>
<td>Control Group</td>
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<tr>
<td>-----</td>
<td>---------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>25</td>
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<td>Warm Up without using SRS.</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>Warm Up without using SRS.</td>
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Table D1 – continued

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<tr>
<td>54</td>
<td>Unit 2 Test - Used SRS without any</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>55</td>
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Table D1 – continued

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<th>Day</th>
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</thead>
<tbody>
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</tr>
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<td>78</td>
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<td>79</td>
<td>Unit 3 Test - Used SRS without any feedback</td>
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</tr>
<tr>
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<tr>
<td>82</td>
<td>Posttest</td>
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<tr>
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<td>No Activities involving SRS.</td>
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Summary of SRS use

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<tr>
<th>Did not use SRS for 11 Days</th>
<th>Did not use SRS for 80 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used SRS for 72 Days</td>
<td>Used SRS for 3 Days</td>
</tr>
</tbody>
</table>
APPENDIX E

A COMPARISON OF STUDIES INVESTIGATING SRS EFFECTS
Table E1

_A Comparison of Studies Investigating the Effects of SRS_

<table>
<thead>
<tr>
<th>#</th>
<th>Investigator(s)</th>
<th>Study (Research methodology)</th>
<th>Effect of SRS</th>
<th>Disadvantages / Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Randolph, J. J. (2007)</td>
<td>Meta-analysis of the research on response cards (meta-analysis) [K-12, university] {English, history, mathematics, psychology, natural science, social science}</td>
<td>Positive</td>
<td>Disadvantages: Waste of instructional time, students’ non-cooperation, and messiness in handling the write-on cards. Recommended educators to use response systems because of the alluring test achievements, student participation, and less-off task behaviors of students, as illustrated in the meta-analysis.</td>
</tr>
<tr>
<td>2</td>
<td>Blood, E., &amp; Neel, R. (2008)</td>
<td>Using student response systems in lecture-based instruction: Does it change student engagement and learning? (Quantitative) [Graduate level] {Special Education}</td>
<td>Positive</td>
<td>Increase in the posttest scores Significant difference in engagement and achievement scores. Recommendations: The learners who used SRS developed more confidence in their learning process. There were students who did not benefit from the use of SRS.</td>
</tr>
<tr>
<td>3</td>
<td>Christopherson, K. M. (2011)</td>
<td>Hardware or Wetware: What are the possible interactions of pedagogy and technology in the classroom? (Mixed method) [College Freshmen] {Developmental Psychology}</td>
<td>No Effect</td>
<td>Merely using SRS in the classrooms did not have any effect on students’ learning outcomes. Recommendations: SRS could address students’ misunderstanding of the concepts, to engage passive learners, and to provide real-time feedback to student responses. The success and the effectiveness of SRS would depend on the effectiveness of the design used to collect student response and provide feedback.</td>
</tr>
</tbody>
</table>
Table E1 - continued

<table>
<thead>
<tr>
<th>#</th>
<th>Investigator(s) (Year)</th>
<th>Study (Research methodology) [Grade level] {Content Area}</th>
<th>Effect of SRS</th>
<th>Disadvantages / Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Jones, M.E., Antonenko, P. D., &amp; Greenwood, C. M. (2012)</td>
<td>The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer (Quantitative) [Undergraduate] {Natural Science}</td>
<td>Positive</td>
<td>Recommendations: Have further investigation on the impacts of SRS in educational achievements, including developing measures to assess learning outcomes using SRS. Further research is necessary to identify the proper integration of SRS into other content areas.</td>
</tr>
<tr>
<td>5</td>
<td>Liu, F. C., Gettig, J.P., &amp; Fjortoft, N. (2010)</td>
<td>Impact of a student response system on short- and long-term learning in a drug literature evaluation course (Quantitative) [University] {Pharmacy}</td>
<td>Positive (short term)</td>
<td>No effect (long term)</td>
</tr>
<tr>
<td>6</td>
<td>Dunham, V. K. (2011)</td>
<td>The impact of a student response system on academic performance (Quantitative) [Grade 7] {mathematics}</td>
<td>No effect</td>
<td>Recommendation: Use of SRS increased student engagement and motivation. (There were limitations to the study including sampling issues, participation criteria of the students, unfamiliarity of the teachers to use SRS, and other implementation problems)</td>
</tr>
<tr>
<td>7</td>
<td>Abode, I. A. (2010)</td>
<td>The impact of student response system on third graders' learning, motivation, and engagement (Mixed method) [Grade 3] {mathematics}</td>
<td>No effect (Quantitative)</td>
<td>Positive (Qualitative)</td>
</tr>
</tbody>
</table>
Table E1- continued

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<td>10</td>
<td>Edens, K. M. (2006)</td>
<td>The interaction of pedagogical approach, gender, self-regulation, and goal orientation using student response system technology (Mixed method) [Undergraduate] {educational psychology}</td>
<td>No effect (Quantitative)</td>
<td>Positive (Qualitative)</td>
</tr>
<tr>
<td>11</td>
<td>Matus, J., Summa, K., &amp; Kuschke, R. (2011)</td>
<td>An analysis of technology-enhanced pedagogy and learning: Student response systems (clickers) - tool or toy? (Quantitative) [Graduate] {business}</td>
<td>No effect</td>
<td>Limitations: Small sample size, Lesser duration of the study, the exam used to determine the academic achievement, and the investigator bias would have influenced the results of the investigation. Recommendations: Further investigations into the determination of the effects of different pedagogical strategies on academic achievement.</td>
</tr>
<tr>
<td>12</td>
<td>Penual, W. R., Boscardin C. K., Masyn, K., &amp; Crawford, V. M. (2007)</td>
<td>Teaching with student response systems in elementary and secondary education settings: A survey study (Qualitative) [K-12 teachers] {all K-12 topics}</td>
<td>No effect</td>
<td>Recommendations: Frequent and continuous use of SRS would undoubtedly enhance learning outcomes. Further research would enable the educational system to reap the benefits of SRS in the near future, as SRS would become more structured and viable to use in K-12 environment.</td>
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</tbody>
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