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DAILY METACOGNITIVE QUESTIONING SHEETS:  
IMPLEMENTING METACOGNITIVE STRATEGIES IN THE SECONDARY CLASSROOM

A Dissertation  
presented in partial fulfillment of requirements  
for the degree of Doctor of Education  
in the Department of Teacher Education  
The University of Mississippi

by

Shawna S. Hill-Robinson

May 2019

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## ABSTRACT

This study investigated the possible impact that incorporating daily metacognitive questioning in a mathematics classroom could have on student achievement. The study integrated metacognition into the classroom through the daily use of metacognitive questioning sheets that were answered by students who participated in the research study. The study also explored patterns that emerged from the students' individual responses on the metacognitive sheets using qualitative coding and analyses. Two classes of heterogeneously grouped high school dual-credit college algebra students were taught the same curriculum by the same teacher and given the same summative assessments during the study. One class received the metacognitive questioning sheets daily for two units, and one class received the questioning sheets for only one unit. The results indicated that there was a statistically significant difference between the two classes on one of the summative assessments at the conclusion of the study. Analyzing the individual students' metacognitive sheets revealed common patterns among the students such as self-assessing during learning, self-confidence in their learning, and transparency about their misunderstandings and lack of knowledge. While there may not have been a significant difference among the students' scores in each of the two classes using an ANOVA and paired samples t-tests, there was still evidence that students' thinking and clearly describing where they were in their own learning had a positive impact on their achievement.

## DEDICATION

To my mom and dad, Clinton and Rebecca Hill, who have always supported me, loved me, and told me that I could do anything that I set my mind to do. To my fiancé, Robert Dobbs, who, every time I made the decision to do just “one more thing,” always supported me and encouraged me through everything. I would also like to thank my “girl gang” – AM, KY, AC, TA, and SW – for helping me when I needed to talk – or just needed to have chocolate and coffee. I also would like to give thanks to my pastor, Dr. Roger McGrew, for checking on me every Sunday morning - “I can do all things through Christ who strengthens me.”

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I also would like to thank Dr. Renee Cunningham and Dr. Amy Wells-Dolan for your willingness to teach a class and to provide me with individualized, constructive feedback. You taught me to be a more observant, reflective, and organized graduate student and teacher.

I am not the same educator graduating from the program as I was enrolling almost three years ago. I sincerely understand what becoming a life-long learner means. I know how to choose what is best for my students at the right moment, and I know how to look at the ever-changing educational and technological trends with a more critical eye. Thank you all.

## TABLE OF CONTENTS

ABSTRACT.....	ii
DEDICATION.....	iii
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	ix
LIST OF FIGURES.....	xi
CHAPTER I: INTRODUCTION.....	1
Statement of the Problem.....	2
Purpose of the Study.....	2
Significance of the Study.....	3
Research Questions and Null Hypotheses.....	4
CHAPTER II: REVIEW OF RELATED LITERATURE.....	5
Terminology.....	5
What is metacognition?.....	6
Is metacognition shown to improve student learning?.....	8
How can teachers help students grow more metacognitive?.....	11
How does metacognitive learning affect the brain?.....	13
CHAPTER III: METHODOLOGY.....	15
Purpose of the Study.....	15
Research Questions and Null Hypotheses Reiterated.....	15
Population and Sampling.....	16
Instrumentation.....	18
Procedure and Time Frame.....	19

Analysis Plan.....	20
Validity and Reliability.....	22
Scope and Limitations.....	23
CHAPTER IV: RESULTS.....	25
Descriptive Statistics.....	25
Question 1 Results.....	31
Question 2 Results.....	33
Question 3 Results.....	35
CHAPTER V: DISCUSSION.....	42
Summary of Results.....	42
Conclusions and Connections to the Literature.....	44
Test Two.....	44
Test Three.....	46
Qualitative Data Correlating to Test Two and Test Three.....	49
ANOVA and Paired Samples T-Test Results.....	65
Conclusions on the Qualitative Data.....	68
Limitations.....	71
Recommendations for Future Research.....	74
CHAPTER VI: INFORMAL ADDENDUM.....	78
Purpose and Research Questions.....	78



Methodology.....	80
Results.....	83
Question 1.....	83
Question 2.....	88
Question 3.....	92
Discussion.....	94
Question 1.....	95
Question 2.....	98
Question 3.....	102
Scope and Limitations.....	105
Future Research.....	108
REFERENCES.....	111
LIST OF APPENDICES.....	118
APPENDIX A.....	119
APPENDIX B.....	121
APPENDIX C.....	123
APPENDIX D.....	131
APPENDIX E.....	147
APPENDIX F.....	161
APPENDIX G.....	162
APPENDIX H.....	163

APPENDIX I.....	172
APPENDIX J.....	184
APPENDIX K.....	185
VITA.....	188

## LIST OF TABLES

Table 1 Participant Demographics.....	18, 26
Table 2 Independent Samples Test Results for Test #1.....	28
Table 3 Group Descriptives for Test #2.....	29
Table 4 Group Descriptives for Test #3.....	30
Table 5 Statistics for Spring 2018.....	31, 65
Table 6 One-Way Repeated Measure ANOVA for Spring 2018's Test Scores.....	31
Table 7 Statistics for Fall 2018.....	32, 67
Table 8 Fall 2018's Paired Samples T-Test Results for Tests 2 & 3.....	32
Table 9 Fall 2018's Paired Samples T-Test Results for Tests 1 & 3.....	33
Table 10 Independent Samples T-Test Results for Test #2.....	34
Table 11 Independent Samples T-Test Results for Test #3.....	34
Table 12 Qualitative Codes and Descriptions.....	36
Table 13 Most Common Reoccurring Patterns and their Frequencies for Test 3.....	37, 50
Table 14 Additional Common Reoccurring Patterns and their Frequencies for Test 3.....	38, 50
Table 15 Spring 2018 Self-Assessment / Self-Confidence/Transparency Excerpts & Gains (+), Losses (-), or No Changes (0) .....	39
Table 16 Fall 2018 Self-Assessment / Self-Confidence/Transparency Excerpts & Gains (+) or Losses (-).....	41
Table 17 Patterns That Emerged for Fall 2018, Test 3.....	51
Table 18 Patterns and Score Changes for Tests Two and Three, Spring 2018.....	56

Table 19 Patterns and Score Changes for Tests Two and Three, Spring 2018..... 65

Table 20 Sample Student Self-Assessment & Transparency Codes..... 82

Table 21 Sample Written Feedback Provided by Teacher..... 82

## LIST OF FIGURES

Figure 1 Histogram of Spring 2018’s Scores, Test Two.....	26
Figure 2 Histogram of Spring 2018’s Scores, Test Three.....	27
Figure 3 Histogram of Fall 2018’s Scores, Test Two.....	27
Figure 4 Histogram of Fall 2018’s Scores, Test Three.....	28
Figure 5 Box and Whisker Plot for Spring 2018, Test #2.....	29, 44
Figure 6 Box and Whisker Plot for Fall 2018, Test #2.....	29, 45
Figure 7 Box and Whicker Plot for Spring 2018, Test #3.....	30, 47
Figure 8 Box and Whisker Plot for Fall 2018, Test #3.....	31, 47
Figure 9 Scatter Plot with Regression Line for Spring 2018, Test #2.....	68
Figure 10 Scatter Plot with Regression Line for Spring 2018, Test #3.....	69
Figure 11 Scatter Plot with Regression Line for Fall 2018, Test #3.....	70
Figure 12 Excerpt Totals for Both Units – Group 1.....	84, 98
Figure 13 Individual Self-Assessment Excerpts – Group 1.....	85
Figure 14 Individual Transparency Excerpts – Group 1.....	86
Figure 15 Individual Self-Assessment & Transparency Totals – Group 1.....	87
Figure 16 Excerpt Totals for Both Units – Group 2.....	88, 98
Figure 17 Individual Self-Assessment Excerpts – Group 2.....	89
Figure 18 Individual Transparency Excerpts – Group 2.....	90
Figure 19 Individual Self-Assessment & Transparency Totals – Group 2.....	91
Figure 20 Group 1 – Number of Metacognitive Sheets Answered.....	92
Figure 21 Group 2 – Number of Metacognitive Sheets Answered.....	93

## **CHAPTER I**

### **Introduction**

The most powerful learners are those who are reflective, who engage in metacognition, and who take control of their own learning (White and Frederiksen, 1998). Students do not always have the knowledge of or an understanding about where they are in their own learning. Teachers can help students develop the ability to think about what they know and understand, to be aware of factors that affect their intellectual performance, and to monitor and adjust their performance on tasks (Wilson & Conyers, 2016). Students need guidance on how to become more aware of where they are in their current understanding and how to redirect themselves when their comprehension has gone wrong. The National Research Council wrote that having students practice self-reflection has been shown to be a powerful strategy to increase both understanding and motivation in the classroom (Bransford et al., 2000).

Many important strategies that support a student's self-questioning and self-assessing are studied under the heading of "metacognition," which is vital in the learning process (Flavell, 1979). Metacognition is purposefully thinking about one's own thinking strategies and knowing how to learn (Kolencik & Hillwig, 2011). Metacognitive ability is central to conceptions of what it means to be educated in this constantly-changing world (Martinez, 2006). When students purposefully think about the mathematics they are exploring, they are better able to set mathematical goals for themselves and take ownership of their education (Boaler, 2016). Teaching students to self-question and self-assess throughout their lessons provides equal

opportunities for them to understand where they were, where they are now, and how they are going to continue to improve. Self-questioning encourages metacognition and reinforces learning for students (Hattie et al., 2017).

### **Statement of the Problem**

Students are not provided enough opportunities to engage in self-assessment and to reflect on their own work and their misconceptions (Wilson & Kenney, 2003). A major failing in some mathematics classes is that students rarely have an idea of what they are learning or where they are in the broader landscape of mathematics; they focus on methods to remember and not what the mathematical concepts truly are (Boaler, 2016). Memorizing without understanding hinders students from deep learning and transferring math concepts to other situations. Students need to be provided opportunities to evaluate what they learn during mathematics lessons from day to day, week to week, and month to month (Hattie et al., 2017; Martinez, 2006). Students lack the metacognitive awareness of what concepts they actually know and understand; they usually think they comprehend concepts better than they truly do (Terada, 2017). Knowing about one's own tendency to commit easy errors may lead to increased self-regulatory activities in test situations (Schneider & Artelt, 2010). It is important for students to accurately monitor their knowledge while reading, studying, or completing tasks to efficiently regulate their study or learning choices (Callender, Franco-Watkins, & Roberts, 2016).

### **Purpose of the Study**

It was the intent of this study to add to the current knowledge regarding metacognition in the classroom and to investigate the possible impact that incorporating daily metacognitive questioning in the mathematics classroom could have on student achievement. Metacognition helps students recognize the gap between being familiar with a topic and understanding it deeply.

Research shows that students can be taught to monitor the efficacy of strategies they practice in the classroom and use that information gained from monitoring in making future strategy selections (Schneider & Artelt, 2010). The key to metacognition is to encourage students to manage their own learning instead of passively absorbing the material (Terada, 2017). Because metacognition is the monitoring and control of thought and research shows that metacognitive ability can be taught, students can learn to coach themselves to stay on track and to not give up when learning new concepts. (Martinez, 2006). By adding metacognitive approaches to instruction, it was proposed that students would take control of their own learning by realizing where they were in their understanding and monitor their progress throughout their learning. By answering metacognitive questions daily, it was suggested that students' test scores would improve. Strategies that target students' metacognition can close a gap that some students experience between how prepared they feel for a test and how prepared they actually are (Terada, 2017). It was also suggested that there would be a connection between test scores and students' responses to the metacognitive questions that were provided.

### **Significance of the Study**

The research was important to education because metacognitive strategies can help students reflect, analyze, and clarify for themselves what they know and understand in the mathematics classroom. "Because metacognition is required in demanding situations, it entails the management of emotions that often accompany difficulty, uncertainty, and the possibility of mistakes and failure," (Martinez, 2006, p. 699). Metacognition helps students learn to take personal responsibility in accomplishing goals that they set for themselves, which is important both inside and outside of the classroom. This research benefits education by showing teachers that creating and using metacognitive questions daily in the math classroom can help develop



mathematically literate students who can evaluate and adjust their own thinking and reasoning. Successful teachers regularly incorporate metacognitive information about effective modification as a part of daily instruction (Pressley, 2002). Metacognition is important for the analysis and understanding of mathematical performance (Schneider & Artelt, 2010). Helping students to observe and to monitor their own thinking allows them to develop mathematical proficiency and helps them to change their strategies and routines based on what best leads them to be more successful (Pressley, 2002).

### **Research Questions and Null Hypotheses**

The study responded to the following research questions:

1. Will providing students with metacognitive questions daily impact their achievement as measured by test scores?

$H_0$ : There will be no statistically significant difference on students' achievement as measured by test scores when provided with metacognitive questions daily.

2. Will providing one group of students with the metacognitive questions during two units impact their achievement as measured by test scores when compared to another group of students who receive the questions during one unit?

$H_0$ : There will be no statistically significant difference on students' achievement as measured by test scores after comparing the group of students who receive the metacognitive questions during two units to the group of students who receive the questions during one unit.

3. Will patterns emerge when comparing the students' responses to the metacognitive questions and their test score

## CHAPTER II

### Review of Related Literature

#### Terminology

1. Metacognition – A person’s knowledge about the cognitive processes necessary for understanding and learning; purposefully thinking about one’s own thinking and learning.
2. Self-assessment – Students’ abilities to evaluate their own work and learning progress; identify their skill gaps, know where their knowledge is weak, set realistic goals, revise their work, reflect on their progress and plan to improve.
3. Semester block schedule – A class period that meets for ninety minutes a day, five days a week for one semester.
4. Dual-Credit College Algebra – A math course for which students receive three hours college credit and one high school credit upon completing the course with a ‘C’ or higher.
5. Daily Metacognitive Questioning Sheets – Questioning sheets that have learning intentions and success criteria listed at the top and that are divided into three sections – pre-lesson, during-lesson, and post-lesson – with different metacognitive questions each day for the students to self-assess their learning.
6. Summative Assessments – Four college algebra assessments that have been verified to test the math concepts that should be measured and to have equal levels of difficulty.
7. Satellite School – A smaller campus that is a part of the local school district and is physically located at a distance from the home campuses within the district. The satellite school offers courses that are not taught on the other home campuses.

## **What is metacognition?**

Metacognition involves the monitoring and control of attitudes, such as students' beliefs about themselves, the value of persistence, the nature of works, and their personal responsibility in accomplishing a goal (Fusco & Fountain, 1992). Metacognition involves the beliefs and attitudes that influence the usage and the development of cognitive and metacognitive abilities (Vula et al., 2017). Metacognition is a person's knowledge about the cognitive processes necessary for understanding and learning (Flavell, 1976). Since developmental psychologist John Flavell first applied the term "metacognition" to the management of information-processing activities that occur during cognitive transactions, much has been written about the importance of thinking about, planning for, and controlling of one's own thinking (Wilson & Conyers, 2016; Girash, 2014). "Metacognitive knowledge is that segment of [a person's] stored world knowledge that has to do with people as cognitive creatures and with their diverse cognitive tasks, goals, actions, and experiences," (Flavell, 1979, p. 906). Metacognition consists of knowledge or beliefs about what learning experiences affect the course and outcome of cognitive operations – an understanding of what such variables imply for how the cognitive experience should best be managed and how successful a person is likely to be in achieving his or her goals (1979). Metacognition involves students' awareness of the process they need to successfully complete a task and their ability to determine if the task is being completed correctly and make corrections as appropriate (Kolencik & Hillwig, 2011). Metacognition refers to people's knowledge of their own information-processing skills and of strategies for coping with tasks; it also includes skills related to monitoring and self-regulating of one's learning (Schneider & Artelt, 2010). Metacognition is the key to becoming an effective self-directed, self-regulated, or

life-long learner (Ambrose & Lovett, 2014). Metacognition can be seen as evaluation turned inward, especially turned toward our own ideas (Martinez, 2006).

Metacognitive regulation is a strategic control process of one's own cognitive activities, which ensures that such a goal has been met (Apaydin & Hossary, 2017). A student who is metacognitive knows how to learn because he or she is aware of what he or she knows and what he or she must do in order to gain new knowledge (Wilson & Bai, 2010). If a student begins to work through a math problem, realizes that the problem is more complex than first thought, makes a conscious decision to begin again and monitors how his or her learning is progressing, he or she is demonstrating self-regulation, or metacognition (Schoenfeld, 1992). Metacognitive practices help students become aware of their strengths and weaknesses and help them to learn how to self-regulate and adjust (Bransford et al., 2000). "Metacognition is what prevents students from going on wild goose chases, pursuing dead-end ideas come hell or high water," (Ray, 2013, p. 156). Metacognition can also be thought of as metacognitive regulation, or critically thinking about one's own thinking (Girash, 2014).

Metacognitive skills include taking conscious control of learning, correcting errors, analyzing the effectiveness of learning strategies, and changing learning behaviors and strategies when necessary, (Ridley et al., 1992). Metacognition includes the ability to know when and why to apply different strategies to study or solve different types of problems. Metacognition is *purposefully* thinking about one's own thinking strategies and knowing how to learn (Kolencik & Hillwig, 2011). Student self-reflection and metacognition are essential to learning. Writing increases opportunities for students to think about their thinking (Hattie et al., 2017). Monitoring one's progress to test whether one can pinpoint and retain important concepts provides a check that comprehension is progressing smoothly; self-directed questioning leads students to actively

monitor their own comprehension (Palinscar & Brown, 1984). Students who are engaged in high-quality metacognition can answer questions like “What am I doing?” “Why am I doing this?” and “How will this help me?” throughout their problem solving (Ray, 2013).

### **Is metacognition shown to improve student learning?**

Metacognition is essential for effective learning in complex situations (Lovett, 2013). A metacognitive approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them (Bransford et al., 2000). Students can be taught the ability to predict outcomes, to self-explain, to note failures, to activate background knowledge, and to make plans to improve (2000). This kind of work demands that students recognize what they know, identify what they still need to learn, and monitor and adjust their learning along their learning curve (Ambrose & Lovett, 2014).

Metacognition involves being knowledgeable about and in control of one’s cognitive abilities; it includes knowledge about oneself as a learner and the factors that might impact the learner’s performance (Wilson & Conyers, 2016). As students get used to persevering in class, they begin the process of their own internal problem-solving conscience; they monitor their progress, check for understanding, and weigh their options (Ray, 2013). The most powerful learners are those who are reflective, who engage in metacognition, and who take control of their own learning (Boaler, 2016). When students think about the mathematics they are learning, they are better able to set mathematical goals and take ownership of their learning (2016). Research shows that metacognitive strategies and self-regulating processes that learners use to control their actions to reason and to reflect are two main resources that influence their successes in mathematics (Vula et al., 2017). Metacognition often takes the form of an internal conversation; however, students may not develop that internal dialogue on their own. Most students are unaware of or fail to

know how to self-assess. “However, it is the case that such [self-assessing] skills can be learned as a result of explicit instruction that focuses on metacognitive aspects of mathematical thinking,” (Schoenfeld, 1992, p. 63).

When students understand that they need to make changes to reach a certain goal in the classroom, they are undoubtedly informed and guided by their metacognitive knowledge, which can lead students to establish new goals and revise or abandon old ones (Flavell, 1979). Metacognition demands that students recognize what they already know to be relevant, identify what they still need to learn, plan an approach to learn that material independently, and monitor and adjust their approaches along the way (Ambrose & Lovett, 2014). Metacognition is essential for effective learning in complex situations; teaching metacognitive skills to students can improve their learning (Lovett, 2008). Students can write answers to self-assessment questions in math class, which help reveal gaps in their knowledge; this writing process strengthens students’ abilities to be self-regulators and to develop metacognition (Martin et al., 2017). Writing tasks that require metacognitive reflection contributes to students’ mathematical learning (2017). Students’ metacognition can be facilitated by an environment in which questions and assignments require reflection, analysis, and mathematical knowledge; the opportunity to engage in reflective writing facilitates the development of metacognition (Garofalo & Lester, 1985).

Similarity and consistency are the keys to teaching students how to be metacognitive. Metacognition helps close the gap between high achievers and struggling students when the latter are guided on how to develop a metacognitive approach to learning (Wilson & Conyers, 2016). By being purposeful, regular, and deliberate about the types of metacognitive strategies that are a part of the classroom, students will learn how to self-assess and monitor their own learning; they will develop the skills necessary to know what to do when they don’t know what

to do (Bransford et al., 2000). Metacognition is about having the *will* to think effectively and the *skill* of being able to think about one's thinking with the goal of steadily improving learning (Wilson & Conyers, 2016).

Adding metacognitive approaches to instruction can help students learn to take control of their own learning (Bransford et al., 2000). These metacognitive approaches have been shown to increase the degree to which students will transfer to new situations without the need for explicit prompting (2000). Palinscar and Brown (1984) wrote that metacognitive awareness involves knowing about our learning selves, understanding what tasks demand and strategies to complete them, and monitoring learning and self-regulation. Children can learn things that they are not predisposed to attend to, and they come to be able to learn almost anything through sheer effort and will; metacognition is an important aspect of children's learning (Bransford et al., 2000). When students aren't provided many metacognitive opportunities to make their own learning decisions and discuss reasons why certain strategies were or were not helpful, they struggle to re-create independently what they experienced (Ray, 2013). Metacognition is particularly important in the classroom as knowledge about one's own learning affects future study choices and learning (Callender, Franco-Watkins, Roberts, 2016). Self-reflection develops metacognitive skills as students evaluate their own thinking (Martin et al., 2017). Metacognition develops gradually and is dependent on knowledge as experience and on topics that children know, and with some effort, they can learn to build on and strengthen their understanding of what it means to learn and remember. Having students practice self-reflection on their own levels of understanding as they relate to a target has been shown to be a powerful strategy to increase both understanding and motivation (Bransford et al., 2000). Becoming more

metacognitive helps learners of all ages – children, teenagers, adults – proactively determine what they know and what they need to know in order to succeed (Wilson & Conyers, 2016).

Schoenfeld (1987) said that metacognition has the potential to increase the meaningfulness of students' classroom learning, and the creation of a "mathematics culture" best fosters metacognition. Schoenfeld also stated that the most important contribution of metacognition to the learning of mathematics can be seen in students' knowledge about their own thought processes and development of adequate monitoring and self-regulation activities (1987). Developing self-regulatory skills with complex mathematics is difficult and often involves "behavior modification," unlearning inappropriate control behaviors developed through prior instruction; however, with persistent incorporation of metacognitive strategies, such modifications can be catalyzed (Schoenfeld, 1992).

### **How can teachers help students grow more metacognitive?**

The demands of the twenty-first century require students to know more than content knowledge; they must know how to learn, which is an active process that requires students to think about their thinking (Wilson & Bai, 2017). Accurately judging one's performance in the classroom can be challenging considering most students tend to be overconfident and overestimate their actual performance (Callender, Franco-Watkins, & Roberts, 2016). Teachers must have a pedagogical understanding of metacognition, which is the teachers' knowledge regarding effective instruction for helping students achieve a learning goal or becoming metacognitive (Wilson & Bai, 2017). Teachers need to encourage students to be metacognitive and deliberate about monitoring their learning and their interactions with others by considering questions about how their learning is going, what they have learned so far, how their learning connects to what they already know, and how they can explain what they know to other students



(Wilson & Conyers, 2016). Students need guidance in how to grow more metacognitive; students need to learn the art of self-questioning and self-reflection (Hattie et al., 2017). Students need to be familiar with metacognitive strategies and how to implement them. If a student reads something confusing and simply keeps going despite not understanding, he or she is not being metacognitive; if the student stops, questions and rereads, he or she is applying metacognition (Wilson & Bai, 2017). Successful metacognition entails students' making accurate judgements of their performance; it is important for students to learn to accurately monitor their knowledge while learning to efficiently regulate their choices (Callender, Franco-Watkins, & Roberts, 2016).

Teachers' understanding of what is necessary for instruction and learning has a strong impact on their pedagogy. Metacognition is not just a skill to be taught, but a disposition of what it means to think and learn (Harpaz, 2007). Metacognition requires that the teacher provide guidance to help the student become metacognitive and allow them to share their own thinking processes (Wilson & Bai, 2016). Teachers play a crucial role as multipliers in supporting their students' self-regulation of learning, and teachers can modify their instructional practices by employing strategies to draw students' attention to learning processes with more self-regulated learning practices (Dignath & Büttner, 2018). If teachers can scaffold metacognitive strategies through modeling, guidance, and reflective feedback, students can learn to self-regulate their learning (2018).

Teachers can create continuous opportunities for students to practice metacognitive skills and provide feedback, so students can refine their skills (Ambrose & Lovett, 2014). Effective teachers regularly incorporate metacognition information on effective strategies as part of their daily instruction; these strategies should not be infrequent but integrated into the curriculum and

taught routinely in mathematics (Schneider & Artelt, 2010). Students should know the meaning and importance of metacognition, and the development of the capacity for it should be an explicit goal for both teacher and student (Martinez, 2006). The goal must have credible and enduring presence in the established curriculum and in assessments (2006).

Writing offers an opportunity for students to “express their thinking, reflect on their learning, and engage in self-reflection strategies,” (Martin, Polly, & Kissel, 2017, p. 538). Writing in mathematics classes can foster metacognition. It takes time and modeling to develop writing practices in math classes, but the potential to become a metacognitive learning tool is present (Schneider & Artelt, 2010). The benefits of written reflections in mathematics are noted in the research surrounding metacognition, self-evaluation, and self-regulation strategies (NCTM, 2012). Writing supports the tenets of writing to learn, strengthening students’ abilities to be self-regulators, and developing metacognition (Martin, Polly, & Kissel, 2017). Writing tasks that require metacognitive reflection contribute to students’ mathematical learning (2017). Having students reflect on math problems that require a written account of the obtained solution supports those students in expressing their mathematical problem-solving processes and in verbalizing their mathematical thinking (van Velzen, 2016).

### **How does metacognitive learning affect the brain?**

When students use metacognitive strategies to improve academic performance, they are actually building brainpower (Wilson & Conyers, 2016). Much research has been conducted that proves that learning changes the structure and function of the brain. The addition of synapses in the brain operates throughout the entire human life span and is actually driven by experience (Bransford et al., 2000). The quality of information to which one is exposed and the amount of information one acquires is reflected throughout ones’ life in the structure of the brain; changes

in the brain structure underlie changes in the functional organization of the brain. Learning imposes new patterns of organization on the brain (2000). Teaching students to become more metacognitive about their academic and personal pursuits can help make the most of the brain's *neural plasticity*, or *brain plasticity*– the brain's capacity to change, to grow, and to become functionally smarter (Wilson & Conyers, 2016). Advances in the science of brain plasticity show that virtually all students can improve their academic performance when their schooling is characterized by effective teaching approaches, plentiful opportunities for practice and relearning when warranted, and explicit instruction on metacognitive strategies that allow them to become self-directed learners (2016).

With the emergence of new technologies, scientists can study children and adults completing all types of tasks and observe how the brain changes as the tasks are worked and completed. It used to be believed that the brains people were born with could not be changed, but this idea has now been resoundingly disproved; study after study has shown that the brain can change within a really short period of time (Boaler, 2016). Some examples that Jo Boaler mentions in *Mathematical Mindsets* include the following: Black Cab Taxi drivers who learn and know over 25,000 streets and 20,000 landmarks within a twenty-five mile radius, a nine-year-old girl, who had the left-half of her brain removed to stop debilitating seizures, showed that the right-half of her brain began recovering left-brain functions on its own, and mental health patients, given a special mental task performed daily over a three-week period, showed structural brain changes when compared to a group who didn't receive the special tasks (2016). Some students may not be ready for some mathematical concepts because they still need to learn foundational skills, but their brains can develop new connections when the students need them (2016).

## **CHAPTER III**

### **Methodology**

#### **Purpose of the Study**

The purpose of this research study was fourfold. The first purpose was to measure one group of college algebra students' test scores to determine if incorporating daily metacognitive questioning for two tests had an impact on their achievement as shown through the test scores. The second purpose was to measure a second group of college algebra students' test scores to determine if the daily questioning for one test had an impact on their achievement as measured through the test scores. The third purpose was to compare the two student groups' test scores to discover if the daily questioning had an impact on one groups' achievement over the other group. The fourth purpose of this study was to see if any patterns emerged when comparing the students' responses to the metacognitive questions and their test scores. Metacognition helps students recognize the gap between being familiar with a topic and understanding it deeply. If teachers want to help students succeed, they can provide students with guidance on how to become more aware of where they are in their learning and how to redirect themselves when their learning has gone the wrong way. Strategies that target students' metacognition can close a gap that some students experience between how prepared they feel for a test and how prepared they actually are (Terada, 2017).

#### **Research Questions and Null Hypotheses**

The study responded to the following research questions:

1. Will providing students with metacognitive questions daily impact their achievement as measured by test scores.

H<sub>0</sub> There will be no statistically significant difference on students' achievement as measured by test scores when provided with metacognitive questions daily.

2. Will providing one group of students with the metacognitive questions during two units impact their achievement as measured by test scores when compared to another group of students who receive the questions during one unit?

H<sub>0</sub>: There will be no statistically significant difference on students' achievement as measured by test scores after comparing the group of students who receive the metacognitive questions during two units to the group of students who receive the questions during one unit.

3. Will patterns emerge when comparing the students' responses to the metacognitive questions and their test scores?

### **Population and Sampling**

The population for this study was from a rural public-school district located in Northeast Mississippi. The school serves students in 9<sup>th</sup> through 12<sup>th</sup> grades. The county school district is made up of three pre-kindergarten through twelfth grade attendance centers, one satellite school for vocational education, and one satellite school for advanced courses. Because the school district is unable to offer additional and advanced course work on all three of the attendance center campuses, a school for advanced course work was created and opened during the 2006-2007 school year. According to the Mississippi Department of Education, the school district served 2,263 students during the 2017-2018 school year. 50.91% of the population was female, and 49.09% was male. The student population consisted of the following: 91.21% Caucasian,

7.42% African-American, < 1% two or more races, and < 1% other races (MCSD, 2017). After the 2016-2017 school year, the district had an 87.2% overall graduation rate, an 86.1% graduation rate for African American students, an 87.2% graduation rate for Caucasian students, a 76.2% graduation rate for economically disadvantaged students, and a 42.1% graduation rate for students with disabilities with a standard high school diploma (NCLB data, n.d.). 67% of the district receives free and reduced lunches.

The sample in this study were two heterogeneously grouped high school dual-credit college algebra classes. All students had to meet two minimum requirements; they were required to have a minimum overall ACT score of sixteen and a math sub score of nineteen to qualify. The school counselors on each individual campus enrolled students in the two classes; the teacher had no input on which students were placed in either of the two sections of college algebra.

In order to conclude if the two different classes were comparable, their test scores on the first college algebra test were used. Neither of the two classes received the daily metacognitive questions while preparing for the first test. It was determined by the teacher that utilizing the first test to determine comparable groups would yield fair results. An independent samples t-test was used to obtain group statistics for both classes. The t-test helped establish that the two groups of students were comparable.

One section received the daily metacognitive questions for two units, and one section received the daily metacognitive questions for one unit. Originally, the teacher wrote “1<sup>st</sup> block college algebra” and “2<sup>nd</sup> block college algebra” on two sticky notes, folded the notes, and placed the notes into a jar. The teacher’s principal drew one of the folded sticky notes from the jar. The class chosen by the principal received the daily questions for two units; the class left in

the jar received the daily questions for one unit. First block received the questions for two units, and second block received the questions for one unit. The title “1<sup>st</sup> block college algebra” was replaced with “Spring 2018 College Algebra.” The class “2<sup>nd</sup> Block College Algebra” was replaced with the new group of students and titled “Fall 2018 College Algebra.”

Table 1

*Participant Demographics*

Students' Information	Spring 2018 College Algebra	Fall 2018 College Algebra
Classified as Seniors	12	7
Classified as Juniors	33%	86%
Caucasian	67%	14%
African-American	83%	100%
Female	17%	0%
Male	83%	29%
	17%	71%

Only one teacher, who was also the researcher, participated in this study. With a bachelor’s degree in secondary English education and an add-on endorsement in secondary mathematics, the teacher/researcher has taught algebra for eighteen years. Since earning a master’s degree in Curriculum and Instruction with an emphasis in secondary mathematics and National Board Certification, she has recently become a doctoral candidate in Secondary Mathematics Education at The University of Mississippi.

**Instrumentation**

The instruments used in this research study were two different college algebra summative assessments and daily metacognitive questioning sheets. Each of the two summative assessments were administered after students took notes and completed lessons to prepare for them. There were two different versions of the assessments that were distributed to the students. The tests have been verified by two outside sources to be equivalent to one another (see Appendices B and C). The problems on the first test were modified with new values to create

the second test. The problems from both tests were created using the college algebra textbook assigned by the community college. The first assessment was comprised of fourteen questions, and the second assessment had thirty questions.

The metacognitive questioning sheets were distributed daily with new questions specific to the day's learning goals (see Appendix D). The questioning sheets listed the explicit learning intentions and success criteria for the lesson at the top. According to Hattie et al. (2017), when students know what their learning target is, there is an increased likelihood that the target will be achieved. The sheet was divided into three sections: pre-lesson, during-lesson, and post-lesson (see Appendix A). Each of the three sections had different metacognitive questions each day for students to answer. Metacognitive awareness is our ability to observe and monitor our own thinking, and students need guidance in how to become more metacognitively aware (Hattie et al., 2017). The questioning sheets were created to help students track their understanding and question themselves throughout each day's lesson.

### **Procedure and Time Frame**

The summative assessments were collected, scored, and recorded by the teacher researcher. The data was analyzed to see if there were statistically significant differences between the classes. The metacognitive questioning sheets were collected at the end of every class period by the researcher, who gave written feedback on each sheet. Copies of the students' sheets were made every day, and the teacher returned the original sheets with the handwritten feedback the next class period. The sheets were also analyzed and coded to see if any patterns emerged when comparing the students' responses to the metacognitive questions and their test scores. If a student was absent from school and missed a day's questions, the teacher gave the student a copy of the metacognitive sheet that he or she missed along with the last questioning



sheet(s) with teacher feedback that the student answered before the absence. The student and teacher had a mini-lesson to discuss the learning goals that the student missed and the returned questioning sheet(s) with teacher feedback. The student was allowed to write on the metacognitive sheet from the day he or she missed for additional feedback; this questioning sheet was not included in the coding this particular day. If a student was absent more than one day, a convenient time outside of class was used for tutoring. The student continued with the daily questioning sheets the next class period.

The research was conducted over four weeks during the spring semester of 2018 and two weeks during the following fall semester of 2018. The students were on a semester block schedule and met five days a week for ninety minutes every day. Spring students were provided the daily questioning sheets for four weeks. Fall students answered the questions for two weeks.

### **Analysis Plan**

A mixed methods research design was used for this study. According to Creswell (2003), a sequential explanatory mixed methods research design involves the collection and analysis of quantitative data followed by a collection and analysis of qualitative data in order to use qualitative results to assist in explaining and interpreting the findings of a quantitative study. A critical alpha level,  $p \leq .05$ , was set to determine statistical significance. To help determine the impact of the metacognitive questioning sheets on students' achievement within each class, a one-way repeated measure analysis of variance was used for the spring 2018 students, and two paired samples t-tests were used for the fall 2018 students. Each classes' scores from the tests were compared to conclude if the metacognitive sheets made a difference.

This study also investigated the possible effect that metacognitive questioning could have on student achievement. To investigate this possibility, an independent samples t-test was used.

Each classes' mean scores for two tests were compared to conclude if a statistically significant difference existed between the two different classes. Both classes took the first of the two tests, and the mean for each class was compared. After both classes took the second test, those mean scores were compared. The t-test was used to help determine if there were differences significant enough to say that the daily metacognitive questioning sheets had an impact.

The metacognitive questions were collected daily, and the teacher gave written feedback. All of the metacognitive sheets were photocopied and given to faculty members at the University of Mississippi to remove all identifiable information, such as names, side notes, and personal doodles, to reduce researcher bias. Coding the qualitative data helped reveal developing patterns between students' answers to the daily questions and their test scores. Dedoose, a web application for mixed-methods research, was used to help organize and analyze the qualitative data. The metacognitive sheets were photocopied, scanned, and uploaded into Dedoose. The teacher created an initial list of pre-set codes, added emergent codes as the qualitative analysis progressed, and wrote detailed descriptions for each code. The teacher read and coded all of the metacognitive sheets for each individual student in both classes. The spring students received the metacognitive sheets for both tests two and three, and the fall students received the daily sheets only for test three.

After the codes were created and all of the sheets were marked and matched to the codes, Dedoose produced co-occurrence and application charts of the codes. Matrices of co-occurrences and individual students' associated codes were created using the software to help detect any patterns among the various codes. The patterns that occurred the most frequently among the data are discussed in the following chapters. All of the students' responses to the metacognitive sheets were included in the qualitative analyses; all students agreed to allow the

researcher to use their responses in the study. Students chose to answer any of the metacognitive questions at any time or to not answer any of the questions. Because all of the students' identifying characteristics had been removed, the anonymity of the metacognitive sheets allowed the teacher to code them free from any unintentional bias.

### **Validity and Reliability**

The teacher administered five summative assessments throughout the college algebra course. All of the assessments, including those used during this research study, were evaluated by the head of the mathematics department from the local community college that sponsored the dual-credit course. The two assessments used for the study were modeled after the math department's practice tests that are released to students each semester. The department head verified that the two assessments were appropriate. The two tests in this study have been used to measure students' knowledge and understanding of certain mathematics concepts for six consecutive semesters. The problems that make-up the two tests are the same from one semester to another. After the students saw their assigned grades and feedback, the teacher collected and stored the tests in a secured room in the school building. Students are not allowed to keep their college algebra tests.

All of the data that was collected was analyzed; no test scores or daily questioning sheets were altered or manipulated in any way in an attempt to prove significance. All students in both classes were given the same two tests, and all students had an equal chance of receiving one of the two test versions. A math colleague in the teacher's district received a copy of all four assessments with answer keys and determined they were equal in difficulty. The teacher graded her own students' assessments. To help remove bias, several assessments were graded by a second math teacher and compared to the scores that were given by the teacher/researcher. The

teacher provided daily written feedback to the students on their metacognitive questioning sheets. This feedback might have influenced the students' reflections and analyses. Any influence was not the teacher's intention.

### **Scope and Limitations**

The study originally involved two consecutive classes from the same spring semester. As the study progressed, the researcher discovered that one class received answers on both tests that were used during that study from the other class. Because the sharing of answers could have had an impact on the research study's results, the teacher decided to collect additional data from another group of students during the following school year. The new research study involved two college algebra classes from two different, consecutive semesters. One class had twelve students, and one class had seven students. Both classes were comprised of students at the school for advanced course work in the district. All of the students in both of the classes chose to take the course after meeting the minimum qualifications required by the local community college who sponsored the dual-credit course. The study took place during the spring and fall semesters during two consecutive school years. Many events, assemblies, and state assessments took place during the spring semester; thus, students were frequently absent. Those who were received a short lesson on the missed math concepts. Students decided for themselves if they wanted to complete the metacognitive sheets for written feedback or not. From past experience, the teacher knew there would be frequent student absences during the spring.

While investigating the students' metacognitive sheets, the list of qualitative codes created by the researcher originally had a code entitled "Honesty." The researcher defined "Honesty" as "Students being open and truthfully clear with themselves or the teacher about being confused, having no or little prior knowledge or math concepts, or experiencing new learning for the first time." However, the researcher did not view students' writing positive comments

about their learning such as “I feel good about what I’m learning,” or “I’m comfortable with the success criteria and feel better,” as “Honesty”; the researcher coded these students’ comments as “Self-Confidence.” The teacher separated the students’ positive comments about their learning, understandings, and abilities on the metacognitive sheets, which she coded as “self-confidence,” from the students’ comments about their misconceptions, misunderstandings, etc. The researcher did not realize that the terms “Self-confidence” and “Honesty” could be misleading and also could be considered perceived as the same code in some cases. To better distinguish between students’ positive statements about their learning and students’ being truthful about what they did not know or understand, the researcher decided to change the code originally entitled “Honesty” to the term “Transparency.” By changing the code’s title, the researcher felt that the change would help distinguish the two types of students’ thinking that she was looking for among the students’ writings on the metacognitive sheets.

This research study involved a small number of students enrolled in two college algebra block classes during part of their respective semesters. The study generated limited data because it only involved one type of mathematics course and nineteen students. If the study were replicated over a longer period of time, two or more semesters if possible, the data collected could be analyzed to see what, if any, patterns emerged. If additional, longer studies consistently produced the same results, they could lend more credibility to daily metacognitive questioning practices in the mathematics classroom.

Due to the limited time frame, the researcher only used the students who were enrolled in college algebra at one school, which limited the amount of data collected. If the researcher had involved students and teachers from other school districts that also offered the same college algebra course sponsored by the same community college, that data could have been included. There would also be more data containing multiple students’ answers to the metacognitive questions and multiple teachers’ feedback that could have been included in this study.

## **CHAPTER IV**

### **Results**

#### **Descriptive Statistics**

This research study sought to determine if providing students with metacognitive questioning opportunities daily could impact their achievement as shown by test scores. This research study responded to the following three research questions:

1. Will providing students with metacognitive questions daily impact their achievement as measured by test scores?
2. Will providing one group of students with the metacognitive questions during two units impact their achievement as measured by test scores when compared to another group of students who receive the questions during one unit?
3. Will patterns emerge when comparing the students' responses to the metacognitive questions and their test scores?

The results of these analyses - both the quantitative and qualitative student data collected from the two different college algebra classes - are shown in the following discussions, tables, and figures.

This research study took place at a satellite school in a rural, public school system located in a northern county in the state of Mississippi. All nineteen students enrolled in the teacher/researcher's two college algebra sections participated in this study. For four weeks during one spring semester, a college algebra class participated in the research study investigating the possible impact daily metacognitive questioning had on the students'

achievement measured by their tests scores. For two weeks during the following fall semester, another college algebra class was a part of the same research study. The spring class answered the metacognitive sheets for four-weeks, and the fall class answered the sheets for two weeks. The student demographics' information, Table 1, is redisplayed from chapter three.

Table 1

<i>Participant Demographics</i>		
Students' Information	Spring 2018 College Algebra	Fall 2018 College Algebra
	12	7
Classified as Seniors	33%	86%
Classified as Juniors	67%	14%
Caucasian	83%	100%
African-American	17%	0%
Female	83%	29%
Male	17%	71%

The majority of spring's students, ten out of twelve, or 83%, scored between fifty and eighty on test two (see Figure 1). Comparing test two to test three (See Figure 2), the number of students scoring lower than sixty decreased by one student. More students, 41%, scored between sixty and sixty-nine, an increase of two students. The number of students scoring between seventy and seventy-nine decreased. The percentage of students scoring between eighty and eighty-nine more than doubled. There were no students, however, who scored between ninety and ninety-nine on test 3; this decreased when compared to test 2.

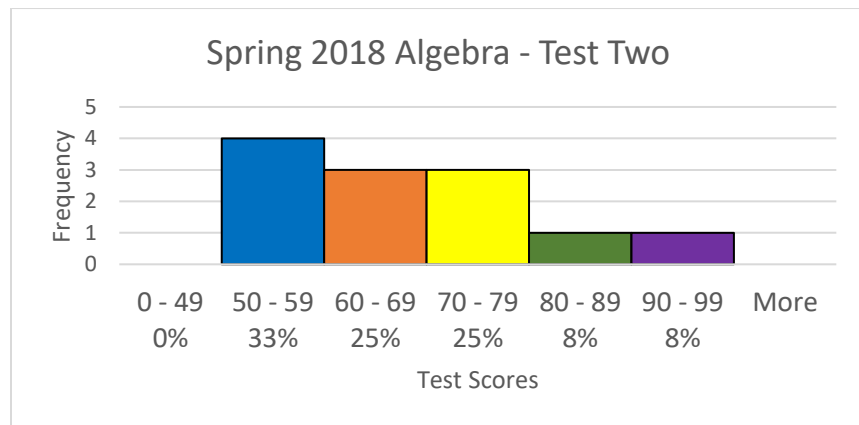


Figure 1. Histogram of Spring 2018's Scores, Test Two

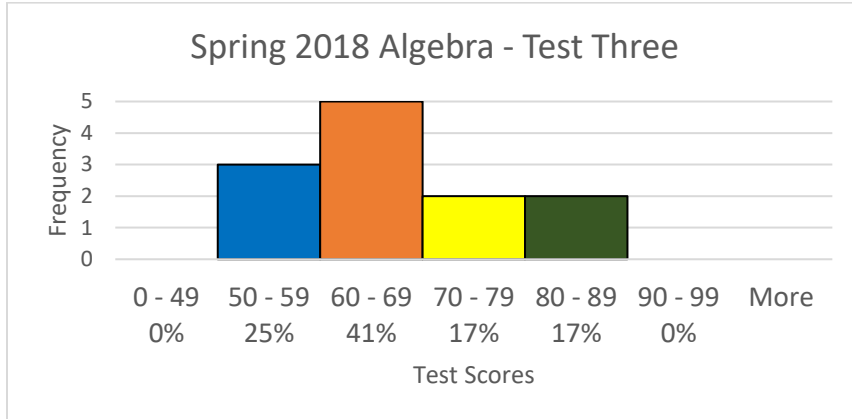


Figure 2. Histogram of Spring 2018's Scores, Test Three

The majority of fall's students, 58%, scored lower than eighty (see Figure 3). The remaining three students scored between eighty and eighty-nine. Comparing test two to test three (See Figure 4), there were noticeable changes. There were no students who scored lower than a sixty on test three. Only two students, 28%, scored lower than eighty, which decreased by half. Four students, 58%, scored between eighty and eighty-nine, which is an increase of 16% when compared to test two. One student scored ninety or above, and no students scored above ninety on test two.

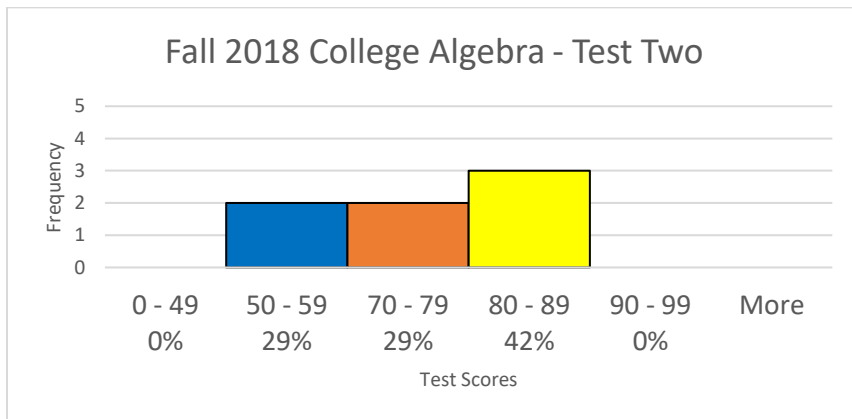


Figure 3. Histogram of Fall 2018's Scores, Test Two



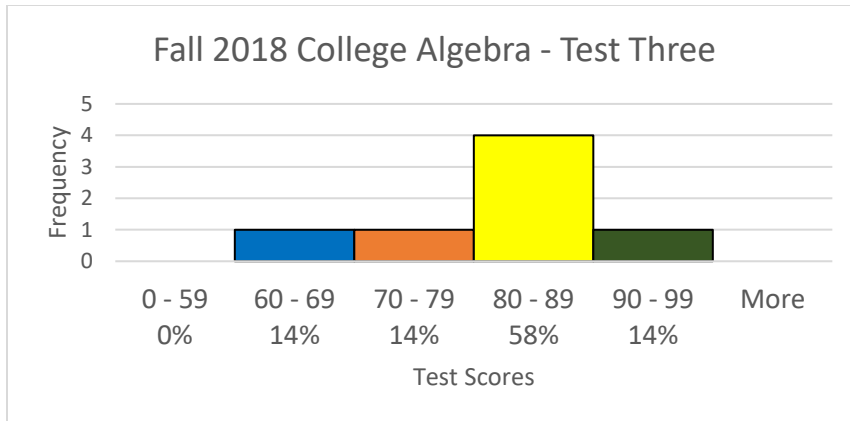


Figure 4. Histogram of Fall 2018's Scores, Test Three

An independent-samples t-test was used to help establish comparable groups and determine if there were differences between the two college algebra classes (see Table 2). A critical alpha level,  $p \leq .05$ , was set at the beginning of the study to check for statistical significance. The t-test showed that there was not a statistically significant difference in the means between the spring and fall students on the first test,  $t(17) = -.843, p = .411$  (2-tailed).

Table 2

*Independent Samples T-Test Results for Test #1*

Levene's Test		t-test for Equality of Means						
F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
1.08	.313	-.843	17	.411	-6.155	7.303	-21.563	9.254

Note. 95% Confidence Interval (CI).

After collecting all of the students' metacognitive sheets and scoring the two tests used in the study, descriptive statistics were calculated for both classes on both tests. Table 3 shows that fall's minimum score, 54, was four points higher than spring's minimum score, 50. There was a more noticeable difference in the two classes' maximum scores; spring's maximum score, 97, was thirteen points higher than fall's maximum score of 84.

Table 3

<i>Group Descriptives for Test #2</i>										
	N	Min.	Max.	Mean	Median	Range	IQR	$s^2$	SD	SE
Spring 2018	12	50.00	97.00	66.67	65.00	47.00	26.00	239.33	15.47	4.47
Fall 2018	7	54.00	84.00	72.71	77.00	30.00	26.00	151.91	12.33	4.66

*Note.* 95% Confidence Interval (CI); IQR = interquartile range;  $s^2$  = sample variance; *SD* = sample standard deviation; SE = standard error mean.

Figures 5 and 6 both reveal that there were no outliers in the data. The IQR showed that the spread was the same for both classes. Both spring and fall classes had a higher number of students who fell into the lower quartile, as clearly seen on the boxplots.

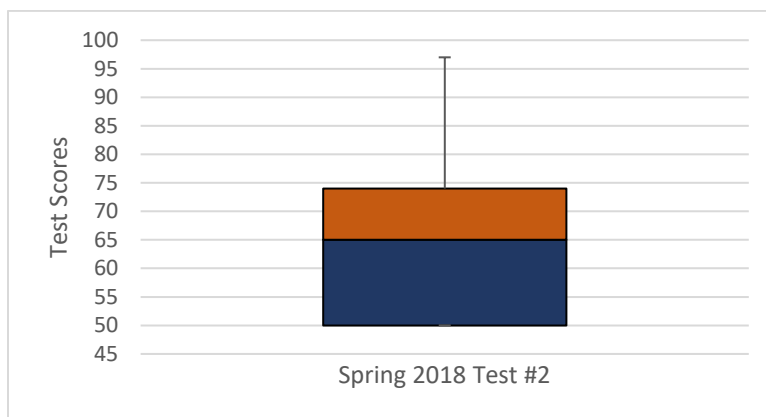


Figure 5. Box and Whisker Plot for Spring 2018, Test #2

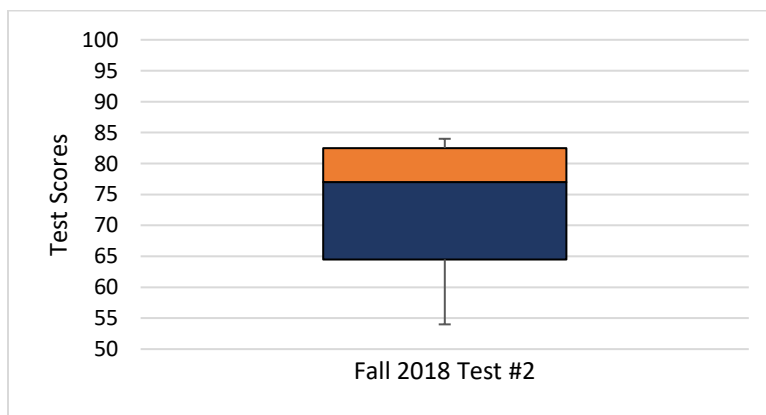


Figure 6. Box and Whisker Plot for Fall 2018, Test #2

Table 4 shows that fall's minimum score, 61, was eleven points higher than spring's minimum score, 50. There was a more noticeable difference on test three when comparing the

maximum scores of both classes, 89 and 90, to the maximum scores on test two. There was less of a spread between the two classes' standard deviations on test three when compared to test two. Fall students had significantly higher mean and median numbers on test three than spring, which were also higher than fall's mean and median scores when compared to their second test.

Table 4

*Group Descriptives for Test #3*

	N	Min.	Max.	Mean	Median	Range	IQR	$s^2$	SD	SE
Spring 2018	12	50.00	89.00	66.84	64.00	39.00	20.50	163.97	12.81	3.70
Fall 2018	7	61.00	90.00	81.57	87.00	29.00	11.00	102.62	10.13	3.83

*Note.* 95% Confidence Interval (CI); IQR = interquartile range;  $s^2$  = sample variance; SD = sample standard deviation; SE = standard error mean.

Figures 7 and 8 both show there were no outliers in the data. The IQR showed that the spread was noticeably higher for spring than fall. The spread decreased for both classes from test two to test three, but fall's IQR showed more of a decrease than spring. The boxplots revealed that fall's minimum score, 61, was the only score that fell lower than the upper quartile of the scores. Because fall's median was twenty-three points higher than spring's median, their scores clustered closer around the median score. Spring had fewer students who fell into the lower quartile when compared to test two, and their IQR decreased from test two to test three. Fall's decreased IQR led to the boxplot revealing no lower quartile for this classes' scores.

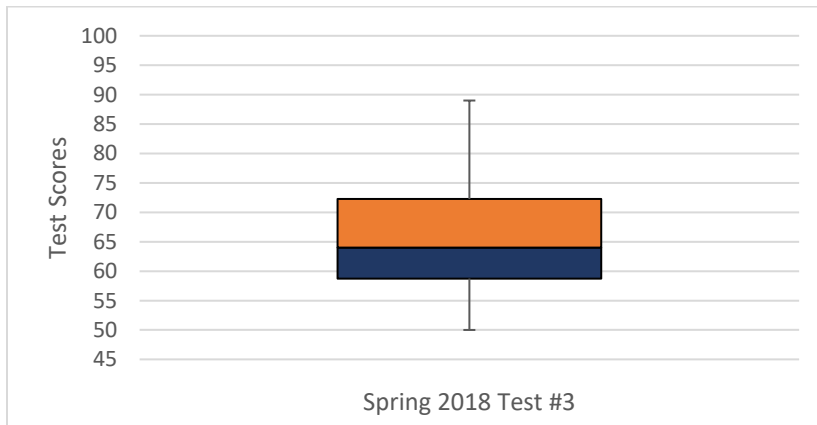


Figure 7. Box and Whisker Plot for Spring 2018, Test #3

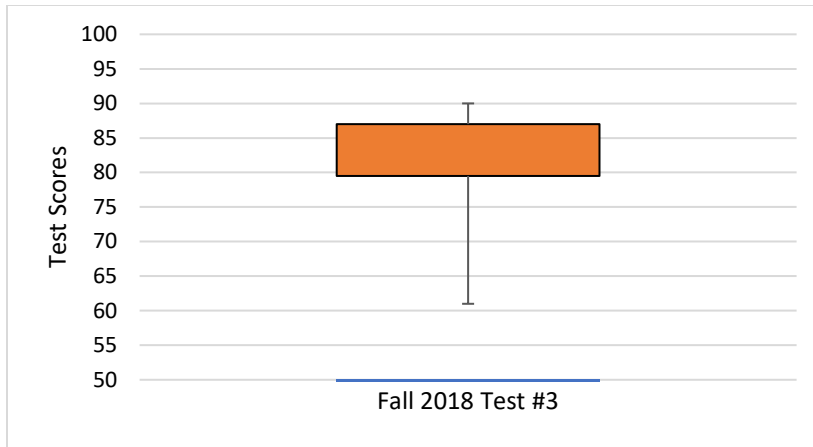


Figure 8. Box and Whisker Plot for Fall 2018, Test #3

### Question 1 Results

Will providing students with metacognitive questions daily impact their achievement as measured by test scores?

Spring's statistics for tests one through three are summarized in Table 5.

Table 5

<i>Statistics for Spring 2018</i>			
	N	Mean	SD
Test 1	12	78.92	15.17
Test 2	12	66.67	15.47
Test 3	12	66.84	12.81

Note. N=Number of Students; SD=Standard Deviation

To best investigate the first research question, a one-way repeated measure analysis of variance (ANOVA) was conducted to compare spring students' scores on the first three tests.

The results are shown in Table 6.

Table 6

<i>One-Way Repeated Measure ANOVA for Spring 2018's Test Scores</i>					
Source	df	SS	MS	F	p
Between groups	2	107.722	53.861	0.368	.696
Within groups	33	7513.250	227.674		
Total	35	7620.972			

Note. 95% Confidence Interval (CI); SS = Sum of Squares; MS = Mean Square.

The results of the ANOVA showed there was not a statistically significant variation at the  $p \leq .05$  level for the three tests [ $F(2, 33) = 0.368, p = .696$ ]. Spring did not receive the metacognitive questions while preparing for the test one, however, they did receive the daily questions while preparing for both the second and third tests.

Fall's statistics for tests one through three are summarized in Table 7 below.

Table 7

*Statistics for Fall 2018*

	N	Mean	SD
Test 1	7	76.57	12.46
Test 2	7	72.71	12.33
Test 3	7	81.57	10.13

*Note.* N=Number of Students; SD=Standard Deviation

To best investigate the first research question, a paired samples t-test was conducted with the following test combinations: tests two and test three, and test one and test three.

Table 8

*Fall 2018's Paired Samples T-Test Results for Tests 2 & 3*

Mean	SD	SE	t	df	Sig. (2-tailed)
-8.857	13.484	5.096	-1.738	6	.133

*Note.* 95% Confidence Interval (CI).

The mean almost increased nine average points from test two to test three (see Table 7), and the standard deviation showed a slight decrease. The students' scores were not as widely spread on the third test when compared to the second test. The t-test results (see Table 8) showed that there was not a statistically significant difference in their scores between test two and test three,  $t(6) = -1.738, p = .133$ , (2-tailed). The  $p$ -value revealed no difference between the two tests' scores.

Table 9

*Fall 2018's Paired Samples T-Test Results for Tests 1 & 3*

Mean	SD	SE	t	df	Sig. (2-tailed)
-5.000	12.014	4.541	-1.101	6	.313

*Note.* 95% Confidence Interval (CI).

A t-test was used to see if there was an impact on students' achievement from test one, which had no daily questions, to test three, which received daily questions (see Table 9). The t-test results showed that there was not a statistically significant difference in their scores between test one and test three,  $t(6) = -1.101, p = .313$ , (2-tailed). The  $p$ -value was larger on this t-test when compared to the  $p$ -value in Table 8. The standard deviation shown in Table 9 revealed a smaller spread when compared to the standard deviation listed in Table 8.

As the ANOVA and the paired samples t-test results revealed, the  $p$ -values showed, in all of the tests comparisons, that there was no statistically significant difference. Therefore, failing to reject the null hypothesis was the conclusion to the first research question.

### **Question 2 Results**

Will providing one group of students with the metacognitive questions during two units impact their achievement as measured by test scores when compared to another group of students who receive the questions during one unit?

During the first two weeks of the study, the spring students were given metacognitive sheets daily by the teacher. The sheets were coordinated with the second test of the semester. The teacher wrote feedback on all of the metacognitive sheets and returned them the next class period (See Appendix A). Both spring and fall classes prepared and took test two during their respective semesters, but only spring students received the metacognitive sheets.

An independent samples t-test was conducted to compare the two classes' means (see

Table 10). The test revealed that there was not a statistically significant difference in their scores between the two classes,  $t(17) = -.881, p = .391$ , (2-tailed).

Table 10

*Independent Samples T-Test Results for Test #2*

Levene's Test		t-test for Equality of Means						
F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
.299	.592	-.881	17	.391	-6.048	6.867	-20.536	8.440

*Note.* 95% Confidence Interval (CI).

Fall students had a slightly higher mean score than spring students on test two (see Table 3). The mean test score for fall was 6.04 points higher than for spring.

For two weeks during their respective semesters, both classes were given metacognitive sheets daily. The sheets were coordinated with the third test of the semester. The teacher wrote feedback on all of the sheets and returned them the next class period (See Appendix A).

An independent samples t-test was conducted to compare the two classes' means (see Table 11). The test revealed that there was a statistically significant difference in their scores between the two classes,  $t(17) = -2.598, p = .019$ , (2-tailed).

Table 11

*Independent Samples Test Results for Test #3*

Levene's Test		t-test for Equality of Means						
F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	Lower	Upper
.693	.417	-2.598	17	.019	-14.738	5.674	-26.709	-2.768

*Note.* 95% Confidence Interval (CI).

Fall students had a noticeably higher mean score than spring students on test three (see Table 4). The mean test score for fall was 14.73 higher than for spring.

As the two independent samples t-test results showed, (see Tables 10 and 11), the  $p$ -values revealed that there was a statistically significant difference ( $p = .019$ ) between spring

and fall students only on test three; this was not the case for test two. Therefore, failing to reject the null hypothesis was the conclusion to the second research question.

### **Question 3 Results**

Will patterns emerge when comparing the students' responses to the metacognitive questions and their test scores?

To investigate the final research question, an initial list of pre-set codes was created, and additional codes were added as the qualitative analysis progressed (see Table 12). The web application, Dedoose, was used to aid in the organization and investigation of the qualitative data. The codes and code descriptions were written to see if patterns of metacognition - students thinking about their own thinking, learning, and understanding - were present among the students' written comments on the daily metacognitive sheets.



Table 12

<i>Qualitative Codes and Descriptions</i>	
Name of the Code	Description of the Code
Clear, Accurate Mathematical Thinking (CAT)	Student clearly and correctly proved by creating a completely original problem, writing and explanation, etc., that shows he/she understands the math concept.
*Transparency (T)	Students being truthful with themselves or the teacher about being confused, having no or little prior knowledge or math concepts, or experiencing new learning for the first time.
Incomplete (Inc)	Students only made part of a mathematical statement/thought but did not make any other statements or fully answer the metacognitive statement to back up their original statement.
*Math Connections (MCon)	Connecting to the day before, the week before, another math course, or even the current day's lesson.
Math Descriptions (MDesc)	Students describing math concepts and/or adapting a problem from class when asked to give an example problem.
*Math Recall (MR)	Recalling math concepts from the day before, the week before, or another mathematics course.
*Mathematical Thinking Error (MTE)	Student has an incorrect understanding of a mathematical concept.
No Answer (NA)	Student did not answer the metacognitive question.
Not Clear (NC)	The student's answer/explanation is not clearly stated or isn't related to the metacognitive statement.
Planning (Pl)	Planning a course of action for test prep, learning, etc.
*Questioning (Qu)	How do I know? Why do I think this? What do I need to work on? Could I explain this?
*Self-Assessment (SA)	Students evaluating their own learning, understanding, and misunderstanding.
*Self-Confidence (SC)	Students stating positive feelings about their learning, understanding, and abilities.
Vocabulary Error (VE)	Student used mathematical language/vocabulary word incorrectly.

*Note.* \*Pre-Set Codes.

There were 671 individual student excerpts for both classes on tests two and three. The total number of excerpts for both spring and fall students on test three was 353, which was the test that both classes received the daily questioning sheets. There were several co-patterns that occurred more frequently than others on test three (see Table 13).

Table 13

*Most Common Reoccurring Patterns and their Frequencies for Test 3*

Paired Patterns	Total Number of Occurrences
Self-Assessment & Self-Confidence	90
Self-Assessment & Transparency	87
Math Descriptions & Math Recall	64
Math Connections & Math Recall	45
Math Connections & Math Descriptions	45
Self-Confidence & Transparency	35
Self-Assessment & Math Descriptions	30

As seen in Table 13, students who assessed where they were in their learning expressed confidence in what they knew and understood; there were ninety student excerpts that had this matching pattern. Students who self-assessed were often truthful about being confused, having no or little prior knowledge or math concepts, or learning a math concept for the first time. These paired codes emerged eighty-seven times, which was only three total excerpts less than the SA/SC co-pattern discussed first. Students who were able to describe math concepts or adapt a classroom problem when asked to create an example problem were often able to recall math concepts/ideas from previous learning. The MDesc/MR co-pattern occurred sixty-four times. Both the MCon/MR and MCon/MDesc co-patterns emerged forty-five times. Students' transparency with themselves and their learning led to their expressing self-confidence, which surfaced thirty-five times, and the SA/MDesc appeared thirty times.

Additional patterns surfaced while investigating the qualitative data; some were slightly less frequent than others (see Table 14).

Table 14

*Additional Common Reoccurring Patterns and their Frequencies for Test 3*

Paired Patterns	Total Number of Occurrences
Clear/Math Recall	27
Math Recall/Self-Assessment	26
Self-Assessment/Planning	25
Clear/Math Connections	24
Not Clear/Incomplete	20
Math Descriptions/Incomplete	19
Math Descriptions/Not Clear	19
Self-Assessment/Incomplete	14
Self-Assessment/Not Clear	13

Clearly and correctly writing or explaining what math concepts they knew led to students' recalling math concepts from previous days or weeks before. The CAT/MR pattern was noted twenty-seven times. Students' evaluating their own learning and understanding led to their recalling math concepts and planning a course of action for future learning. The SA/MR co-pattern occurred twenty-six times, and SA paired with the PI code twenty-five times. As some students created their own math problems or clearly explained what they understood, they made connections to previously learned math concepts from days, weeks, or months prior to their current learning. This CAT/MCon pattern was marked twenty-four times. Several additional patterns that developed included an "incomplete" or "not clear" code. Both the MDesc/Inc and MDesc/NC co-paired nineteen times. Multiple excerpts revealed that students would partially describe their thinking on the metacognitive questions but either not clearly finish their thinking or not relate their explanations to the questions. On twenty occasions, students' responses were simply incomplete and not clear. Codes that emerged from the metacognitive excerpts the least were mathematical thinking errors and vocabulary errors. When paired with all of the other

qualitative codes, there were a total of twenty-five mathematical thinking errors, twenty-one vocabulary errors, and twenty mathematical misconceptions. When compared to the total number of excerpts for test three, 353, only sixty-six - 19% - of those total excerpts were MTE and VE. Also, there were only three “No Answer” co-occurrences were marked, which was <1% of total number of excerpts.

Further investigation into the self-assessment/self-confidence co-occurrence pattern revealed possible relationships for Spring. Several students who had a higher number of self-assessment excerpts that were close to the number of self-confidence excerpts gained points or lost fewer points when compared to their classmates. There were some exceptions, and these are indicated in the table. Some students had excerpts that were close together but not as high as others who still gained points or lost fewer points. A few students had higher self-assessment numbers and lower self-confidence numbers and still gained points (see Table 15).

Table 15

*Spring Self-Assessment/Self-Confidence/Transparency Excerpts & Gains(+), Losses(-) or No Change(0)*

	Test 2				Test 3			
	SA	SC	T	Point Changes from Test 1	SA	SC	T	Point Changes from Test 2
FB – 4	16	10	8	+1	10	7	3	-4
FB – 5	13	10	4	-3	9	6	3	-5
FB – 11	12	8	5	+25	8	2	6	-17
FB – 9	12	8	6	+3	11	7	3	+15
FB – 6	11	7	10	-5	9	3	7	0
FB – 7	13	6	6	-7	10	5	4	+5**
FB – 10	13	5	8	-8	8	3	3	+5**
FB – 3	13	5	7	-13	5	4	2	+10*
FB – 2	15	5	7	-13	6	4	2	-9
FB – 12	14	3	14	-27	9	4	5	+14*
FB – 1	6	5	10	+4*	8	3	4	-8
FB – 8	11	1	7	+19**	19	5	8	-4

*Note.* SA=Self-Assessment; SC=Self-Confidence; \* Point Gain with Low SA Number Close to SC Number; \*\*Point Gain with High SA Number Not Close to SC Number

Several students who had a higher number of self-assessment passages on test two maintained a higher number on test three and gained points or lost no points. Some students who had a higher number of selections for their second test did not repeat that pattern for the third test and lost points in comparison. There were some exceptions, as noted in Table 15. One exception was FB – 8 who had more self-assessment/self-confident excerpts for the third test and lost points; this student, however, did not lose many points when compared to others in this class. As a whole, most of the students had a reduction in the number of self-assessment excerpts from test two to test three, with two exceptions being FB – 8 and FB – 1.

An additional pattern that emerged was transparency. Both FB – 1 and FB – 8 had higher transparency excerpts when compared to others in the class. FB – 1 had ten excerpts, and FB – 8 had eight. Even though FB – 8 lost points on test three, the student only lost four points while maintaining a higher number of transparency excerpts – nine. FB – 1 lost points on test three as well, however, this student dropped to three transparency excerpts. FB – 4 had seven transparency selections for test two and gained one point; the student lost points on test three and dropped to three passages. FB – 5, who had higher self-assessment/self-confident citations, lost a small number of points on both tests and had low transparency excerpts – four and three. FB – 9 gained points on both tests and had transparency excerpts that were close in number – six and four. The main exception to this pattern is FB – 12 who lost the most points on test two and gained the most points on test three; this student had very high transparency selections, fourteen, on test two and only had five selections on test three.

Fall had lower self-assessment excerpts when compared to first block on test three (see Table 16). Fall only had seven students, which was five fewer students than spring's twelve.

Table 16

*Fall Self-Assessment / Self-Confidence/Transparency Excerpts & Gains (+) or Losses (-)*

	Test 3			Point Changes from Test 2
	SA	SC	T	
S2	14	5	12	+22**
S6	13	7	10	-1
S7	11	7	7	+23
S1	11	5	10	+3
S3	10	8	11	+13
S4	9	8	7	+6
S5	5	2	6	-10*

*Note.* SA=Self-Assessment; SC=Self-Confidence; \*Low in both SA and SC excerpts; \*\*Point Gain with High SA Number Not Close to SC Number

Most of fall’s students had self-assessment selections that were nine or higher. Several students had SA excerpts that were close to their number of SC selections; S2 was an exception to this pattern. They exhibited some of the same characteristics as spring by gaining points or losing a small number of points. There were a couple of exceptions, as noted in Table 16. S2 had the highest number of SA excerpts and one of the lowest SC excerpts and almost gained the highest number of points from test two to three. Interestingly, S2 also had the highest number of transparency selections, twelve, which was higher than most of the classes’ SA selections. S6 had both higher SA and SC passages along with ten transparency excerpts and lost one point. S5, who had the lowest number of both SA and SC excerpts, was another exception. This student lost the most points from test two to test three and had one of the lowest T selections, six, in the class.

In response to research question three, there were patterns that emerged after investigating and analyzing the qualitative data further. Students did answer the metacognitive questions and did not leave very many questions blank, as discussed above. The most frequent patterns involved self-assessment, self-confidence, and transparency (see Tables 13, 15 and 16). These patterns could have impacted student achievement when investigated in tandem.

## **CHAPTER V**

### **Discussion**

#### **Summary of Results**

This research study investigated the possible impact that using daily metacognitive questioning in the classroom had on students' achievement as shown by test scores. The study also explored emerging patterns after comparing students' responses to the metacognitive questions and their test scores.

The researcher wanted to verify that the two classes were comparable at the start of the study. Because neither of the two classes received the metacognitive sheets while preparing for the first test, these scores were used to help show that the classes were comparable. Spring had a mean of seventy-nine, and fall had a mean of seventy-seven. Spring had a standard deviation of about fifteen, and second had a standard deviation of about twelve. An independent samples t-test was used to further establish that the two classes were indeed comparable.

After spring students wrote on the sheets for two weeks, their mean dropped from seventy-nine on the first test to sixty-seven on the second test. Their scores' spread about the mean was fifteen, which was the same approximation as the first test. After looking at the decline in the class mean, it would appear that the metacognitive sheets did not lead to a positive change in student achievement. The students may have needed more time and practice writing on the daily sheets. Fall students did not answer the sheets, and their mean decreased slightly from seventy-seven on the first test to seventy-three on the second test. Their scores were slightly less dispersed compared to their first test, which was smaller than the spring students. If

the metacognitive sheets had an impact, one would think that spring's scores would have increased and would be noticeably different from fall's scores.

Both classes wrote on the metacognitive sheets before the third test. Spring's mean stayed the same, sixty-seven. The mean did not improve, but it did not decrease, either. This class maintained their mean from the second test to the third test. Their scores were also less spread than both of their previous tests. The metacognitive sheets could have helped this class maintain their mean, which could lead to an improvement on the remaining semester tests. Fall had a higher mean on test three than first block, and their mean increased from seventy-three to eighty-two. Their scores' spread decreased slightly over two points when compared to their second test, so they did get closer to their mean. Fall only wrote on the metacognitive sheets for two weeks, which could have led to their scores' increasing and their spread decreasing. Spring wrote on the daily sheets for four weeks, and the extra preparation could have helped them maintain their mean from test two. Even though the metacognitive sheets did not lead to a substantial improvement, they still could have had a positive effect on spring. Spring students had the more noticeable decrease in mean scores from the first test to the second test, but they did not experience a decline on test three. Their receiving two cycles of the metacognitive questions could account for their mean not decreasing on the third test. Fall had a noticeable increase from test two to three, and the metacognitive sheets could help account for this increase.

The potential impact on student achievement after receiving the daily metacognitive questions was also investigated. There were several patterns that surfaced while analyzing the qualitative data. Students who gauged their own learning, understanding, and mistakes sometimes expressed confidence in themselves and revealed confusion in their previous or current knowledge many times. Students' self-confidence was connected to their self-



assessments and transparency more often than to any other set of co-patterns. Recalling previous math concepts and describing math ideas or problems were also linked to many of the students' daily self-assessment. Because not all students are alike and writing on the sheets was optional, incomplete and unclear answers also appeared on the metacognitive sheets. Students sometimes began writing their explanations, and they either did not finish what they were discussing or did not express what they meant clearly enough to be understood. Most students attempted to answer all of the questions on their completed sheets. There were very few questions that were left blank, so this was not a pattern that appeared habitually.

## Conclusions and Connections to the Literature

### Test Two

Spring students scored lower on test two than fall, as seen on the box and whisker plots redisplayed from chapter four (see Figures 5 and 6). The figures show that there were differences between the two classes.

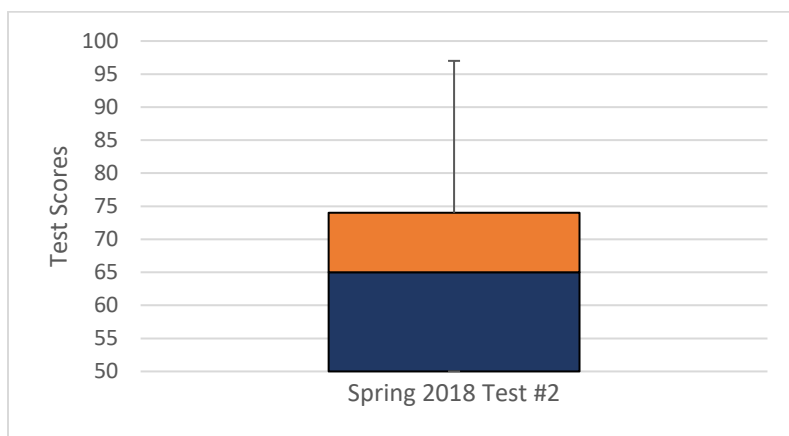


Figure 5. Box and Whisker Plot for Spring 2018, Test #2

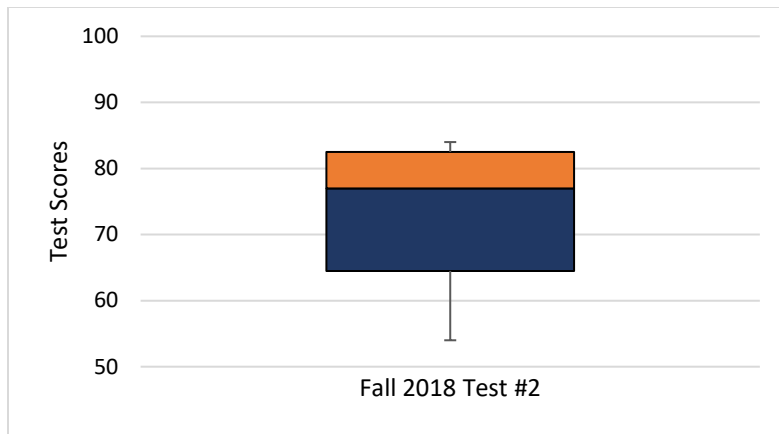


Figure 6. *Box and Whisker Plot for Fall 2018, Test #2*

Figures 5 and 6 provide a clear, visible difference between the two classes. However, this difference was not proven significant using an independent samples t-test. Spring had a mean of 66.67 and a median of 65; fall had both a mean of 72.71 and median of 77. While the lowest test scores in each class were close, the highest test scores were not. As shown in Figure 5, fifty percent of spring students scored between fifty and seventy-four, and there was a larger spread between the lowest score and the median. These scores were also not as close to the mean, either. Fewer students scored above the median than below. Figure 6 shows that fifty percent of fall students scored between sixty-four and eighty-three. There was a smaller spread among the test scores in upper quartile and a larger spread in the lower quartile. Fall's scores were also not close to the mean, which was similar to spring's scores. As a whole, spring scored lower but had the same spread among their test scores as fall.

While neither class answered the metacognitive sheets before taking the first test, spring completed the metacognitive sheets for two weeks before taking test two. They had a mean of seventy-nine on the first test, but their mean decreased to sixty-seven. This class did not show an improvement after the first cycle of questioning sheets. One explanation for the decline in test scores could be that the students were inexperienced at self-assessing where they were in their learning. Knowing about one's own tendency to commit easy errors may lead to increased self-

regulatory activities in test situations (Schneider & Artelt, 2010). With the scores from the first test being higher than the second, the students could have been overconfident about the math concepts that they thought they knew. Another possibility could be that the first series of metacognitive sheets did not provide enough time for students to develop stronger metacognitive skills, which could have improved their scores on test two. According to Robert Marzano (2007), “Students must periodically reexamine their understanding of the content being investigated. This reevaluation can help them shape and sharpen their knowledge,” (p. 84).

Fall did not show an improvement from the first test to the second, but their decreased mean was not as noticeable as spring. Fall had a mean of seventy-seven on the first test, and their mean slightly decreased to seventy-three on test two. This class did not answer the metacognitive sheets before taking test two. Because this class did not answer the questions, it is not known whether or not the daily questions could have improved their test scores. The decrease in their mean was only four points, and it is not known what helped fall’s students have a closer mean between the first two tests than spring’s students.

### **Test Three**

Spring’s students scored lower on test three than fall’s students, as seen on the box and whisker plots redisplayed from chapter four (see Figures 7 and 8). The figures show that there was a difference between the two classes, and this difference between the two classes is more noticeable when compared to the second test. This difference was proven statistically significant ( $p = .019$ ) using an independent samples t-test.

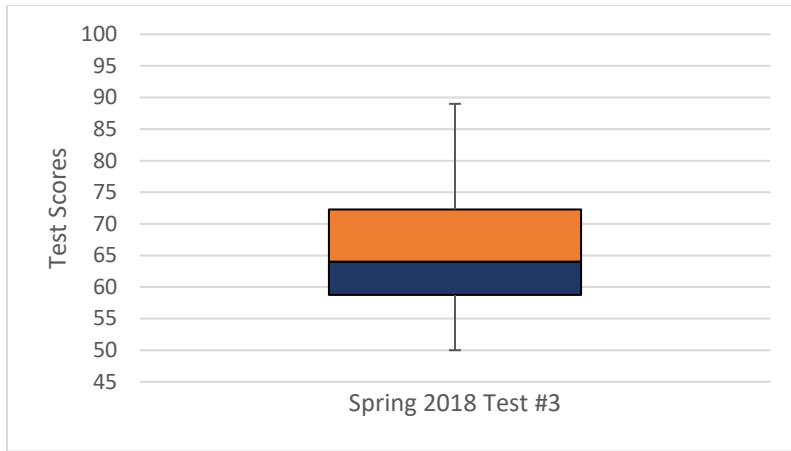


Figure 7. *Box and Whisker Plot for Spring 2018, Test #3*

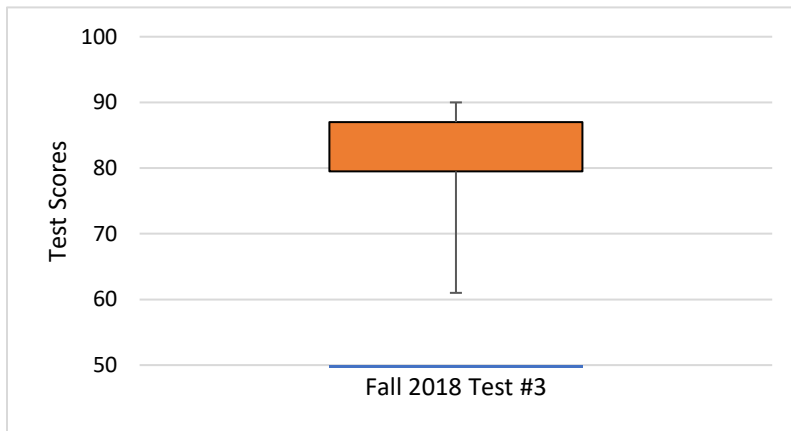


Figure 8. *Box and Whisker Plot for Fall 2018, Test #3*

Spring had a mean of 66.84 and a median of 64, which was lower when compared to fall's mean of 81.57 and median of 87. The highest test scores in each class were within one point of one another, 89 and 90, when compared to test two. The lowest test score differences were more evident than test two; fall's minimum score, 61, was eleven points higher than spring's minimum score of 50. As shown in Figure 7, fifty percent of first block scored between the fifty-nine and seventy-two, which rose when compared to their second test. The spread between both the upper and lower quartiles and the median decreased on this test, with the larger decrease being in the lower quartile. These test scores are closer to the median than the previous test. Figure 8 showed that fifty percent of fall's students scored between seventy-nine and

eighty-seven, which changed from their second test, which showed fifty percent of them scored between sixty-four and eighty-three. Figure 8 revealed no lower quartile for this classes' scores, which was clearly different from spring's decreased lower quartile. As a whole, spring scored lower on test three than fall. Figures 7 and 8 provide a visual for the differences between the two classes, which, again, were proven significant with the t-test.

Spring maintained a mean of sixty-seven on test three. Even though the mean did not change from the second test to the third, it did not decrease, either. The spread among the test scores decreased, and the scores were less varied. The class completed the metacognitive questioning sheets for four weeks before taking test three, and this could explain the continued mean score and the decreased spread among the scores. This class had a longer period to write on the metacognitive sheets, and this could have made a difference. The more time the students practiced evaluating what they knew and understood, the more their self-assessment skills could have improved. When students self-assess on a regular (daily) basis, significant improvements can be attained in students' achievement (Fernandes & Fontana, 1996). Being exposed to daily questioning sheets for an additional two weeks might have provided enough time for them to develop stronger metacognitive skills, which could explain their slightly higher median score and the increase in the middle fifty percent of their scores. Metacognition develops gradually and is dependent on knowledge and experience, and on topics that children know, and with some effort, they can learn to build on and strengthen their understanding of what it means to learn and remember (Bransford et al., 2000).

Fall had improvements on this test when compared to test two. Fall's mean increased from seventy-three on test two to eighty-two on test three, which was a notable change when compared to spring's mean of sixty-seven. One explanation for the higher mean could be that

their completing the metacognitive sheets helped them improve their mean and decrease the spread of their scores. This class completed the metacognitive sheets for two weeks prior to taking test three, and this opportunity to write and practice metacognitive skills could account for their scores improving when compared to the previous test. Student self-reflection and metacognition are essential to learning; writing increases opportunities for students to think about their thinking (Hattie et al., 2017). Writing supports the beliefs of writing to learn, of strengthening students' abilities to be self-regulators, and of developing metacognition; writing tasks that require metacognitive reflection contribute to students' mathematical learning (Martin, Polly, & Kissel, 2017). Fall's students earned a higher mean score on test three when compared to spring despite completing fewer metacognitive sheets. One reason for their improved scores could be that these students' responses were more descriptive, self-reflective, and honest. These students' improved scores could be a direct result of their answering the sheets daily, which could have had an impact on test three. With more practice, one might conclude that their test scores could improve more if given more time to think about what they knew and to grow more honest about what they did not know and understand. Developing self-regulatory skills with complex mathematics is difficult and often involves unlearning inappropriate control behaviors developed through prior instruction; however, with persistence and time, modifications can be sparked (Schoenfeld, 1992).

### **Qualitative Data Correlating to Test Two and Test Three**

Table 13 from chapter four showed the most common co-patterns that surfaced from test three's qualitative data. The table is redisplayed below.

Table 13

*Most Common Reoccurring Patterns and their Frequencies for Test 3*

Paired Patterns	Total Number of Occurrences
Self-Assessment & Self-Confidence	90
Self-Assessment & Transparency	87
Math Descriptions & Math Recall	64
Math Connections & Math Recall	45
Math Connections & Math Descriptions	45
Self-Confidence & Transparency	35
Self-Assessment & Math Descriptions	30

Spring was the only class to complete the questioning sheets before taking test two. Because both classes answered the metacognitive sheets before taking test three, Table 13 displays only test three's co-patterns. The relationships that arose more often than others were self-assessment, self-confidence, transparency, math descriptions, math recall, and math connections. Because a high number of students' excerpts received these codes, further investigation was conducted on the possible influence the patterns had on both classes' scores.

Additional codes also appeared that could have had an impact on the students' achievement. Table 14 from chapter four is redisplayed to show the other co-occurrences. Both classes wrote on the sheets prior to taking test three.

Table 14

*Additional Common Reoccurring Patterns and their Frequencies for Test 3*

Paired Patterns	Total Number of Occurrences
Clear/Math Recall	27
Math Recall/Self-Assessment	26
Self-Assessment/Planning	25
Clear/Math Connections	24
Not Clear/Incomplete	20
Math Descriptions/Incomplete	19
Math Descriptions/Not Clear	19
Self-Assessment/Incomplete	14
Self-Assessment/Not Clear	13

Many of the reoccurring patterns shown in Table 14 involved clear, mathematical thinking and planning and their connections to math recall and self-assessment. There were also several passages that involved incomplete and unclear student answers. Even though these co-occurrences did not happen as frequently as the ones shown in Table 13, they surfaced enough to further investigate any impact on test scores.

Fall students answered the metacognitive sheets for two weeks before taking the third test. This class had a total of 384 excerpts on the sheets, which was a lower number than spring's selections on both tests. However, the fall class only had seven students, and spring had twelve. An investigation of the excerpts revealed patterns in the students' answers that could have affected student achievement on test three. Table 17 displays the more common co-occurrences shown in Tables 13 and 14, broken into their individual qualitative codes and associated with the individual students for fall 2018.

Table 17

*Patterns That Emerged for Fall 2018, Test 3*

Student	Point Change	Excerpt Total	SA	SC	T	MDesc	MR	MCon	PI	Inc	NC
S7	*+23	62	11	7	7	9	8	5	1	4	8
S2	*+22	62	14	3	12	6	3	5	7	4	2
S3	+13	53	10	8	11	7	4	6	0	2	1
S4	+6	64	9	8	7	7	11	7	3	4	1
S1	+3	58	11	5	10	8	6	5	5	1	0
S6	*-1	64	13	7	10	7	8	5	7	1	1
S5	-10	21	5	2	6	1	1	0	2	2	2

*Note.* \* Exceptions to the table pattern. SA=Self-assessment; SC=Self-confidence; T=Transparency; MDesc=Math Descriptions; MR=Math Recall; MCon=Math Connections; PI=Planning; Inc=Incomplete; NC=Not Clear

As seen in Table 17, all of the students except two earned a higher score on test three than test two. S6 lost only one point on test three, and S5 lost ten points. Fall students had higher excerpt totals with the only exception being S5; this student also had the fewest number of



excerpts and only five SA passages. The highest number of excerpt totals were the self-assessment (SA) codes. This class only answered the questioning sheets for only one two-week cycle, and some of these students had higher SA passages than spring's students. The math descriptions (MDesc), transparency (T), and math recall (MR) varied among the students with S7 earning the most points and the highest number of MDesc and MR excerpts but lower T passages. The planning (Pl) and not clear (NC) excerpts varied more than others. All of the students had higher MR and math connections (MC) responses than incomplete (Inc) responses.

There did appear to be a connection between the total number of excerpts and improved scores or a small loss of points. All of the students had over fifty total excerpts with only one exception; S5 had only twenty-one. Four students had over sixty selections. Three out of those four students gained points, and the remaining student only lost one point. Both S1 with fifty-eight excerpts and S3 with fifty-three excerpts scored higher on test three. Along with S7, S2 also had sixty-two excerpts and gained the second highest number of points. Both S4 and S6 had the highest number of passages, sixty-four. S4 gained six points, and S6 only lost one point. S5, who had the lowest number of excerpts, lost the greatest number of points. Even though the two students with the highest number of excerpts did not gain the most points, they remained close to the scores that they earned on test two.

S7 had the second highest number of total excerpts and high SA, MDesc, and MR passages. However, he or she also had the highest number of NC excerpts. S7 gained the most points from test two to three in the class. One reason for this student's improved score could be because of the higher MDesc and MR and average T excerpts. One reason for the MDesc and MR totals could be because he or she either had a stronger math background or had taken a previous math course close in proximity to college algebra. S7 also had average T excerpts,

which could have helped him or her feel comfortable with being confused about certain math concepts. This transparency, in connection with the higher SA totals, could have had an impact on his or her improvement on test three. The higher MR number could have also helped this student to earn twenty-three points on test three despite having the most NC excerpts in class.

There were other connections present among the students. The connection between SA and H was strong among these students, and this connection could have led to improved test scores. S6 lost one point despite the higher SA, and MR numbers. This student also had one of the highest T and PI excerpts. One reason for this connection could be because this student was able to analyze and to be honest about what he or she knew and understood. Admitting confusion or misunderstandings could have helped this student remain close to test two's score.

S5 lost the most points on test three even though his or her T total did not vary too much among the other student totals. However, S5 also had the smallest total excerpts in the class, twenty-one, and four of those passages were marked Inc and NC. S5 made no mathematical connections and only had two PI excerpts. This student only had one MR and MDesc excerpts. Because the students had the freedom to choose to answer the sheets or not, this student may have chosen not to complete the sheets every day. Even though this student expressed transparency about being confused or having little knowledge of the math concepts being covered in class, his or her lower overall excerpt total could indicate that S5 may not have written enough on the metacognitive sheets to develop an understanding of his or her learning. The lower SA passages when included with the other lower excerpt totals could be one reason why this student lost the highest number of points on test three.

S2 had one of the highest number of excerpts, sixty-two, and the highest T excerpts in the class, twelve. S2 almost had the lowest SC excerpts but was more honest about what he or she

did not know or understand. This transparency could have led to this student earning the second highest number of points out of the class. The student had one of the highest total PI excerpts; making plans to improve learning also could have helped this student gain twenty-two points. S1 showed similar patterns as S2. S1 had higher SA and T excerpts and one of the lower SC totals. This student assessed his or her learning and was honest about not understanding or knowing certain concepts, which could explain S1 earning three points on this test. S1 also had the lowest number of Inc excerpts, had no NC passages, and high MR excerpts. His or her writing more complete and clearer discussions also could have led to his or her gaining points on test three. S1 also planned a path for learning; the student had the second highest number of PI excerpts in the class, five. S1, however, had lower SC excerpts, five; this student did not state positive feelings about his or her learning and abilities often. This lack of self-confidence could explain why this student gained the least amount of points in the class.

Students S3 and S4 both had SA and T excerpts that were close in together. Both of them had the highest number of SC excerpts, eight, and both had the same MDesc totals, seven. Both students had only one NC excerpt each and average Inc selections and gained points on test three. S3's SA and T totals were higher than S4, which could have led to S3 earning more points than S4. S3 had a lower MR total but had a higher number of MCon passages. This student recalled previous math concepts and connected those concepts to another problem or math course, which could account for the thirteen-point increase despite having no PI excerpts. If the student had developed a path for learning, he or she might could have earned more points on test three. S4 had fewer T totals than S3 but had the highest number of MR excerpts MCon excerpts in the class. Making connections to previous knowledge could have helped this student gain points on the third test. This student had one of the lowest numbers of PI excerpts, three. Had

the student increased the number of planning excerpts, this could have had an impact of greater than six points.

The patterns displayed in Table 17 show students who, as a whole, were honest in their self-assessments. They were able to recall math concepts and describe them, for most part, completely and clearly. SA and T, when linked to students' clearly describing their learning, connecting mathematical concepts, and assessing where they were as they learned led to higher student achievement. Also, most of this group not only had high SA and T excerpts, they also had low Inc and NC excerpts. One could predict that students who wrote more MR and MDesc more clearly and completely along with a higher number of SA and T excerpts should show a more noticeable improvement in achievement when compared to students who did not have these characteristics in their responses. Students with less self-confidence appeared more honest about not knowing a concept than some students who had higher SA and SC excerpts. Two students with higher SA and SC selections scored the lowest in this group, and one explanation for this could be that they were overconfident about their knowledge and inaccurately assessed what they knew. The two students who had the highest PI excerpts were at opposite ends of the class with one student earning twenty-two points and the other losing one point. One explanation for this pattern could be that the student who earned a higher score could have developed a more specific learning path than the other one who lost a point. One could conclude that writing on the questioning sheets and practicing metacognitive skills every day could have positively affected the overall academic achievement of this group. More exposure to daily metacognitive thinking and questioning could provide enough practice to help students grow their self-evaluating skills, create a more individualized learning path, and encourage more honest descriptions about what they understand as their learning progresses. A more detailed investigation into the qualitative

data allowed for a better understanding of how metacognitive thinking, when conducted consistently, could have had a positive impact on student achievement.

Spring students answered the metacognitive sheets for two weeks before taking test two and for two weeks prior to taking test three. They had a total of 702 excerpts for test two and 579 for test three. An investigation of the excerpts revealed patterns in the students' responses that could have had an impact on student achievement on the two tests. Tables 18 and 19 display the more common co-occurrences shown in Tables 13 and 14, broken into their individual qualitative codes and associated with the individual students in first block.

Table 18 displays the five students in spring 2018 who gained points after taking test two. These same students' scores for test three are listed below their test two scores. This table design was chosen because the students' patterns, whether continued or changed, were more easily seen from one student to the next over the course of both tests.

Table 18

*Patterns and Score Changes for Tests Two and Three, Spring 2018*

FB Number	Point Change	Excerpt Total	SA	SC	T	MDes c	Inc	M R	NC
11	25	61	12	6	5	9	1	11	0
*11	-17	29	8	3	6	12	0	10	1
8	19	46	11	4	7	6	5	3	5
*8	-4	78	19	6	8	14	10	6	7
1	4	47	8	5	10	8	0	5	0
*1	-8	45	7	3	4	8	0	7	0
9	3	56	12	8	6	5	3	9	2
*9	15	53	11	7	3	11	3	8	1
4	1	79	16	10	8	11	2	8	3
*4	-4	51	10	7	3	6	5	6	2

*Note.* \*Test Three

As seen in Table 18, almost all of the students had a higher number of SA excerpts on test two when compared to test three. The students had lower excerpt totals on the third test

compared to test two, with FB-8 being the only exception. FB-8 had eight more SA excerpts on test three when compared to test two. Most of the students had higher MDesc totals on test three, with FB-4 decreasing six SA passages and FB-1 only decreasing one excerpt on test three. FB-9 was the only student in this group who earned points on both tests, and this student gained fifteen points from test two to test three. One reason for this student's improved score could be because he or she remained fairly consistent through the SA, T, and MR excerpts and increased the number of MDesc excerpts on test three by six excerpts.

The excerpt totals varied among these students on both tests. There did not appear to be a clear connection between the total number of excerpts and improved scores on test two. Two students who earned the fewest points on test two had a higher number of excerpts, FB-9 and FB-4. The excerpts varied on test three as well, but students who maintained a higher number of excerpts did not lose a large number of points. There were other connections that surfaced through a closer inspection of the students' excerpts on test two. What could have helped these students' scores improve on this test? One reason could be that the MDesc excerpts for all the students were five and greater. Also, all but FB-8 had average Inc and NC excerpts, which could help explain the point gains. When students created and discussed math problems on their daily sheets and did so clearly and completely, that could have also led to the positive change in their scores. Another explanation could be that all of these students had a higher number of SA excerpts, with FB-1 having eight, which was the smallest number.

FB-11 earned the most points on test two, and this student had a high number of SA and SC excerpts and five T excerpts. When these excerpts were matched to FB-11's Inc, MR and NC codes, it was revealed that the student had a higher number of MR passages and very low or non-existent Inc and NC passages. This student not only assessed his or her learning but was

confident enough to be honest about what was confusing. The student was able to discuss math concepts and problems multiple times and recall math ideas covered during an earlier time with fewer incomplete and unclear statements. These excerpt connections also appeared with FB-1, FB-9, and FB-4. One could conclude that these connections could lead to greater student achievement. FB-8 had the highest number of Inc and NC excerpts but still gained a significant number of points. One reason for FB-8's improve score could be because of the higher number of T selections; he or she was less confident and admitted when unsure or confused. When paired with the higher SA excerpts, this could be one explanation for FB-8's increase.

Could this group carry their self-analyses from the second test to the third? The majority of the excerpt totals decreased on test three. FB-8 was the only student who had a substantial increase in some excerpts on test three. All of this student's excerpt totals increased, which means that his or her Inc and NC excerpts increased as well. FB-8 doubled the number of Inc excerpts on this test, but he or she increased the SA excerpt by eight and the SC by two. This student still lost points from test two to three. One explanation for the loss could be that the student was overconfident about his or her understanding and incorrectly assessed what he or she actually knew. These incorrect analyses could have been influenced by the substantial point increase that this student earned on the second test. This could lead one to conclude that students who are inaccurate or inexperienced with self-assessment and are incomplete and unclear in their thinking and writing would be less likely to see higher test scores.

FB-9 was the only student from this group who gained points on both tests. This student had similar SA, SC, and MR excerpts compared to test two, but the MDesc excerpts more than doubled. The increased writing and describing mathematics could be a reason for the considerable score increase. This student also had a slight decrease in the number of NC

excerpts on the daily sheets. FB-11 lost the highest number of points on test three. This student had a reduction in the number of SA and SC excerpts but gained T and MDesc selections. These gains, however, did not translate to a higher test score. One explanation for decrease could be because the student did not self-assess as often, which could have had a negative impact on his or her self-confidence. The increased T excerpts could be the result of his or her lack of reflecting on what he or she actually did know and understand. The increased MDesc might not necessarily mean more detailed. They might have been shorter and less descriptive than the writings on test two but not necessarily unclear or less complete.

The patterns displayed in Table 18 show students who frequently self-assessed, expressed transparency, and wrote a generous amount of math descriptions as they progressed through their learning. Their higher number of SA and MDesc could mean that these students were positively influenced by completing the questioning sheets each day. There were some students who were less accurate in determining their understanding, and this could have led to the loss of points. With only two exceptions, all of these students lost a small number of points from test two to three; one reason for this could be that the students completed the metacognitive sheets for four weeks. One could conclude that practicing metacognitive skills every day via the questioning sheets could have positively affected the overall academic achievement of this group.



Table 19

*Patterns and Score Changes for Tests Two and Three, Spring 2018*

FB Number	Point Change	Excerpt Total	SA	SC	T	MDesc	Inc	MR	NC
5	-3	55	13	10	4	3	1	7	6
*5	-5	47	9	6	3	6	5	4	7
6	-5	45	11	5	10	4	3	5	3
*6	0	33	9	3	7	3	3	2	4
7	-7	58	13	5	6	12	3	6	3
*7	5	46	10	5	4	10	2	6	0
10	-8	64	10	6	8	9	5	11	5
*10	5	45	7	3	3	5	3	4	3
3	-13	53	13	5	7	8	2	6	2
*3	10	44	5	4	2	10	2	9	4
2	-13	68	15	5	7	8	7	5	6
*2	-9	47	6	5	2	9	5	2	7
12	-27	66	14	3	14	10	1	11	3
*12	14	53	9	4	5	6	0	8	2

*Note.* \*Test Three

Table 19 displays the seven students in spring 2018 who did not gain points after taking test two. These same students' scores on test three are listed below their test two scores. This table was designed for the same reason as Table 18. The students' patterns, whether continued or changed, were more easily seen from one student to the next over the course of both tests.

As Table 19 shows, almost all of these students had a higher number of SA, SC, and T excerpts on test two when compared to test three, with only a few exceptions. FB-7 and FB-2's SC excerpts did not change, and FB-12 had one more SC excerpt on test three when compared to test two. Both FB-5 and FB-2 lost points on both tests. FB-5 lost five points from test two to test three, and FB-2 lost nine points. One reason for their losing points could be because FB-5 decreased both of the SA and SC excerpts by four points and increased the number of Inc

excerpts by four points. FB-2 did not have a change in SC excerpts, but he or she did have noticeable decreases in both the SA and T selections. These changes could explain the negative impact on both FB-5 and FB-2's scores. One could expect that students have to continue to analyze what they know, write complete discussions, and honestly evaluate their understandings as they learn. Failure to think and admit what they know and do not know could lead to a negative impact on student achievement.

The excerpt totals varied within this group on both tests. There did not appear to be a clear connection between the total number of excerpts and improved tests scores on test two because everyone lost points on this test. Two students who lost some of the most points had the highest number of excerpts, FB-2 and FB-12. The excerpts varied on test three as well, but five out of seven students had excerpt totals greater than forty. What could have been a reason for the loss in points? One reason could be that many in this group had lower SC excerpts and higher T excerpts. FB-5 was the exception; this student had one of the highest SA numbers, the highest SC numbers, and lowest T numbers on test two. This student's excerpt numbers could account for his or her losing the least amount of points on test two. Even though FB-5 had six NC selections, having higher SA and SC excerpts could have led to the small loss. When students are honest about not understanding concepts but do not have the self-confidence to investigate what confused them, one could expect that they would struggle to improve their scores.

FB-6, FB-7, and FB-10 were close in the number of points that they lost on test two, but after further investigations, there were different patterns that surfaced among these students. All three students had higher SA and T excerpts, but their other qualitative codes diverged from there. FB-6 had average SC selections, but when compared to one of the highest T excerpts among the three, this student's transparency and self-assessment numbers could have led to the

small loss of five points on test two. FB-7 had the second lowest number of T excerpts but had the highest number of MDesc passages. He or she had the same number of Inc and NC citations as FB-6 but lost more points. One explanation could be that the high MDesc excerpts did not necessarily mean that they were particularly descriptive; some of the Inc and NC excerpts could have been one of the co-occurrence pairs. FB-10 had the lowest number of SA excerpts among the trio and average SC and T selections. This student did have one of the highest numbers of MR and MDesc selections but also had higher Inc and NC excerpts. Because FB-10 did have one of the highest MR totals, he or she might have a little stronger math background, which could account for this student only losing one more point than FB-7.

Could writing on the metacognitive sheets for two weeks prior to test three have made an impact? Did they maintain the same patterns and show no improvement? Did they build on what they learned about themselves after test two? All of students' excerpt totals decreased on test three, but almost all of the students' test scores improved. FB-5, FB-2, and FB-6 were the only exceptions. FB-5 lost five points, but the student had a significant increase in the number of Inc excerpts; he or she had the highest increase of Inc excerpts among all of the students in this group. He or she already had a high number of NC selections from test two and gained an additional excerpt on this test. Also, this student had among the highest number of SA and SC excerpts, but he or she could have overestimated and been overconfident in his or her current understanding.

FB-2 lost nine points, and this student had a decrease in the number of SA and T excerpts. This student already had a higher number of NC excerpts from test two and gained an additional NC excerpt on this test. Also, this student did not have a change in number of SC selections and still had one of the highest Inc numbers among this group. Because of this

student's higher Inc and NC numbers, he or she did not explain and clarify his or her thinking better when compared to test two. This student's lower SA and T numbers and higher Inc and NC numbers could be reasons for his or her losing nine points on the third test.

FB-6 had no point change from test two and did not have any major excerpt changes, either. The minor changes in FB-6's excerpts could explain why this student's scores did not change. If a student does not have a noticeable difference in his or her assessing what they know or what they don't understand, then one could expect that there would more than likely not be a noticeable increase in the student's achievement.

FB-3 and FB-12 both gained the highest number of points on test three. FB-3 earned a score ten points higher on test three when compared to test two. This student had the lowest number of SA excerpts in the class. The student was also among the lowest T and Inc excerpts as well. He or she had an increase in the number of MDesc and MR citations. The student did not have a high number of SC selections, which could have led this student to not overestimate what he or she knew. The higher MDesc and MR coupled with lower Inc and NC excerpts could account for this student's point gain.

FB-12 not only lost the most points on test two but gained the most points on test three. The student had decreases in almost all of his or her excerpts except for a slight increase in SC. However, this student could be held up as an ideal example of a student transferring what was learned on the metacognitive sheets from test two and assessing what was needed to improve on test three. This student had some of the highest excerpts for SA, T, MDesc, and MR on test two. Even though almost all of these excerpts decreased in number, this student's substantial point gain on the third test could be due to the higher excerpt numbers from test two. Both of the student's Inc and NC slightly decreased, and both the SA and MR selections remained higher. If

a student can self-assess what they knew previously and carry that understanding into another unit, then one could conclude that this type of student should see greater achievement reflected in noticeably improved test scores.

The patterns displayed in Table 19 show students who, with two exceptions, were able to either maintain or notably increase their test scores. These students continued to maintain a reasonably high number of excerpts despite all of them losing points on test two. Overall, they had more self-confidence and self-assessment practice, which could have led to their improved achievement as seen through their test scores. This group appeared to frequently self-assess and wrote an ample amount of math descriptions as they completed the daily metacognitive sheets. The students who had lower Inc and NC and higher MDesc excerpts earned higher test scores. There were a few students who did not have significant improvements on this test, and they, as a whole, had a decent number of MDesc passages, but they frequently had higher Inc and NC excerpts as well. Another reason for the consistent point gains could be because these students had written on the metacognitive sheets for four weeks. One could conclude that writing on the metacognitive sheets daily did positively affect the academic achievement of this group.

Table 13 showed the most frequent co-occurrences from both groups on test three, and these patterns did occur after further investigations into the individual student excerpts. Interestingly, the patterns displayed in Table 14 had an impact on student achievement as well, sometimes as much of an influence as the patterns in Table 13. This could have been anticipated, because MDesc and Inc were co-patterned nineteen times, and the NC and Inc patterns occurred twenty times. Individual students who had higher SA and SC or SA and T co-patterns were able to earn higher test scores, which confirmed what Table 13 displayed. Students who were less clear and incomplete with their math descriptions, even if their MDesc

and MR numbers were higher, did not earn any additional points or lost points on their assessments. When students evaluated what they knew, expressed more transparency about what confused them, and wrote more descriptive excerpts, they were able to raise their test scores or maintain their scores from one test to the next. A more detailed investigation into the qualitative data allowed for a better understanding of how metacognitive thinking, when conducted consistently, could have had a positive impact on student achievement.

### **ANOVA and Paired Samples T-Test Results**

Spring’s statistics showed changes over the course of three tests, as seen on the table redisplayed from chapter four (see Table 5).

Table 5

*Statistics for Spring 2018*

	N	Mean	SD
Test 1	12	78.92	15.17
Test 2	12	66.67	15.47
Test 3	12	66.84	12.81

*Note.* N=Number of Students; SD=Standard Deviation

Table 5 shows that this class had the highest mean on the first test. The students did not answer the metacognitive sheets before taking test one. Even though the class did not complete the sheets prior to the first test, there may be a reason for this test having the highest mean. Students often aspire to succeed on exams, and their ability to learn course material partly relies on their assessing what they know and what they don’t know (Foster, Was, Dunlosky, & Isaacson, 2017). Test one was the first college algebra test that this class had seen. From past experience, the teacher expected that out of the first three tests, test one had the potential to yield the highest scores. Students often spend more time evaluating their knowledge and planning their strategies to perform well on the first test because the semester has just begun. It is a fresh

beginning, and they have opportunities to do well in a new math course. This could account for the higher mean scores on the first test.

Tests two and three had very similar mean scores, which were both lower than the first test. Spring students did answer the questioning sheets for two weeks prior to taking test two, but the mean noticeably decreased by over twelve points. One reason for this decrease could be the limited amount of time that the students were exposed to the metacognitive sheets. The two-week period may not have given this class enough experience with assessing what they knew and understood. They may have presumed to comprehend more than they did. Students' predictions of their classroom understanding are not always very accurate, and most students tend to be overconfident in their self-assessments (Foster, Was, Dunlosky, & Isaacson, 2017). The mean on test three showed a slight increase compared to test two. The standard deviation on test three, however, was noticeably smaller than the previous two tests. The scores were not as spread and were closer to the mean. This class completed the questioning sheets for four weeks before taking test three, and this could have affected the mean score. Being given daily opportunities to write and self-reflect on their learning and understanding over four weeks could be a reason that the mean on test three slightly increased and the spread of the scores decreased. Self-reflection is a follow-up technique once a lesson has occurred that helps students understand where they were and where they are not (Hattie et. al., 2017).

Even though differences can be seen in Table 5, these differences were not statistically significant. The variances among the three means were proven to not be significant using a one-way repeated measure ANOVA, ( $p = .696$ ). Spring still showed improvements from test two to test three, and the metacognitive sheets could have had an impact on those changes. More experience, in this case, did not return a greater improvement in student achievement, as seen

through their test scores. Metacognitive skills take time to develop, and these students might show greater improvements further into the semester given more time.

Fall's statistics showed changes over the course of three tests, as seen on the table redisplayed from chapter four (see Table 7).

Table 7

*Statistics for Fall 2018*

	N	Mean	SD
Test 1	7	76.57	12.46
Test 2	7	72.71	12.33
Test 3	7	81.57	10.13

*Note.* N=Number of Students; SD=Standard Deviation

Table 7 shows that this class had the highest mean on test three and the lowest mean on test two. There was a slight decrease from the first test to the second. The mean for test three was almost nine average points higher than test two, and the spread was smaller. Fall students completed the questioning sheets for two weeks before taking test three, and this could have had a positive impact on the mean. These students were given opportunities every day to write and reflect on their learning and understanding for two weeks before the test. The daily reflections could have led to students' evaluating what they knew and develop a plan to perform well on the third test. When students become more aware of their own tendencies to commit careless errors, that awareness may lead to increased self-regulatory actions in test situations (Schneider & Artelt, 2010).

Tests one and two had means and standard deviations that were more similar to one another when compared to the third test. The class did not answer the metacognitive sheets prior to the first two tests. Their mean decreased from test one to test two, and the standard deviation only decreased slightly. One reason for these small changes could be that the class did not receive the metacognitive sheets which could have helped develop their self-assessing and self-



questioning skills. These skills are vital to develop students' metacognitive abilities. Writing on the questioning sheets daily prior to taking test two could have had a positive impact on fall's scores for test two.

Even though differences can be seen in Table 7, these differences were not statistically significant. The variances between tests two and three's means and tests one and three's means were proven to not be significant using paired samples t-tests ( $p = .133$  and  $p = .313$ ). Fall showed the greatest improvement on test three when compared to both tests one and two, and the metacognitive sheets could have helped the class earn that higher mean. More experience answering the daily sheets could lead to even greater improvements in student achievement further into the semester when given more time to practice self-assessing where they are in their understanding and planning ways to improve their learning.

### Conclusions on the Qualitative Data

Could a relationship exist between the total number of metacognitive sheets that each student completed and their test scores? To investigate this question, the total number of daily sheets completed by each student were tallied and graphed using a scatter plot. Spring's daily sheets were calculated for both tests, and fall's sheets were counted for test three.

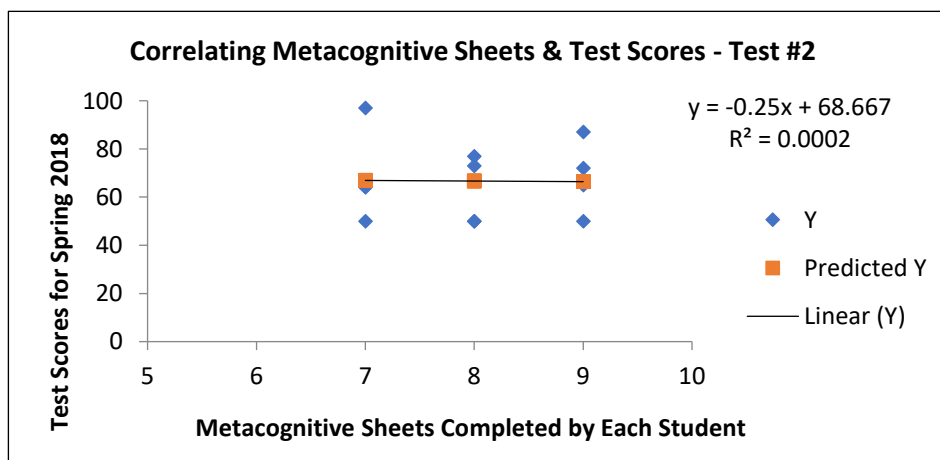


Figure 9. Scatter Plot with Regression Line for Spring 2018, Test #2

Figure 9 shows the relationship between students' individual sheets and test scores. A trend line was constructed onto the scatter plot. The data was widely dispersed and did not reveal a linear relationship. This graph gives a visual representation of the spread of the test scores discussed in the group statistics for test two (SD = 15.47). The slope of the regression line was slightly negative, and the graphed scores had no linear pattern. There appeared to be no correlation between the total number of individual students' metacognitive sheets and their test scores on test two. The total number of students' excerpts for test two were 287, but the students only answered the sheets for two weeks prior to taking test two. This limited amount of time might explain the absence of a correlation.

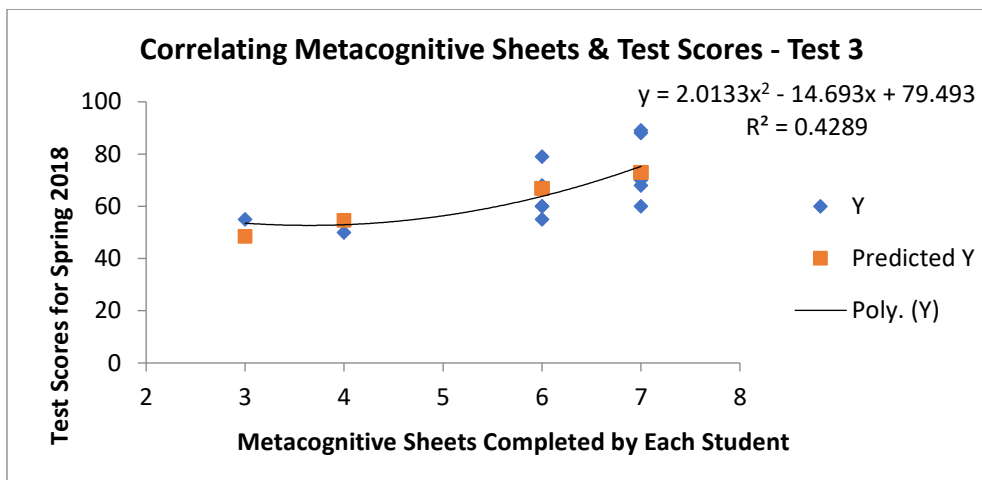


Figure 10. Scatter Plot with Regression Line for Spring 2018, Test #3

Figure 10 shows the relationship between students' individual sheets and test scores. A regression line was constructed onto the scatter plot. The data appeared to show more of a correlation between students' sheets and test scores when compared to test two. This graph gives a visual representation of the spread of the test scores discussed previously in the group statistics for test three (SD = 12.81). As seen in Figure 10, the data appeared more curved than test two's data, and a quadratic regression was a better fit. The total number of students' excerpts for test

three were 242, and the students answered the questioning sheets for four weeks prior to taking test three. Completing the daily metacognitive sheets over four weeks could have impacted test scores and led to the quadratic relationship shown in Figure 10. The additional time spent writing, assessing, and reflecting after test two and preparing to take test three could account for the relationship on test three. They had more time to develop their assessment skills and to describe the mathematics that they were learning. Even though not all of the students' totals increased, a number of the students did improve. The increase in some students' totals could account for the scores not decreasing from test two to test three and also could help to verify that given more time, the students did show improvements. The benefits of written reflections in mathematics are noted in the research surrounding metacognition, self-evaluation, and self-regulation strategies (NCTM, 2012). Having students reflect on math problems that require a written account of the obtained solution to support students in verbalizing their mathematical thinking better supports those students in expressing their knowledge of their mathematical problem-solving process (van Velzen, 2016).

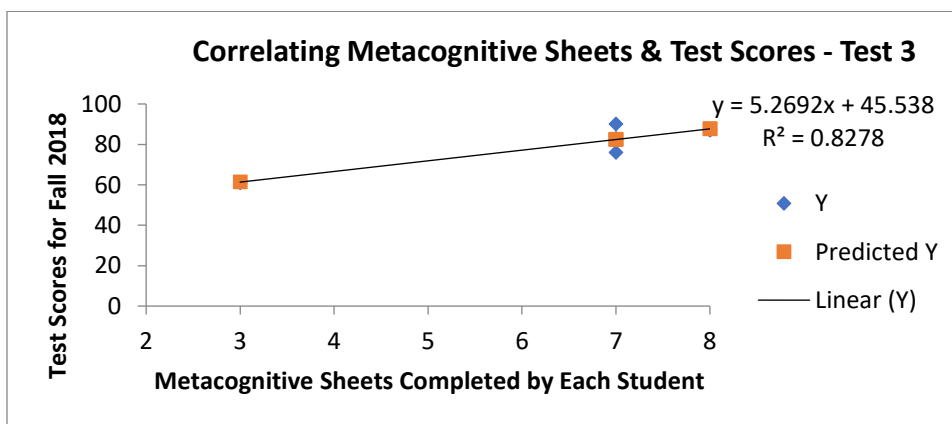


Figure 11. Scatter Plot with Regression Line for Fall 2018, Test #3

Figure 11 shows the relationship between students' individual sheets and test scores for fall's students. The data reveals a positive regression line. There does appear to be a stronger correlation ( $R^2 = 0.8278$ ) between the sheets and the test scores for fall when compared to

spring's correlations. The data was less dispersed and did reveal a linear relationship. This graph gives a visual representation of the spread of the test scores discussed in the group statistics for test three ( $SD = 10.13$ ). The slope of the regression line was positive, and the test scores did appear to show a linear pattern. There appeared to be a correlation between the total number of individual students' metacognitive sheets and their test scores on test three. The total number of students' excerpts for test three were 144, which was a lower total than both of spring's tests. This class answered the metacognitive sheets for two weeks prior to taking test three. Students need guidance in how to become more metacognitively aware; students need to learn the art of self-questioning and self-reflection (Hattie et al., 2017). By answering the sheets daily while preparing for the third test, the questions could have provided students with the guidance necessary to develop a plan to improve after test two. The statistically significant difference ( $p = .019$ ) can be seen when comparing Figures 10 and 11.

### **Scope and Limitations**

In this study, time and the small number of student participants were two delimitations that were found. The study was only conducted four weeks during one semester and two weeks during the next semester. The teacher was only able to use two block college algebra classes and nineteen students. The outcome of the research study resulted in a limited amount of data because this study only had one type of mathematics course and a small number of students from one particular satellite school.

Half of the research study investigated the impact of daily metacognitive questioning during the spring semester at one satellite school. Spring semester was more active than the fall semester. Students were pulled out of academic classes to travel for many athletic games, tournaments, and playoffs. Academic competitions, robotics' competitions, senior college fairs

and assemblies, junior ACT registrations and preparations, etc. took students out of the classroom more often than during the fall semester. Many of the assemblies and meetings that occurred during this study took place during first block, and this caused the first block students in the spring to miss most or all of their class period. Because this study involved one satellite school that served students from three different secondary schools in one county, the events and competitions were multiplied by three. Student absences during this semester could have had an impact on some of the results for the spring students. The ANOVA and the paired t-tests revealed no significant differences within each of the classes, which gave the overall indication that the metacognitive sheets did not have impact on student learning. The lower student daily attendance due to the timing of the research study could help account for there not appearing to be a significant difference for the spring students. For example, if the entire research study had taken place during the fall semester, the athletic and academic events were not as frequent, and this could have had a different influence on the results.

The study involved two consecutive tests over a four-week period. The students were only compared within their own class and to the one other class in the study; they were not compared to other students during additional semesters. Because the study took place during a small window of time, the students' metacognitive skills were still developing. It takes time for students to make metacognitive thinking a habit; self-assessing and self-questioning are not skills that most students do naturally or have previous knowledge. It is important for students to have time to reflect, compare, and adjust their learning and change their behaviors, which will improve performance (Lovett, 2013). Only investigating two tests over four weeks may not have been enough time to evaluate whether or not students were successful in developing these new habits and call on those skills throughout the rest of the semester. Some students may not be

ready for some mathematical concepts because they still need more time to learn some foundational skills (Boaler, 2016). The study might have shown different results if conducted over a longer period of time.

Feedback has been shown to hold great potential for student learning (Jonsson, 2012). Feedback can be one of the most powerful influences on student learning and achievement, but this impact can either be positive or negative. (Hattie and Timperley, 2007). A new research study should consider the frequency and types of feedback. Initial, short written feedback statements could have been given to help guide students' thinking. Limited feedback could have been dispersed throughout the semester as guides for students. Continuous feedback, however, does not have to be included on every metacognitive sheet. The daily feedback could have encouraged students to rely on the teacher's remarks and questioning instead of trying to assess themselves. The feedback could have led some students to write more explanations that matched the teacher's questions from the day before without truly analyzing and reflecting on their own thoughts and understandings.

The teacher feedback also could have inadvertently discouraged students during their learning paths. According to research, feedback does not always lead to self-analysis. People's self-perceptions of skill and the reality of that skill correlate, at best, only moderately, and at worst, they do not correlate at all (Zell & Krizan, 2014). At many times in education, students badly judge their comprehension of education materials; at times, judgements of other people anticipate a person's outcomes better than that person's own self-judgements (Dunning, Heath, Suls, 2018). Feedback does not always lead to self-insight and improvement; feedback often leads the people who need it the least, rather than those who need it the most, to energize themselves toward self-improvement (2018). Sometimes students could profit from peer

assessments to achieve a better self-understanding of their academic performance, in that peers tend to provide evaluations that better match what students think (Lennon, 1995). The written feedback provided by the teacher every day could have had an impact on the results of the study.

### **Recommendations for Future Research**

It is recommended that future research be conducted on the impact of daily metacognitive questioning in more than one school setting. The small number of students, the singular school, and the one teacher during the study should be improved. To improve the validity and reliability of extending the research to other schools or districts, a team of mathematics teachers could collectively write the tests and create an equivalent scoring system for the study. The tests could be used for at least one entire school year, graded using the teacher-created scoring system, and the scores analyzed to strengthen the tests. When the responsibility of creating common assessments and grading systems is given to a team of math teachers instead of one teacher, the internal validity of the test could be strengthened. Using multiple students' test scores on the same assessments over time could also strengthen the reliability of the tests and lead to more confidence in the research.

If additional college algebra students from neighboring school district could have been involved in the current study, their data could have been included. Including other students would have provided additional results on the impact of daily metacognitive questioning. Including metacognitive questioning sheets created and used by multiple teachers instead of one teacher could reveal additional patterns. A master list of metacognitive questions could be created by the same team of math teachers, and they could choose from the uniform list of questions to use in the classroom. This would strengthen the validity of the metacognitive

questions when evaluated later. If the metacognitive sheets were used daily over multiple semesters, their reliability would increase.

Metacognition should be a part of the normal, everyday classroom routine to help students develop skills of realizing where they are, what they know, what is confusing them, and what they can do to improve. Metacognitive thinking does not happen quickly; it takes time for students to cultivate the mindset of questioning themselves and being honest about what they know and understand. A future research study should involve multiple groups of students over several semesters to get a better understanding of the possible impact daily metacognitive questioning can have over time. If possible, some groups of students could be involved in a research study beginning in a lower math class and continuing through an upper math class. What impact does daily metacognitive questioning have on the same groups of students through more than one math course? Do those students know how to think and to assess where they are in their learning paths better than students who only have the questions for one math course? Do they stop and assess themselves through all of their learning without being prompted to do so? Can they explain what they know? What makes them think that they know a certain math concept? These questions could be considered for exploration in future research.

The summative assessments should be designed with problems that elicit more discussion, exploration, and metacognitive thinking. Summative assessments should call students to experience productive struggle, make mathematical connections, construct and describe their thinking, and explain their thinking and solutions. By creating math problems that are beyond one final, correct solution, these types of assessments could help limit opportunities to discuss answers among the various classes of students. “Assessment should not merely be



done *to* students; rather, it should also be done *for* students, to guide and enhance their learning,” (NCTM, 2000, p. 22).

When the researcher created the initial list of codes to use with the students’ metacognitive sheets, there were two different codes that could be construed as describing the same type of metacognitive thinking. The researcher wanted to investigate students’ expressing both positive feelings and negative feelings/confusion about their learning; she felt that both of these types of comments were important characteristics of students’ beginning to incorporate metacognitive thinking into their answers on the daily questioning sheets. The researcher knew the differences between the original qualitative codes – “Self-confidence” and “Transparency,” but the terminology chosen to represent these two lines of thinking only blurred the concepts together. In the future, titles of qualitative codes should be used that are more clear representations of what the researcher wants readers to understand, or categories that the codes represent – if the categories are closely related – could be combined under one code.

If the written feedback in this research study unintentionally influenced what some students wrote on their metacognitive sheets, then a future research study could limit the amount of feedback given and focus more on the types of feedback that is most beneficial to students. The effect size of feedback varies considerably; feedback with the highest effect size involves students receiving feedback about a task and how to do it more effectively; lower effect sizes were related to praise, rewards, and punishment (Nicol and Macfarlane-Dick, 2007). Specifically, feedback is more effective when it provides information on correct rather than incorrect responses and builds on changes from previous trials. This limited number of feedback statements would allow the teacher to see how much self-assessing and self-questioning the students do on their own without being influenced by the teacher’s comments and guidance.

And by being more conscientious about the types of feedback that is given could benefit students more than commenting on every phrase that they write. Feedback should not only provide information about past performance but also help students to improve their current performance (2007). “Feedback is also important for successful learning and helping students connect to prior knowledge. Students can use feedback to help them know when, where, and how to use the knowledge that they know and are learning,” (Bransford et al., 2000, p. 59). Would students maintain their knowledge on their own without help? Would their own self-assessments grow more accurate over time without any outside interference? Would they continue to honest with where they are and question themselves on their own? Would they be able to cultivate plans to improve their learning? These questions could be explored in future research studies. Learning to become more metacognitive helps learners of all ages take charge of what they know and what they need to know in order to be successful (Wilson & Conyers, 2016).

## **CHAPTER VI**

### **Informal Addendum**

#### **Purpose and Research Questions**

In the original research, feedback was written on each students' metacognitive sheets each day. The metacognitive sheets were also coded to investigate possible patterns among the students' responses. The original research study investigated two groups of college algebra students who answered daily metacognitive questions differently. One group answered the questioning sheets during two consecutive math units, and a second group answered the sheets only during the second unit. Both groups received written feedback on their metacognitive sheets. While the original research focused on students' daily written reflections and their possible impact on student achievement as measured through test scores, the research did not investigate students who completed the metacognitive sheets for the same length of time and any patterns that surfaced. The original research also did not investigate whether students would continue to exhibit metacognitive thinking if written feedback were limited.

Butler and Nisan (1996) investigated students who received descriptive feedback from the teacher and students who received no feedback on various tasks; they discovered that students who received no feedback performed poorly on tasks during class and were also less motivated to improve their understanding as the school year progressed. Would this be the case if one group of students received only verbal feedback on their daily sheets? Butler and Winne's (1995) research review showed that both teacher feedback and student self-evaluation affect student knowledge and beliefs. Would students be able to gauge their learning after the teacher's

written feedback were removed? The addendum to this research study explores the possible effect that limiting written feedback could have on students' continuing to self-assess what they know and what they are learning in the classroom. "Feedback has a powerful impact on student learning, with a high effect size of 0.75, placing it in the top ten influences on student achievement," (Hattie et al., 2017, p. 203).

In the original research study, students answered three questions each day at three different points during their lessons. The study showed that students self-assessed where they were during their mathematical learning. They were also honest about what they did not know or expressed confusion about the math concepts during the daily lessons. "Good feedback gives students information that they need so that they can understand where they are in their learning and what to do next," (Brookhart, 2017, p. 2). Because daily written feedback was provided by the teacher, could this feedback have inadvertently led students to write what they believed the teacher wanted to read? If the written feedback were removed and only verbal feedback was given, would the students continue to self-assess? Would they continue to be honest about their learning?

Verbal feedback is a normal characteristic of the researcher's everyday teaching practice. Both groups of students who took part in this addendum received verbal feedback daily, and written feedback was also provided to these two groups for one math unit. The written feedback was removed from the first student group who took part in this addendum during a second math unit; they received daily verbal feedback from the teacher. Written feedback, however, continued with the second group during the next math unit. The same daily questioning sheets were used for both classes. The students were asked to answer the questions during the lessons at three different times each day. Because the original research study revealed that the daily

incorporation of metacognitive questioning could have been one reason for the positive correlation between the sheets and test scores, the teacher continued to use these metacognitive sheets during the addendum (See Appendix A). The following research questions were examined during the addendum:

1. Did students who received written feedback only during the first unit continue to self-assess and to be transparent about the math concepts that they did not know or understand during the second unit when the written feedback was removed?
2. Did students who received written feedback for two math units increase their self-assessment and transparency excerpts during the second unit?
3. Did the students who received the written feedback for two units demonstrate more self-assessment and transparency in their writings when compared to the students who received written feedback only for the first unit?

## **Methodology**

The addendum took place in the same rural public school located in a northern county in the state of Mississippi. The school serves students in 9<sup>th</sup> through 12<sup>th</sup> grades. The student sample in this addendum was a convenience sample of two heterogeneously grouped high school dual-credit college algebra classes; there were thirty-six students altogether. The researcher is also the teacher in these courses. The students are comparable because both classes have similar percentages of juniors to seniors; around 45% of both classes are juniors. All of the students also had to meet the same requirements set by the sponsoring community college and the school district to take the course. None of the students in this addendum took part in the original research study.

Both student groups were asked to answer the daily questioning sheets at three different points during their lessons – before the lesson, during the lesson, and at the end of the lesson – for two math units. (See Appendix E). The sheets were collected at the end of each class period. The teacher made a copy of the sheets and returned the originals to the students the next class period. Both groups received written feedback during the first unit. The first group did not receive written feedback for the second math unit while the second group did.

In the original research study, three of the most common codes were students' self-assessment, self-confidence, and transparency. In this addendum, the researcher chose to focus on self-assessment and transparency. If students are honest about what they do not know or understand, could this transparency lead them to plan, monitor, and assess their learning progress? If students expressed transparency less frequently, could this lead them to self-assess their learning less often? What connections, if any, could be present between students' being honest about their misunderstandings and their self-reflections? The teacher felt that students' transparency could lead to more frequent self-assessing and truthful comments on the metacognitive sheets. The teacher also felt that students' who were less frequently honest could also have fewer recurring self-assessment excerpts. To investigate any connections or patterns, the researcher coded the students' metacognitive sheets for self-assessment and transparency. Table 20 shows some examples of the codes for a few students.

Table 20  
*Sample Student Self-Assessment & Transparency Codes*

Student Number	Self-Assessment	Transparency
S31	“At this point I definitely understand. I would like to see more fraction problems although I feel good about what I’ve learned, I want to practice more”	“I am still confused about imaginary numbers, I am not sure how to get these answers, I need some extra help”
S32	“I am understanding this lesson. The fractions were kind of tough, but I got them now.”	“I think I may struggle on quadratic function (sic) just due to the fact that they’re longer problems with more room for me to mess up.”
S3	“I am pretty confident in Inequalities & Absolute Value problems as well. I am slowly getting better”	“I was so confused on the graphing part I really don’t know which # to put first like the board problem 12 yesterday.”
S12	“I’ve gotten more comfortable with the success criteria today, the more practice problems we solved. I’m not second guessing myself right now.”	“I’m really shaky on the rational inequality problems, but I’m, starting to understand some. I think I need a some more help.”

Table 21 shows some samples of the written feedback provided by the teacher to various students’ self-assessment and transparency answers on the metacognitive sheets.

Table 21  
*Sample Written Feedback Provided by Teacher*

Self-Assessment	Transparency
“I like how you are expressing your confidence in complex numbers. How could your conclusion today connect to your learning from yesterday?”	“I’m glad that you feel comfortable telling me that you are confused about the square root property. Are you more confident that you were at the beginning of class?”
“I know that ‘explaining to a classmate’ may not be something you are ‘good at doing,’ but explaining and communicating well is a great skill to have!”	“This is something that many students have trouble with. Thank you for letting me know! Do you know at what point in Example #2 you got lost?”
“I love your drive to understand the concepts that you are less comfortable about! This is a great self-assessment of what you are confused about.”	“Thank you for being honest about not knowing rational inequalities. It is important to admit when you don’t know about or understand a math concept.”
“Yes! This is fantastic to note for yourself here. I see that you are thinking about how your understanding of quadratic inequalities has improved.”	“I’m glad that you feel confident and safe enough to tell me that I confused you today. I will get together with you tomorrow to discuss what we need to do to help you understand better.”

The researcher wanted to explore the students' responses to the daily questioning sheets and code their self-assessment and transparency responses for both units. She wanted to compare the student group who received written feedback during two math units to the group who received written feedback for only one math unit. She also wanted to see if students continued to self-assess their learning and understanding after the written feedback was removed. Feedback provided to students can inform them about errors and misconceptions that need to be addressed when that feedback is received and absorbed (Hattie et al., 2017). “[Feedback] can lead to increased effort, motivation or engagement to reduce the discrepancy between the current status and the goal,” (Hattie & Clarke, 2019).

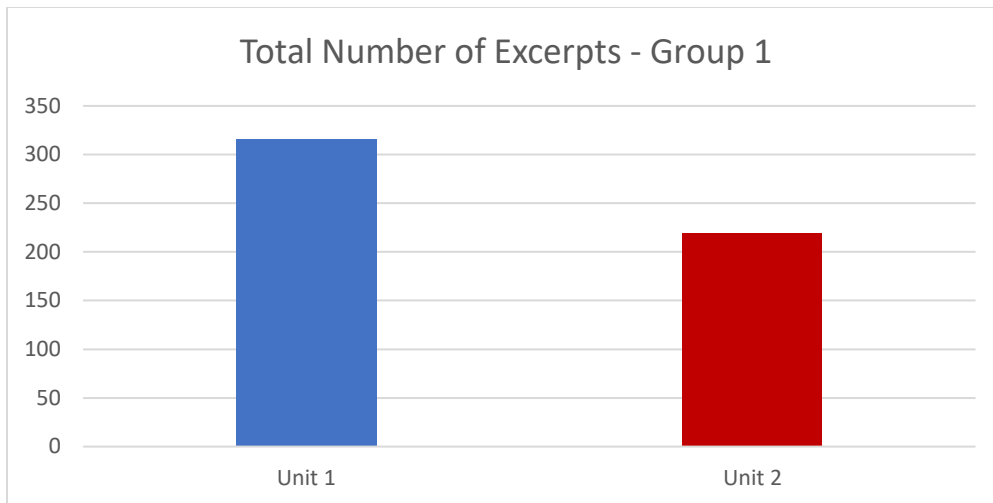
## **Results**

### **Question 1**

Did students who received written feedback only during the first unit continue to self-assess and to be honest about the math concepts that they did not know or understand during the second unit when the written feedback was removed?

There were eighteen students in Group one. Figure 12 shows the total number of excerpts that were coded for Group one for both units in this addendum. Three students who were absent during part of the first or second unit were provided a copy of the metacognitive sheet(s) that they missed and were given the opportunity to answer the sheets for written feedback during the first unit. Those sheets were not included in the data. Group one received written feedback for one math unit.





*Figure 12. Excerpt Totals for Both Units.*

Figure 12 shows that Group one's self-assessment and transparency codes decreased from 316 on unit one to 219 on unit two; this was a reduction of almost one hundred comments. The group had almost a 70% decrease from unit one to unit two. This decrease is a slightly less decrease when compared to group two, which is shown on the subsequent pages. These students received written feedback during the first unit and received no written feedback, only verbal feedback, during the second unit.

Figure 13 shows the total number of Group one's individual self-assessment excerpts for both math units.

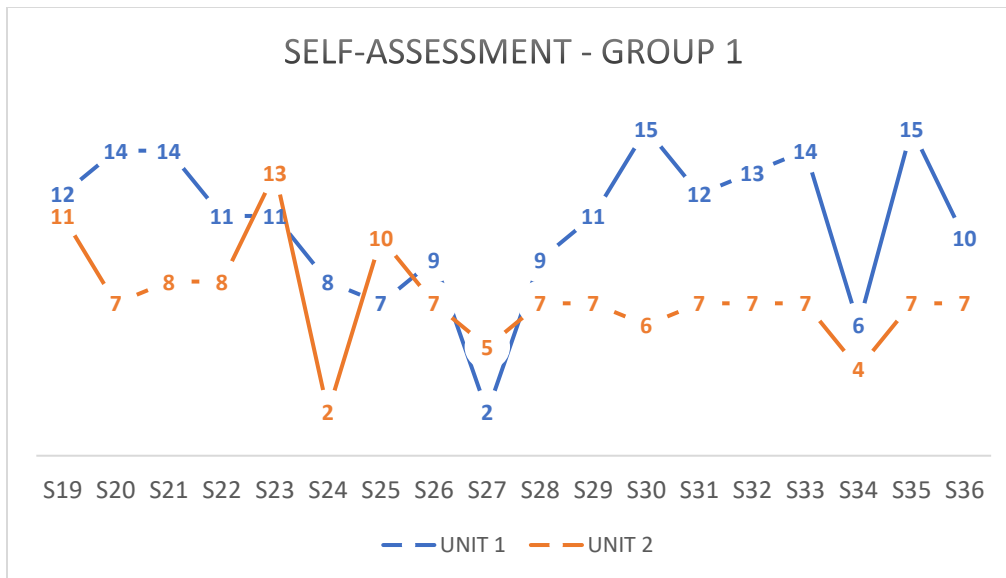


Figure 13. Individual Self-Assessment Excerpts – Only 1 Unit with Feedback

Figure 13 shows that three students, S23, S25, and S27, had slightly higher self-assessment excerpts during the second unit when compared to the first unit, which is the unit that this group received the written feedback each day. Interestingly, S27 had the lowest total during unit one but did slightly improve during unit two. Several students – S20, S21, S24, S30, S33, and S35 – had noticeable decreases from unit one to two. Unit one’s excerpt totals were less consistent when compared to the second unit, and unit two’s excerpts were fewer in number. Unit two had more uniformity than the first unit. Half of the students had seven excerpts during unit two, which were still notable decreases from unit one to unit two. Most of the remaining students were within a point or two from seven, with S24 and S34 being exceptions. S24 was absent for two classes during unit two, but the student only chose to write two self-assessment statements during the remaining days during unit two. S34 only had two excerpts during the second unit, which was the lowest total in this unit; this student was not absent at all during either unit. Most of the group did not self-assess as frequently during the second unit after the written feedback was removed.

Figure 14 shows the total number of Group one’s individual transparency excerpts for both math units.

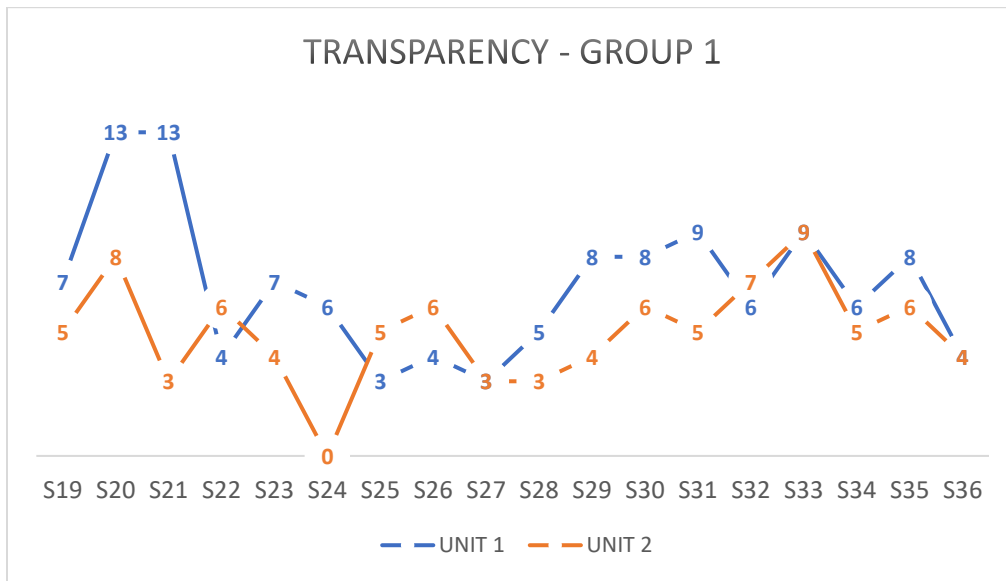


Figure 14. Individual Transparency Excerpts – Only 1 Unit with Feedback

Figure 14 reveals that some students were more honest during the first unit when compared to the second unit. Four students, S22, S25, S26, and S32, had slightly higher transparency excerpts during unit two when compared to their first unit. S27 and S33 made no gains during unit two but maintained their same totals from unit one. The remaining students were less honest after the written feedback was removed during unit two. S24 was one of the students who missed school during unit two. However, S24 did not express transparency at all during the remaining days of unit two; this was the only student with no transparency comments. S25 was also absent during unit one and did not notably increase transparency during unit two. A second student, S21, had the largest excerpt decrease. S21 had thirteen transparency excerpts during the first unit and decreased ten excerpts to only three during the second unit. S36 was also absent for one day during units one and two, and this student chose to write enough on the daily sheets to earn the same number of excerpts for both units. Figure 14 shows that this group does not appear to have any consistency among their transparency excerpts during either unit. Despite

receiving written feedback during unit one, the excerpts for this unit were not markedly much higher than unit two in which the students received only verbal feedback. The majority of them did not express their confusion or lack of understanding during the second unit.

Figure 15 shows the sum of the students’ self-assessment, and the sum of their transparency for both units one and two.

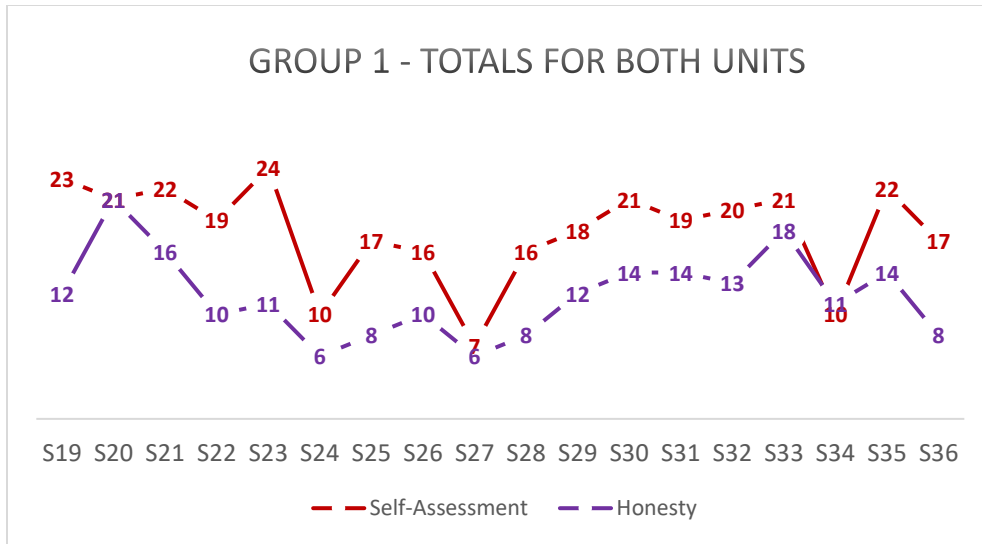


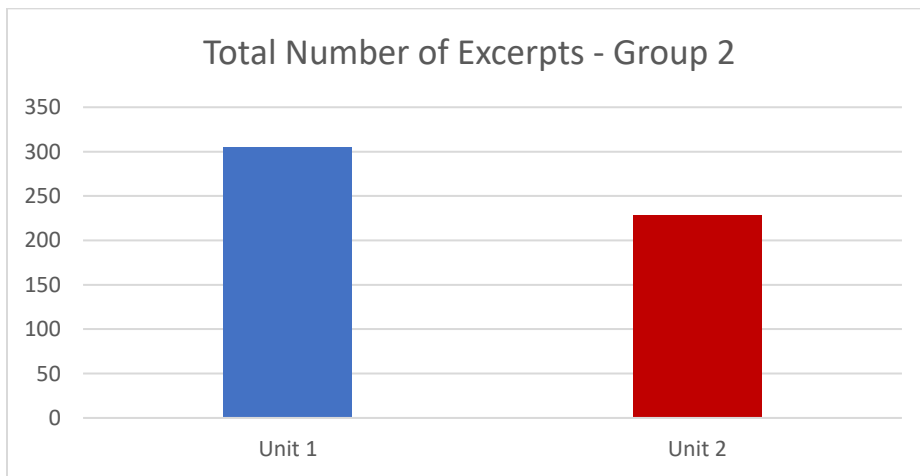
Figure 15. Individual Self-Assessment and Transparency Totals

All of this group, with two exceptions, had lower transparency when compared to self-assessment overall. S34 is the only student with one higher self-assessment comment than transparency on unit one, and S20 showed no difference between self-assessment and transparency. S23 showed the greatest difference between the two codes – thirteen higher self-assessment than transparency. S19 also had a noticeable difference between self-assessment and transparency – eleven higher self-assessment. Neither S23 nor S19 was absent any days like S24 and S36. About half of the group wrote close to the same number of self-assessment and transparency comments, but remaining students varied more. Higher self-assessment did not lead this group to higher transparency.

## Question 2

Did students who received written feedback for two math units increase in their self-assessment and transparency on the second unit?

There were also eighteen students in Group two. Figure 16 shows the total number of excerpts that were coded for Group two for both units in this addendum. Two students who absent during part of the first or second unit were provided copies of the metacognitive sheet(s) that they missed and were given the opportunity to answer the sheets for written feedback. Those sheets were not included in the data for the units. Group two received written feedback during two math units.



*Figure 16. Excerpt Totals for Both Units.*

Figure 16 shows that Group one's self-assessment and transparency codes decreased from 305 on unit one to 228 on unit two; this was a decrease of almost eighty comments. The group had almost a 75% decrease from unit one to unit two. This decrease is actually a slightly higher decrease when compared to group one, who had a decrease of almost 70%. It is important to remember that group two received written feedback during both units one and two. Group one received written feedback during unit one, verbal feedback during unit two, and had less of a decrease in the total number of excerpts.

Figure 17 shows the total number of Group two’s individual self-assessment excerpts for both units.

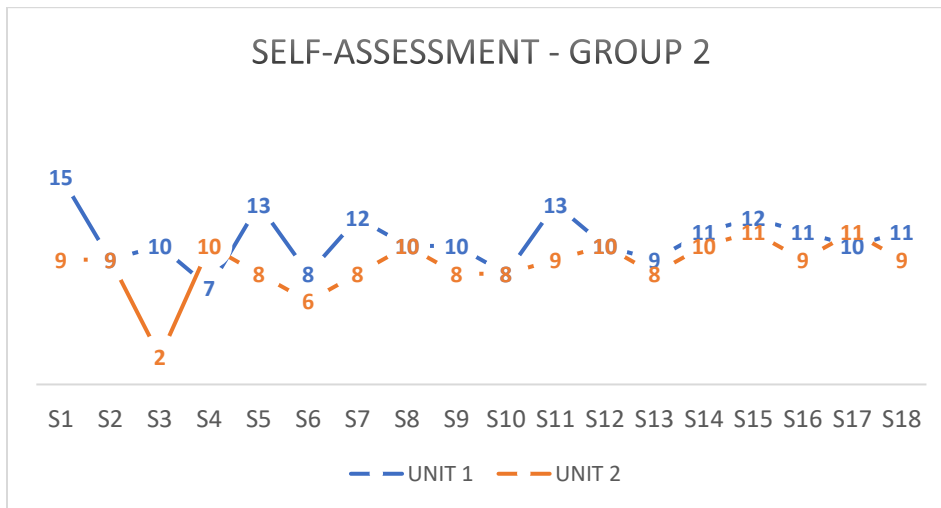


Figure 17. Individual Self-Assessment Excerpts – Two Units with Feedback

Figure 17 reveals that this group had self-assessment totals during unit one that were greater than eight, with one exception, S4, who had seven. Interestingly, group one had more students with self-assessment comments that were fourteen and fifteen than group 2. Most of group two self-assessed consistently during unit two; this group continued to receive written feedback during the second unit. Only two students, S2 and S3, had more notable decreases in self-assessment from unit one to two; neither of these students were absent during unit two. S4 and S17 had slightly higher self-assessment on unit two. S1, S8 and S12 had the same self-assessment on both units. The remaining students had only slight decreases in their comments between the two units. S2 decreased from fifteen excerpts during the first unit to nine; S3 dropped from ten comments to two. S5 decreased from thirteen during unit one to eight during unit two, and this student completed all of the questioning sheets every day. The remaining students decreased between two and four self-assessment excerpts from unit one to two. Figure 17 shows that this group, for the most part, self-assessed steadily during both units.

Figure 18 shows the total number of Group two’s individual transparency excerpts for both math units.

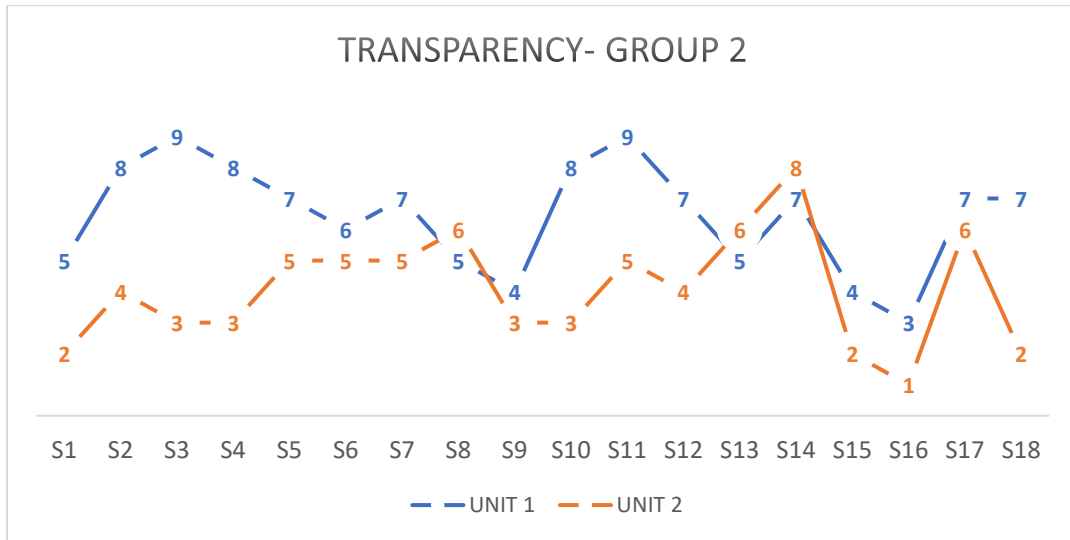


Figure 18. Individual Transparency Excerpts – Two Units with Feedback

As Figure 18 shows, almost all of these students were more honest during unit one when compared to unit two. All of the students except three, S8, S13, and S14, had fewer transparency excerpts on the second unit. These students did receive the written feedback for both units one and two, but they did not continue to express transparency about any misconceptions or confusion. S8, S13, and S14 all had a slight increase of one comment during unit two. The remaining fifteen students decreased their excerpts from unit one to two. When compared to group one, group two had fewer students with higher transparency on unit two. This group also had no students with excerpts that had zero changes from unit one to two, but group one had three students with zero change. This group’s transparency excerpts vary from unit one to unit two, which is similar to group one’s transparency. Figure 18 shows a group whose transparency fluctuates from student to student during both units. Despite receiving written feedback during both units one and two, the excerpts for unit two did not show a notable improvement. The

majority of them did not express their confusion or lack of understanding consistently during either unit.

Figure 19 shows the sum of the students’ self-assessment and transparency excerpts for both units.

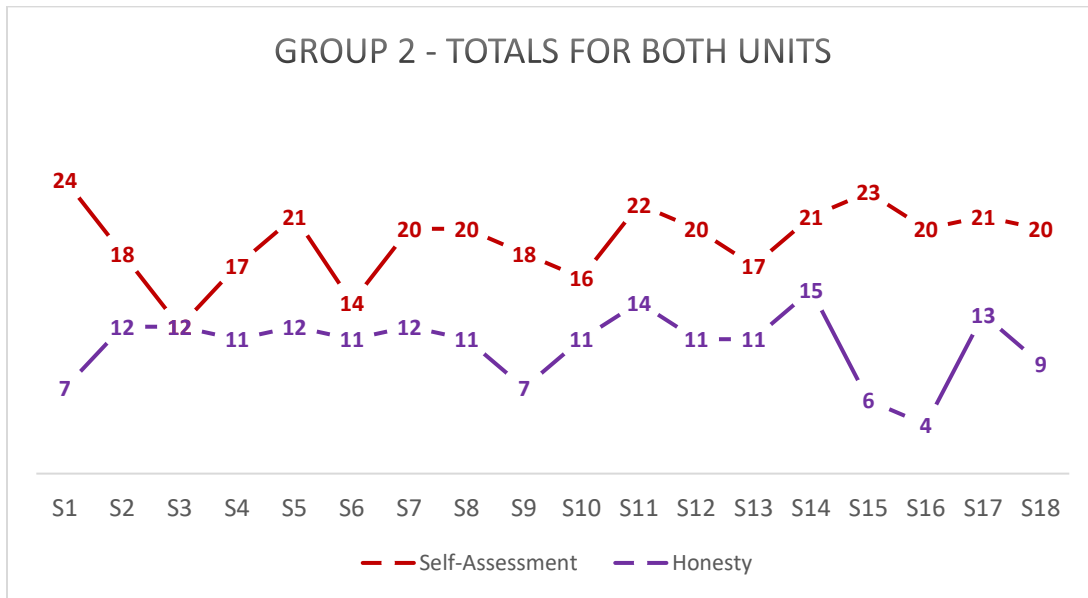


Figure 19. Individual Self-Assessment and Transparency Totals

All of this group, with one exception, had lower transparency when compared to self-assessment overall. S3 is the only student who showed no difference between self-assessment and transparency. Both S1 and S15 showed the greatest difference between the two codes – seventeen higher self-assessment than transparency. S1 also had one of the four lowest transparency totals in this group. S16 also had a notable difference – sixteen higher self-assessment than transparency. Thirteen students in this group had transparency totals higher than ten; these totals were slightly less than group one. This group did have high self-assessment excerpt totals like group one. Group two’s transparency excerpts were also similar to group one’s transparency. Even though this group received written feedback during both units, they did not show improved self-assessment and transparency when compared to group one.



### Question 3

Did the students who received the written feedback for two units demonstrate more self-assessment and transparency in their writings when compared to the students who received written feedback only for the first unit?

Figure 20 shows the total number of metacognitive sheets that group one answered for both units one and two.

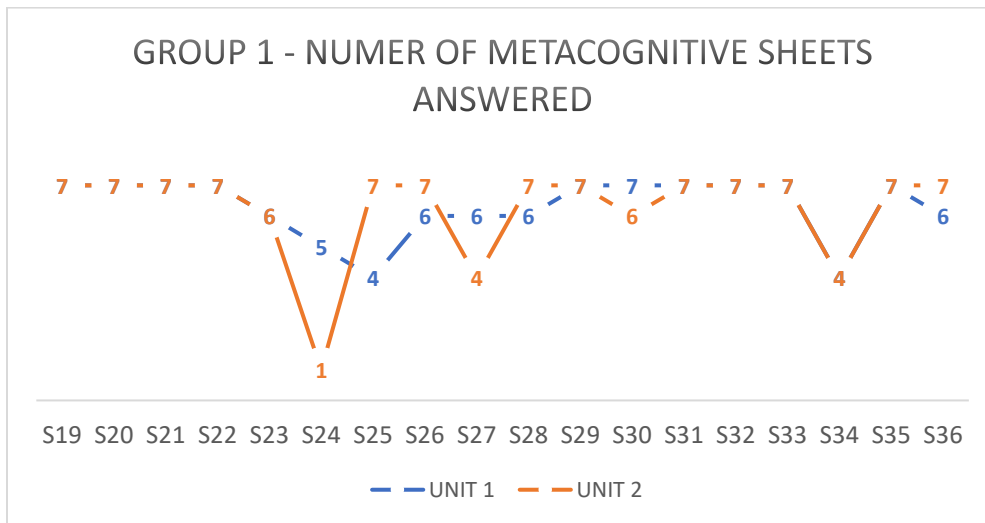


Figure 20. Only Unit 1 with Feedback

S25, S26, S28, and S36 wrote on more metacognitive sheets during the second unit than the first, and S25 was absent two days during the first unit. Half of these students, nine out of eighteen, wrote on the metacognitive sheets all seven days for both units. Eleven students completed the same number of sheets for both units. S24, S27, and S30 answered more sheets during unit one. S24 answered the least number of sheets, but this student was also absent two days during unit two. This student, however, only chose to answer one sheet. S25, as stated earlier, was absent during part of unit one but chose to answer four sheets. Even though most of this group had noted decreases in their self-assessment and transparency comments, eighty-three percent of this group increased or maintained the same total of metacognitive sheets during both

units. Figure 20 shows that most all of the students were willing to complete the sheets every day; their answers, however, did not reveal consistent metacognitive thinking.

Figure 21 shows the total number of metacognitive sheets that group two answered for both units one and two.

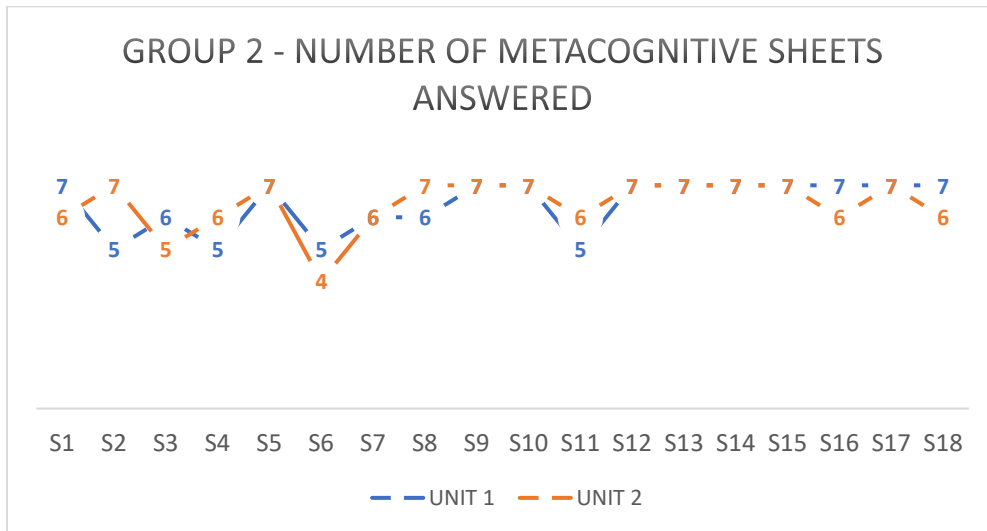


Figure 21. Two Units with Feedback

S2, S4, S8, and S11 wrote on more metacognitive sheets during the second unit than the first. Eight out of eighteen students wrote on the metacognitive sheets all seven days for both units. Nine students completed the same number of sheets for both units. S1, S3, S6, S16, and S18 wrote on more sheets during the first unit. S6 answered the least number of sheets during unit two; this student was not absent during either unit. Figure 21 reveals that almost half of the students from group two consistently answered their metacognitive sheets each day. Even though group one had five students who answered one less metacognitive sheet during unit two, seventy-eight percent of the group either increased or kept the same daily totals or from unit one to two, which is slightly lower than the first group. However, group two did not have a student who showed a noticeable drop in the number of metacognitive sheets completed; the first group did have the one student who chose to answer one metacognitive sheet during unit two. Figure

21 shows that most all of the students were willing to complete the sheets every day. Paired with self-assessment and transparency, however, does not reveal consistent metacognitive thinking.

## **Discussion**

The addendum to this research study sought to determine if removing written feedback from students' daily metacognitive sheets would affect their continuing to self-assess about their learning and to express transparency about what confused them. The addendum also sought to compare two groups of students to see if there were any noticeable differences between them. Did the two student groups have comparable self-assessment and transparency excerpts after receiving the written feedback differently? Did the written feedback for two units increase group two's self-assessment and transparency? Did removing the written feedback from group one impact their comments?

To help address the aforementioned questions and investigate some explanations for the groups' patterns on the metacognitive sheets, the teacher asked the students in each group to complete a student survey (See Appendices F and G). The students were asked to reflect on their daily metacognitive sheets. Students were asked to explain why they did not answer any sheets that were missing for units one or two. They were asked to analyze their answers to the questions and assess the quality of what they wrote. They were also asked if they felt that the written feedback and the verbal feedback for group one during unit one were helpful. Did the students feel that the sheets helped them? Would they change anything? Did they want to continue to answer the questions for feedback? How did group one feel about their receiving only verbal feedback during unit two? The students' survey answers helped shed light on their self-assessment and transparency during both units (See Appendices H and I).

## Question 1

Did students who received written feedback only during the first unit continue to self-assess and to be honest about the math concepts that they did not know or understand during the second unit when the written feedback was removed?

Group one had almost one-hundred more excerpts during the first unit when compared to the second unit, which was almost a 70% decrease from unit one to unit two (See Figure 12). Group one also had fewer comments on both units when compared to the second group, but group two had almost a 75% decrease from unit one to unit two. One might conclude that one reasonable explanation for this decline could be the removal of the individualized written feedback. Because the students did not receive any written feedback during unit two, this could have led students to express their transparency and analyze their learning less frequently. Students may have relied on the feedback during the first unit to direct their written explanations. They may not have had enough time to develop stronger self-assessment skills. One unit could possibly have not been enough time for these students.

Some of the students' comments, however, revealed that most of them did not feel that receiving the verbal feedback instead of written negatively impacted them. When asked how they felt about receiving only the verbal feedback, many students responded "Good," "I appreciated it," "Okay, some days I may have needed more, but I ended up coming to your desk to ask questions," and "It was different from other feedback I have gotten before." Some students wrote that they didn't feel much different about the verbal feedback, and many other students said that it either helped them or did not hurt them. These same students also admitted that most of them did not write any more during unit two than they did during unit one; these students also had no suggestions for the teacher to improve the written or verbal feedback.

However, this group did write longer responses to the questions concerning unit one with the written feedback. Their responses to the written feedback were more detailed such as “It was helpful. I was told whether I was wrong or not and reassured that I can always ask for help...,” “Your feedback helped explain it more in depth,” and “It was encouraging to have positive feedback on what I write down.” They may have thought the removal of the written feedback did not affect them, but their receiving only written feedback for one unit may not have been long enough for this group to grow more metacognitive.

Only three out of eighteen students – S23, S25, and S27 - increased their self-assessment excerpts during unit two when compared unit one, and these students only had small increases. These students stated on the surveys that the verbal feedback either helped some them or, “They [verbal comments] don’t really do anything to me really.” This could be an explanation for the small increase. A few students had small decreases, but the remaining six students showed significant reductions in self-assessment. When this group received the written feedback during the first unit, over half of them wrote more comments that were greater than ten. This pattern was not repeated during unit two. One reason for this decrease could be that the students were more motivated by the feedback to continue self-assessing themselves during the unit. The teacher individualized each written comment that the students received, and this could have helped them grow more confident as unit one progressed. This could be one reason why the majority of this group felt that the verbal feedback did help them. Another reason could be that the students simply over-assessed what they thought they knew when, instead, they should have been more honest about what they knew and what they did not understand.

The students’ transparency answers also decreased as a whole. The decreases were not as noticeable as their self-assessment excerpts. One explanation could be because their

transparency comments overall were not as high as their self-assessment. S22, S25, S26, and S32 had slight increases in transparency during unit two, and S27 and S33 made no gains. Some of these students admitted that they could have been more descriptive during unit one, however, not all of them said this. Only two students decreased by four or five, while two students had more visible decreases – S24 by six and S21 by ten. S21 wrote that he or she “I wrote everything I was having trouble with,” and “I like knowing that you know what I’m struggling with.” However, these statements, when compared to the student’s transparency, did not match. This student also could have over-assessed what he or she knew. The remaining students did have comment totals for both units that were similar. The group, however, did not continue to be as honest as they were during the first unit when they received the daily written feedback.

After the written feedback was removed and the teacher gave individual verbal feedback instead, the students’ comments decreased overall. However, it is interesting that this group did not feel that the removal of the written feedback hurt them. Most students wrote that the verbal feedback continued to help them. Even though the verbal feedback was well-received from most of students, not all students are the same. Another reason for the decrease could be that the students felt that their answers to the daily questions were not as important as they were during the first unit. More students wrote on their survey questions phrases like, “I didn’t feel much different,” “The sheets helped me on the first test more,” and “The first test, in my opinion, required more work from me.” Maybe feelings such as the previous examples accounted for some of the students’ decline in their self-assessment and transparency totals such as the ones shown in Figure 15.

## Question 2

Did students who received written feedback for two math units increase in their self-assessment and transparency on the second unit?

Group two had almost eighty more excerpts during unit one when compared to the second unit. This decrease, however, was only slightly larger when compared to group one's decrease. Group two's students also had eleven less comments during the first unit when compared to group one. Because group two started out with fewer excerpts than group one, their decrease of almost excerpts was more noticeable – 75% - when compared to group one's 70% decrease, redisplayed below in Figures 12 and 16.

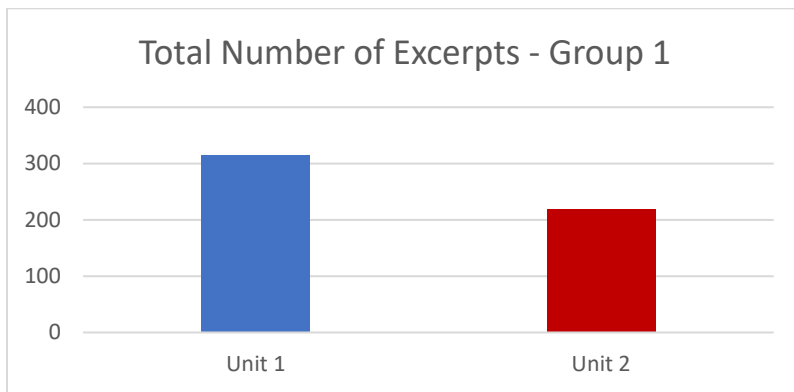


Figure 12. Excerpt Totals for Both Units.

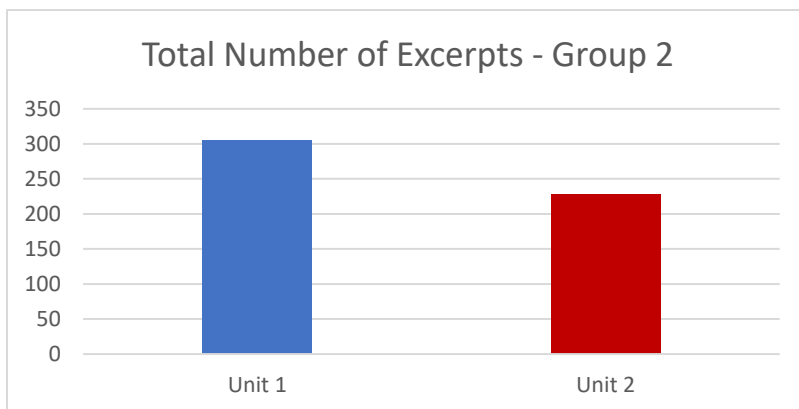


Figure 16. Excerpt Totals for Both Units.

Both groups received the written feedback during unit one. Group two's excerpt totals are more comparable during the first unit. Because the written feedback was not removed during

the second unit, these students continued to receive guidance from the teacher for two consecutive units. The feedback could have helped some of these students write honest comments and assess their learning as frequently as group one.

Because these students did receive individualized feedback, one might conclude that they would have maintained or surpassed unit one's excerpt totals, however, students do not instinctively think metacognitively. Students have to learn and to develop metacognitive habits and changing their thinking and reflecting routines takes time. The feedback for two units may not have been adequate enough to help students fully understand self-assessment and metacognitive thinking practices. Also, answering the questions was voluntary, and some of the students chose not to complete as many daily questioning sheets during unit two.

Another conclusion about group two's excerpt decline could be that students simply did not want to write as much during the second unit as they did during the first unit. More students in this group expressed indifference or negative feelings about the metacognitive sheets that group one did. Some of the survey comments were, "I feel that they weren't helpful to me," "I found it[sheets] helpful sometimes, but most of the time it [writing on the sheets] kind of felt like an extra task," and "It [the feedback] was simple but I didn't really need it." Because this class did decrease by 75% from unit one to two, maybe some students did not deem their self-assessing as valuable or self-assessing their learning as important. The students who felt that the sheets were insignificant could have led to this group's slightly higher decline in their excerpt totals when compare to group one.

Figure 19 showed that most students were willing to answer the metacognitive sheets daily, however, this consistency did not necessarily lead the students to write more self-assessing and honest answers during unit two. Self-assessing and metacognitive thinking were unfamiliar



concepts to these students prior to the addendum of this research study, and some students did not feel that metacognition had a positive impact on their learning. However, there were students who were adamant that answering the questions did have a positive impact on them. Some of these comments were “Yes!! Because they [the sheets] gave me a chance to ask my questions without having to talk in front of the class...,” “Yes. The sheets help me put more thought into what we learn every day,” “Yes. I feel that they [the sheets] were very helpful. Because it gives you an idea about what we are having trouble in...,” and “It reinforced what I knew in the past...I felt like the feedback was very helpful.”

All of these students had self-assessment totals during unit one that were greater than eight except for S4 who only had seven. Most of this group self-assessed consistently during units one and two. While this group received written feedback during both units, eleven of them had self-assessment excerpts that were ten or higher during the first unit. This pattern was slightly lower during unit two. Six students had comments that ten or higher. Despite the overall decrease in self-assessment excerpts, group two’s comments were more consistent between the two units when compared to group one. One reason for this pattern could be that these students receive the written feedback during both units. Reading through many of the students’ answers on the survey, the feedback did motivate most of them to continue to self-assess during the second unit.

This group’s transparency excerpts varied more when compared to their self-assessment excerpts. All of this group except three had fewer transparency excerpts on the second unit, which was more similar group one than the self-assessment totals. One explanation could be that the students did not use the feedback from the first unit to continue to be honest about their learning. Students should gain information about where they are in their learning and about what

to do next; once they understand what to do and why, most students develop a feeling about what they know and understand and what they don't (Brookhart, 2017). Although feedback can help to reduce the gap between what students know and what they don't know, students can also choose to reject the feedback and deem it as irrelevant or not informative (Hattie & Clarke, 2019). Several students' comments revealed that some did not find the written feedback as beneficial. "It was more of a neutral feeling [useful or not]," "I didn't really need it," "Eh. It neither helped me nor hurt me," and "I don't think it really helps."

Because the written feedback was provided to this group for both units, one might expect that the students would at least continue to self-assess and be honest about their learning from unit one to unit two. However, this was not the case. As seen in Figure 19, there were very large gaps between students' self-assessment totals and their transparency totals. S1, who did not feel that the daily questioning sheets and feedback had any impact on his or her learning, had a self-assessment sum seventeen points than transparency. When asked on the survey to explain why this student felt he or she wrote less during unit two than unit one, the student wrote, "[He wrote less because] I realized that the metacognition didn't really help me or hurt me all that much...I'm sure that this question-answer is very helpful to many people, but not I." S11, who had a nine-point difference between self-assessment and transparency, stated, "The feedback was only helpful sometimes...I wrote less [because] once I got more comfortable with the class, the sheets became a task rather than a comfort." S16 also expressed some indifference to the sheets and feedback as well, which could explain his or her larger differences. One interesting note here is that these students continued to write on the sheets regularly despite the fact that answering the sheets was completely voluntary. If they felt as if the writing was not helpful, one

might conclude that they would choose to complete the daily sheets less often than others in the class, but this was not the case.

Their self-assessment totals were more consistent for both units when compared to group one, but these totals did not noticeably increase even with the written feedback. They also did not have increased transparency totals, either. These were interesting patterns because this group did receive the written feedback during both units; one would expect that they would have shown more consistency and an increase in their excerpt totals when compared to the first group. However, with several students expressing apathy with the metacognitive sheets and the consistent written feedback, this could explain the larger differences between self-assessment and transparency as shown in Figure 19.

### **Question 3**

Did the students who received the written feedback for two units demonstrate more self-assessment and transparency in their writings when compared to the students who received written feedback only for the first unit?

As Figures 20 and 21 showed, most of the students in both groups made an effort to answer the metacognitive sheets every day, in spite of several students in group one expressing obligation to writing on the sheets daily. The students who did try to write on the sheets every day continued this pattern during both units. Even though most students exhibited this pattern, it did not lead the majority of students to increase their number of self-assessment and transparency excerpts from unit one to two. This pattern was present in both groups.

Half of group one's students, nine out of eighteen, answered the sheets all seven days during both units. Even with their deliberate efforts to answer the sheets, this did not lead to their being consistent in self-assessment and transparency. This group's self-assessment excerpts

varied between the units, but they remained more consistent among the students within each unit. Some of the students' comments to the survey questions revealed that they felt the removal of the written feedback did not negatively affect their learning, but only receiving the verbal feedback may not have been adequate. Many students who wrote every day during unit one had some of the largest decreases in their self-assessment comments when compared to unit two. Their willingness to write everyday did not lead the group to increase their self-assessment. The transparency totals were less varied for this group; their will to write each day could be one explanation for their frequent transparency responses about being confused. Many were also honest about the quality of their answers. Some stated, "On the days that I was rushing to finish, the questions were probably not as lengthy as I wanted them to be," "On some I feel like I could have explained it better," and "I didn't spend too much time on them [the sheets]." Another pattern to note is that the students who wrote less frequently did have the lowest self-assessment and transparency totals when compared to the rest of the group.

Group two had eight out of eighteen students who answered the sheets every day during both units; this was one less student who made this effort when compared to group one. The remaining students' daily totals were similar between the units, but this did not lead them to be more consistent self-assessing or being honest about their learning each day. Group two's self-assessment and transparency sums shown in Figure 19 revealed totals that were more visible than group one. Group two had three students who had higher than a fifteen-point difference between their self-assessment and transparency sums; group one's highest two differences were thirteen and eleven. Also, group one had two students who only had a difference of one between the aforementioned sums, and group two had did not have a student with this difference. With several students having either apathetic or negative feelings about the metacognitive sheets –

feelings which was not frequently expressed in group one - this could explain why group two had a slightly larger decrease in their excerpt totals from unit one to two. Their survey answers could also explain their varied and inconsistent transparency during unit two.

One might conclude that group two's receiving both verbal and written feedback for two units would lead to more student being consistent in their writings. The whole group did not show this pattern. Group one had more students who wrote on the metacognitive sheets every day when compared to group two, but this did not lead group one's self-assessment totals to increase. Their transparency totals were varied, and these totals overall were not as high as group two's totals. However, their honest excerpt totals were more similar between the two units than their self-assessment excerpt totals. Both groups had students who chose to answer a high number of the metacognitive sheets daily, but the two groups did diverge from here.

Group one had more students who increased their transparency from unit one to two than group two had. One explanation for this difference could be because group one did not have as many students who viewed the daily sheets and feedback as negatively as some of group two. If group one had received the same amount of written feedback as the second group, the students might have shown more consistency. Group two did have many students who were consistent in their self-assessment, but not all of the group exhibited consistency in their transparency. Group one's totals revealed that they possibly need more time and guidance that written feedback could provide. Group one may have needed more than just written feedback; they may have needed a break from written feedback, which could mean that possibly they needed more verbal and less written feedback from the teacher.

## Scope and Limitations

This study is limited by the small number of students and the singular mathematics course; only thirty-six students participated in the addendum to the research study. Because the study was conducted in a dual-credit college algebra course, students in a course that does not require an ACT score may not produce similar results in the same amount of time. Even within the study, the students' ACT scores could vary considerably as could the number of mathematics courses taken prior to college algebra. Several students wrote comments about their prior math knowledge such as, "I don't remember anything about imaginary numbers," or "I don't think my algebra teacher talked about this [rational expressions]," and sometimes, "I've never heard of quadratic inequalities before." Over half of the students in both groups had not taking a math course in almost two years, and some of these students' highest math course prior to college algebra was algebra II. It is possible that many students truthfully did not retain math concepts from their previous courses because of the time that had passed between that course and college algebra. It is also possible that they were not as confident in previous math courses and did not want to write something that revealed this to the teacher. There are many unknowns that could explain the variability among the students beyond the aforementioned possibilities.

Answering the metacognitive sheets were optional, which could explain why some students chose not to answer the questioning sheets every day. However, this does not provide a clear reason why some students answered the sheets every day even though they felt it was a tedious "task" or felt "obligated" to answer them. The parental consent form clearly stated that participation in the research study was optional and that there was no penalty for opting out of the study. Students were also reminded by the teacher that writing on the metacognitive sheets was both welcome and helpful in planning the next day's lesson, but students did not have to

answer the sheets. It is possible that students simply chose on some days not to answer the questions. Some students chose not to answer all of the questions every day. One explanation for this could be that the students did not have any questions or confusion about the day's lesson. It is possible that they were not sure how to word their answer and chose not to write a response. It is also possible that some students simply grew tired of answering the questions; maybe they did not want to write any more beyond the lesson of the day. Some of the students' answers to the survey questions revealed that some of them did feel that the daily sheets were not applicable to them and their learning. Some students wrote, "I'm really indifferent about them [the sheets]. I personally am not helped by the sheets," "They weren't helpful. It did not affect what I learned," and "[The sheets] It doesn't change me. I still would get the information and understand it."

Though the addendum to this research did indicate that some students from group one did continue to self-assess and express transparency, this was not the case with the majority of the group. It is possible that the students from the first group who only received written feedback for the first unit did not receive enough guidance that individualized written feedback could provide. The feedback might have been removed from these students too soon. They may have needed more exposure to the feedback and more time to use this feedback to improve their abilities to self-assess areas where their prior knowledge was weak and to track how their understanding is improving. It is also possible the students would need more than two units of feedback to develop stronger self-assessment skills. Many students in this group felt that they did not feel discouraged in their learning after the written feedback was removed. Many students stated, "[wrote more during unit two] Cause (sic) I realized how much they helped me," "[wrote

more during unit two] Because it helped last time, so why stop now,” and “[wrote more during unit two] I think I started to understand the importance of writing down on the sheets.”

The second group did exhibit more consistent self-assessment responses, but they had inconsistent and varied transparency excerpts than the first group. Group two’s self-assessment and transparency responses as a whole did not increase in spite of the continued written feedback. One explanation for this could be that the students did not feel that it was necessary to write more detailed answers to the questions. As mentioned previously, this group had several students who did not feel that the daily sheets had a positive impact on their learning. They could have taken the feedback as a positive influence and could have challenged themselves to write more self-assessment or transparency comments, but many of them did not. It is possible that this group could have benefitted more if the feedback were limited. This slow removal is an interesting idea that could be explored with additional research.

After reading many of the students’ answers to the survey questions, the teacher realized that the format of the daily metacognitive sheets could have led to several students in both groups to see the sheets as tedious and unhelpful. Some students wrote that they would like to see more warm-up problems and closing problems on the metacognitive sheets. Several students asked the teacher about replacing the pre-lesson and end-of-lesson questions with challenging problems or more problems that they can create and solve themselves; they expressed that they did not always feel like answering three questions every day. Had the students not completed the surveys honestly and did not feel safe in the classroom to express their feelings, the teacher would not have known about their feelings. “Some days I did not like filling out the sheets,” and “Maybe give us more questions where we make up our own problems or a small example to work on the sheet would be nice,” were a couple of the students’ requests. These are changes



that can be made easily. Writing on the sheets every day, three times a day, may just have led to several students viewing the sheets as a tedious task rather than as an asset to them.

Several students also did not feel that the feedback was consistently helpful or needed. Some comments were “Sometimes they were just compliments and questions back to me that I never got to answer,” “There is only so much you can find feedback on...it was helpful sometimes,” “It was simple,” “I like longer responses [than I’m getting], but I would rather get a response than not one at all,” and “I don’t feel like it [the feedback] affected me at all.” The teacher reexamined the written feedback that she provided, and more personalized feedback could have been written. Also, students expressed that they did not know how or if to respond to the probing questions provided by the teacher on their daily sheets. When asked specific, purposeful questions about their thinking, one student wrote, “How can I respond to the questions you ask me on there [the sheets]?” Setting aside a space and an additional time for student conferences discussing the additional questions are some things that the teacher did not think about prior to this addendum. The most effective feedback is just feedback that students actually use to improve their learning (William & Leahy, 2015). “Good feedback contains information that students can use, which means that students have to be able to hear it and understand it,” (Brookhart, 2017, p. 2). The students need guidance on how to use that feedback effectively; feedback must be used by the students to improve their learning in the classroom.

### **Future Research**

A natural next step in this research could focus on moving beyond pencil/paper and hand-written responses to using technology with the metacognitive sheets. Incorporating technology and using devices could investigate would give students opportunities to types their answers on an online platform, which could have a positive impact on their responses. Technology could

lead students to type lengthier and more detailed responses. With the current online platforms available to both students and teachers, collecting, reading, and responding to students could be more easily accomplished. Since voice recognition capabilities are becoming more standard with the online platforms, students could verbally answer metacognitive questions instead of hand write their answers. This could open a door to students giving more detailed, complete answers. Teacher also could benefit from the online platform; they can provide feedback verbally. The technology could also help teachers organize all of the students' responses and teacher feedback more easily to explore later for student growth or patterns. The average high school student has a confidence in and an understanding of various technological devices; they use technology every day. Embedding daily metacognitive in the students' familiarity with technology would be an interesting investigation.

All students in Mississippi are required to take information and communication technology (ICT) one and two in middle school. They also take a science, technology, engineering, and mathematics (STEM) course. All three courses help students learn and use computer software and applications including online platforms. By changing the questioning sheet delivery, it would be interesting to research whether students' responses were more detailed, more frequent, and possibly more accurate over time. The students would also have constant and instantaneous access to their personal responses. The communication between the teacher and the student – in real time – could have a positive impact on students' self-assessing and being truthful with themselves. More research is needed on the impact that technology could have on typed responses when compared to written responses on the metacognitive sheets.

All students, both high and low achievers, need up to five exposures to their learning over several days before there is a reasonable probability that they will learn, (Nuthall, 2005).

Students may not always develop self-assessing skills quickly. It may take longer than four weeks for students to improve in their metacognitive thinking, but, given time, students can learn to note their errors and have chances to address them (Hattie et al., 2017). Students need to practice how to monitor, evaluate, and make plans about their own work in relation to the learning targets; training and practice in self-assessment can help students grow more accurate in their self-evaluations (Brookhart, 2017). Altering the metacognitive sheets to possibly include differentiated warm-up problems and more student-created problems to as exit ticket would break-up the monotony of answering questions three times daily. Giving students more choices would put the learning in their hands. These changes might lead students to be more willing to metacognitive thinking if questions are presented in different forms. “We must make sure that we not only commend learners when and specifically on what they are doing well, but also help them identify actions they need to take in order to get back on the path [to learning],” (Hattie et al., 2017, p. 208). Giving students more choices – beyond simply choosing whether or not to answer daily questions – could lead them to being more receptive to evaluating their own work and learning progress, which can help them get back on the path to becoming a more metacognitive learner.

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## LIST OF APPENDICES

Appendix A

Daily Metacognitive Sheets Format and Student Example

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Remember: Metacognition – “The gift that keeps on giving.”

Daily Learning Intention: \_\_\_\_\_

Daily Success Criteria: \_\_\_\_\_

Pre-Lesson

During-Lesson

Post -Lesson (Exit Ticket) –

Name \_\_\_\_\_

Date: 2/7/18

"The gift that keeps on giving."

Daily Learning Intention: Solve and represent rational inequalities and on number lines and in interval notation; solve square root and cubed root equations and verify their solutions.

Daily Success Criteria:

I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation.

I can solve a square root equation and check the solutions to verify that the solutions are true.

I can solve a cubed root equation and check the solutions to verify that the solutions are true.

Pre-Lesson - What is one thing that you know about square roots and cubed roots in general?

$$\sqrt{x} = x^{\frac{1}{2}}$$

$$\sqrt[3]{x} = x^{\frac{1}{3}}$$

Are these two expressions equivalent?

Did you mean these to be equal?

During-Lesson - What have you learned so far in this lesson about square roots and cubed roots? Try to name something specific.

- On #5, I learned you had to square the whole side instead of just the square root.  $(1+\sqrt{x+4})^2$  instead of  $(\sqrt{x+4})^2$ . <sup>good to</sup>
- I learned the pattern  $(x^2, x^1, \text{whole \#})$  that makes solving the equations easier. <sup>remember.</sup>   
 ↳ when were we able to notice this pattern? Did you understand when we did it?

Post-Lesson (Exit Ticket) - What are three things that you learned from the lesson today that stood out to you?

- $x^2, x^1, \#$  pattern
- square whole side instead of square root only
- Rational exponents are just multiplied by its reciprocal.   
 ↳ Can we do this with any fractional exponent? Positive or negative?

Appendix B

College Algebra Test #2 – Versions 1 & 2

**Name:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**MAT 1313 – College Algebra**

**Test #2**

Write solutions only on the test. Work only on scratch paper. Solve each equation.

1)  $\frac{-2}{x-3} + \frac{3}{x+3} = \frac{-12}{x^2-9}$

2)  $\frac{2x+5}{2} - \frac{3x}{x-2} = x$

3)  $|4 - 3x| = |2 - 3x|$

4)  $\sqrt{3x} - \sqrt{5x+1} = -1$

5)  $\sqrt[3]{5x^2 - 6x + 2} - \sqrt[3]{x} = 0$

6)  $x^{-2/3} + x^{-1/3} - 6 = 0$

7)  $\left| \frac{6x+1}{x-1} \right| = 3$

Solve each inequality. Write your answers in interval notation.

8)  $2 - 4x + 5(x - 1) < -6(x - 2)$

9)  $10 \leq 2x + 4 \leq 16$

10)  $2x^2 - 9x \leq 18$

11)  $\frac{x+2}{3+2x} \leq 5$

12)  $4|x - 3| > 12$

13)  $\left| 5x + \frac{1}{2} \right| - 2 < 5$

14)  $x^2 < 25$

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**MAT 1313 College Algebra**

**Test #2**

Write solutions only on the test. Work only on scratch paper. Solve each equation.

1)  $\frac{3}{x-2} + \frac{1}{x+2} = \frac{12}{x^2-4}$

2)  $\frac{4x+3}{4} - \frac{2x}{x+1} = x$

3)  $|3 - 2x| = |5 - 2x|$

4)  $\sqrt{2x} - \sqrt{3x + 12} = -2$

5)  $\sqrt[3]{3x^2 - 9x + 8} - \sqrt[3]{x} = 0$

6)  $2x^{-2/5} - x^{-1/5} - 1 = 0$

7)  $\left| \frac{2x+3}{3x-4} \right| = 1$

Solve each inequality. Write your answers in interval notation.

8)  $8x - 3(x + 5) < -6(x - 2)$

9)  $-6 \leq 6x + 3 \leq 21$

10)  $3x^2 + x \leq 4$

11)  $\frac{x+2}{x-5} \leq 1$

12)  $5|x + 1| > 10$

13)  $\left| 2x + \frac{1}{3} \right| + 1 < 4$

14)  $x^2 > 16$

Appendix C

College Algebra Test #3 – Versions 1 & 2

**Name:** \_\_\_\_\_  
**MAT 1313 College Algebra**

**Date:** \_\_\_\_\_  
**Test #3**

Write answers on the test. You must show your work to receive credit for an answer.

For the points (2, -2) and (10, -6), give each of the following:

1. Distance between the points
2. Midpoint of the line segment joining the points

For the points (-5, 3) and (7, -5), give each of the following:

3. Distance between the points
4. Midpoint of the line segment joining the points

**Given the center (4, -6) and radius (5) of a circle,**

5. Give the equation of the circle in center-radius form.
6. Give the equation of the circle in general form.
7. Sketch a graph of the circle (on the graph paper)
8. Give the center & radius of the circle with equation

$$x^2 + y^2 - 4x + 12y + 4 = 0.$$

Center:

Radius:



9. Give the center & radius of the circle with equation

$$4x^2 + 4y^2 + 4x - 16y - 19 = 0.$$

Center:

Radius:

Decide whether each relation defines  $y$  as a function of  $x$ . If it is not a function, explain why. Give the domain and range of each relation.

10.  $y = 2x^2 + x + 2$

Function? If no, why?

Domain:

Range:

11.  $y = -2x^2 - 2$

Function? If no, why?

Domain:

Range:

12.  $y = -x^3 + 2$

Function? If no, why?

Domain:

Range:

13.  $x = -y^2 - 3$

Function? If no, why?

Domain:

Range:

14.  $y = \sqrt{2x + 4}$

Function? If no, why?

Domain:

Range:

15. Sketch a graph of  $y = -2x^2 - 2$

16. Sketch a graph of  $x = -y^2 - 3$

17. Sketch a graph of  $y = \sqrt{2x + 4}$

Let  $f(x) = -x^2 + 2x + 1$  and  $g(x) = -2x + 3$ . Find each of the following in simplest form.

18.  $f(g(x)) =$

19.  $g(f(x)) =$

20.  $(f + g)(x)$

21.  $(f - g)(x)$

22.  $(fg)(x)$

23.  $\frac{f}{g}(x)$

Domain of  $\frac{f}{g}(x)$

Let  $f(x) = \sqrt{5x - 1}$  and  $g(x) = \frac{1}{x}$ . Find each of the following in simplest form.

24.  $f(5) =$

25.  $g(0) =$

26.  $(fg)(x) =$

27.  $\frac{f}{g}(x)$

Domain of  $\frac{f}{g}(x)$

Using the difference quotient, find the following parts for  $f(x) = 2 + 2x^2$

28.  $f(x + h)$

29.  $f(x + h) - f(x)$

30.  $\frac{f(x+h)-f(x)}{h}$

**Name:** \_\_\_\_\_  
**MAT 1313 College Algebra**

**Date:** \_\_\_\_\_  
**Test #3**

Write answers on the test. You must show your work to receive credit for an answer.

For the points (5, -2) and (13, -6), give each of the following:

1. Distance between the points
2. Midpoint of the line segment joining the points

For the points (-4, 3) and (2, -5), give each of the following:

3. Distance between the points
4. Midpoint of the line segment joining the points

**Given the center (5, -4) and radius (7) of a circle,**

5. Give the equation of the circle in center-radius form.

6. Give the equation of the circle in general form.

7. Sketch a graph of the circle (on the graph paper)

8. Give the center & radius of the circle with equation

$$x^2 + y^2 - 12x + 10y + 25 = 0.$$

Center:

Radius:

9. Give the center and the radius of the circle with equation

$$4x^2 + 4y^2 + 4x - 8y - 7 = 0.$$

Center:

Radius:

Decide whether each relation defines  $y$  as a function of  $x$ . If it is not a function, why? Explain. Give the domain and range of each relation.

10.  $y = 3x^2 + x + 2$

Function? If no, why?

Domain:

Range:

11.  $y = -2x^2 - 1$

Function? If no, why?

Domain:

Range:

12.  $y = -x^3 + 3$

Function? If no, why?

Domain:

Range:

13.  $x = -y^2 - 2$

Function? If no, why?

Domain:

Range:

14.  $y = \sqrt{2x + 2}$

Function? If no, why?

Domain:

Range:

15. Sketch a graph of  $y = -2x^2 - 1$

16. Sketch a graph of  $x = -y^2 - 2$

17. Sketch a graph of  $y = \sqrt{2x + 2}$

Let  $f(x) = -x^2 + 4x + 1$  and  $g(x) = -3x + 4$ . Find each of the following in simplest form.

18.  $f(g(x)) =$

19.  $g(f(x)) =$

20.  $(f + g)(x)$

21.  $(f - g)(x)$

22.  $(fg)(x)$

23.  $\frac{f}{g}(x)$

Domain of  $\frac{f}{g}(x)$ :

Let  $f(x) = \sqrt{4x - 1}$  and  $g(x) = \frac{1}{x}$ . Find each of the following in simplest form.

24.  $f(5) =$

25.  $g(0) =$

26.  $(fg)(x) =$

27.  $\frac{f}{g}(x)$

Domain of  $\frac{f}{g}(x)$

Using the difference quotient, find the following parts for  $f(x) = 1 + x^2$

28.  $f(x + h)$

29.  $f(x + h) - f(x)$

30.  $\frac{f(x+h)-f(x)}{h}$

## Appendix D

### Daily Metacognitive Questions – Learning Intentions, Success Criteria, & Lesson Questions

<h1>DAY 1</h1>
<b>Daily Learning Intention: Solve absolute value equations and inequalities and write solutions in interval notation.</b>
<b>Daily Success Criteria:</b> <ul style="list-style-type: none"><li>• <b>I can solve an absolute value equation in one variable.</b></li><li>• <b>I can solve an absolute value inequality in one variable and represent the solution in interval notation.</b></li><li>• <b>I can solve special case absolute value equations and inequalities.</b></li></ul>
<u>Pre-Lesson</u> – What do you already know about absolute value in general? What do you know and understand about linear inequalities?
<u>During-Lesson</u> – How well do you understand absolute value equations and inequalities so far? Why do you think that?
<u>Post -Lesson (Exit Ticket)</u> – Create your own problem similar to one that we did today in class and solve it. How could you verify that your solution is correct?



## DAY 2

**Daily Learning Intention: Solve absolute value & linear inequalities in one variable and write solutions in interval notation.**

**Daily Success Criteria:**

- **I can solve an absolute value inequality in one variable and represent the solution in interval notation.**
- **I can solve special case absolute value equations and inequalities.**
- **I can solve a linear inequality in one variable and represent the solution on both a number line and in interval notation.**

Pre-Lesson – What did you learn in yesterday’s lesson that was new to you?

During-Lesson – What have I learned so far that made the learning intention clearer for me? What makes me think this?

Post -Lesson (Exit Ticket)

Name one way that today’s lesson was different from yesterday’s lesson.

Name one way that today’s lesson was the same as yesterday’s lesson.

## DAY 3

Daily Learning Intention: **Apply learning of absolute value equations and inequalities with solutions written in interval notation to the MathLab homework assignment for Chapter 1, Section 8.**

Daily Success Criteria:

- **I can solve an absolute value equation in one variable.**
- **I can solve an absolute value inequality in one variable and represent the solution in interval notation.**
- **I can solve special case absolute value equations and inequalities.**

Pre-Lesson – Summarize what you have learned so far about absolute value equations and inequalities so far.

During-Lesson – The hardest thing about this section on absolute value equations and inequalities for you has been what? Why?

Post-Lesson (Exit Ticket) – After looking back at the section, where do you think you could make a careless mistake? What makes you say that?

## DAY 4

Daily Learning Intention: **Solve and represent linear, three-part, and quadratic inequalities on number lines and in interval notation.**

Daily Success Criteria:

- **I can solve a linear inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a three-part linear inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a quadratic inequality in one variable and represent the solution on both a number line and in interval notation.**

Pre-Lesson – What do you think that linear, quadratic, and three-part inequalities could all have in common? What makes you think that?

During-Lesson – Do I have any questions about what I am learning in class today? What makes me say this?

Post-Lesson (Exit Ticket) – What were the main mathematical concepts that we discussed in class today? What stood out to you as new?

## DAY 5

Daily Learning Intention: **Solve and represent quadratic & rational inequalities and on number lines and in interval notation.**

Daily Success Criteria:

- **I can solve a quadratic inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a rational equation that gives a linear solution and verify that the solution is true.**

Pre-Lesson – What do you already know about solving rational (fraction) equations with variables?

During-Lesson – What have you noticed about this lesson so far that reminds you of what we investigated in last week's lesson?

Post-Lesson (Exit Ticket) – How would you explain what we did in today's lesson to a classmate that was absent? Give an example to help him or her understand clearly.

## DAY 6

Daily Learning Intention: **Solve and represent rational inequalities and on number lines and in interval notation; solve rational equations and determine which numbers do not work in the denominator.**

Daily Success Criteria:

- **I can solve a rational equation that gives a linear solution & verify that the solution is true.**
- **I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a rational equation that gives quadratic solutions and verify the solutions are true.**

Pre-Lesson – I think today’s learning intentions will be ... (“very easy” to “very hard”).  
Why do I think this?

During-Lesson – Am I making progress toward today’s learning intention so far? What specifically makes me think this?

Post -Lesson (Exit Ticket) – Describe any patterns that you noticed after today’s lesson. Be as specific as you can.

## DAY 7

Daily Learning Intention: **Solve and represent rational inequalities and on number lines and in interval notation; solve square root and cubed root equations and verify their solutions.**

Daily Success Criteria:

- **I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation.**
- **I can solve a square root equation and check the solutions to verify that the solutions are true.**
- **I can solve a cubed root equation and check the solutions to verify that the solutions are true.**

Pre-Lesson – What is one thing that you know about square roots and cubed roots in general?

During-Lesson – What have you learned so far in this lesson about square roots and cubed roots? Try to name something specific.

Post -Lesson (Exit Ticket) – What are three things that you learned from the lesson today that stood out to you?

## DAY 8

Daily Learning Intention: **Use learning intentions and success criteria to complete Chapter 1, Section 7 of the Math Labs homework problems.**

Daily Success Criteria:

- **I can solve a linear inequality in one variable and represent it on a number line & in interval notation.**
- **I can solve a three-point inequality and represent the solutions on a number line & in interval notation.**
- **I can solve a quadratic inequality and represent the solutions on a number line & in interval notation.**

Pre-Lesson – Name some things that you remember about Chapter 1, Section 7 after you have ready the success criteria. What stands out to you as important concepts?

During-Lesson – How well am I remembering these success criteria so far? What makes me say that?

Post -Lesson (Exit Ticket) – What do I need to do to prepare for my test containing this section? What do I know the best? What do I know the least?

## DAY 9

Daily Learning Intention: **Use all Success Criteria for Test #2 to complete Practice Test #2.**

- **I can solve a rational equation that gives quadratic solutions and verify that the solutions are true.**
- **I can solve a rational equation that gives a linear solution and verify that the solution is true.**
- **I can solve an absolute value equation in one variable.**
- **I can solve a square root equation & a cubed root equation and check the solutions to verify that the solutions are true.**
- **I can solve an equation written in quadratic form that has fractional exponents like I solve quadratic equations with positive integer exponents.**
- **I can solve a linear inequality in one variable and represent it on a number line & in interval notation.**
- **I can solve a three-point inequality and represent the solutions on a number line & in interval notation.**
- **I can solve a quadratic inequality and represent the solutions on a number line & in interval notation.**
- **I can solve a rational inequality and represent the solutions on a number line & in interval notation.**
- **I can solve an absolute value inequality in one variable and represent the solution on a number line & in interval notation.**

Success Criteria for Test #2

Pre-Lesson – Which of the above success criteria do you think you remember the least?

What makes you think this?

During-Lesson – How well am I remembering the success criteria for Test #2 so far?

Post-Lesson (Exit Ticket) – After completing the practice test, what do I still feel that I need to work on the most? What am I the most comfortable with after today?



## DAY 10

Daily Learning Intention: **Remember prior knowledge of graphing linear equations using a table and finding the distance and midpoint between two ordered pairs on a line.**

Daily Success Criteria:

- **I can find the length of a line segment given two points using the distance formula.**
- **I can find the middle of line segment given two points using the midpoint formula.**
- **I can verify that any point on a graph will result in a true equation when their coordinates are substituted into the equation.**
- **I can graph an equation by creating a table of values and plotting the points.**

Pre-Lesson – What do you already know about finding the distance and the half-way point between two ordered pairs?

During-Lesson – How comfortable are you with the learning intentions so far?

Post -Lesson (Exit Ticket) – Do you have any questions about what we have learned so far? Is there anything confusing you right now?

# DAY 11

Daily Learning Intention: **Write equations for circles and graph circles using the center & radius.**

Daily Success Criteria:

- **I can write the center-radius form of a circle given the center and the radius.**
- **I can graph a circle given to me in center-radius form.**
- **I can write the equation of a circle in General Form given the center & the radius.**

Pre-Lesson – What learning intentions do you remember from the last lesson? Can you specifically name one?

During-Lesson – The hardest thing about this lesson so far for you has been what? What makes you say this?

Post -Lesson (Exit Ticket) – Name one way that today's lesson was different from the previous lesson? How do you think that you could relate the last lesson to today's lesson? (Be specific)

## DAY 12

Daily Learning Intention: **Use knowledge of center-radius form and determine if equations for circles exist; connect characteristics of a circle to a relation and a function.**

Daily Success Criteria:

- **I can determine if a given equation is a circle with a radius, a single point, or doesn't exist.**
- **I can determine if a graph, table, or set of ordered pairs represents a function.**
- **I can explain how I know that a circle is not a function.**
- **I can explain how the domain and range of a function is represented on a graph, in a table, or in a set of ordered pairs.**

Pre-Lesson – Which Success Criteria for today connects to yesterday's Success Criteria? Explain what you think the connection is.

During-Lesson – How can you reword one of today's Success Criteria in a different way?

Post-Lesson (Exit Ticket) – Create a problem of your own similar to a problem that you worked yesterday or today on circles. Show how you would work it below.

## DAY 13

Daily Learning Intention: **Understand function notation and apply that knowledge to solve equations.**

Daily Success Criteria:

- **I can explain what function notation is and how the output of a function is matched to its input.**
- **I can use function notation to solve various problems that involve  $x$  &  $f(x)$ .**
- **I can write an equation and solve it using function notation.**

Pre-Lesson – Read through the learning intention and success criteria. How much do you already know about them? Explain your previous knowledge.

During-Lesson – Is there something that you have learned so far in this lesson that has caused you to change your mind about something that you thought you already knew? What was it?

Post -Lesson (Exit Ticket) – What have I learned about function and function notation so far? What do I still need to know?

## DAY 14

Daily Learning Intention: **Transfer your previous knowledge of functions to new situations – operations with functions, domain and range after these operations, and composite functions.**

Daily Success Criteria:

- **I can calculate the four operations using functions.**
- **I can solve combinations of functions given graphs or tables the functions.**
- **I can use the difference quotient to solve problems given the functions.**
- **I can explain what the composition of functions means and use that knowledge to solve problems.**
- **I can find the domain of a composite function.**

Pre-Lesson – What do you remember about how to tell if a graph, table, ordered pairs, or mapping input/output representations are functions or are not functions? Please be specific.

During-Lesson – Is there anything that you are confused about right now with functions, operations with functions, or function notation?

Post -Lesson (Exit Ticket) – What have you learned about functions so far today? What do you still need to know about anything that we explored in today's lesson?

# DAY 15

Daily Learning Intention: **Transfer your previous knowledge of functions to new situations – operations with functions, domain and range after these operations, and composite functions.**

Daily Success Criteria:

- **I can calculate the four operations using functions.**
- **I can solve combinations of functions given graphs or tables the functions.**
- **I can use the difference quotient to solve problems given the functions.**
- **I can explain what the composition of functions means and use that knowledge to solve problems.**
- **I can find the domain of a composite function.**

Pre-Lesson – How much do you already know about function operations? What do you think you might struggle understanding in the success criteria for today?

During-Lesson – What could you write or draw that might help you remember and understand the success criteria so far?

Post -Lesson (Exit Ticket) – Explain what a composite function is in your own words and tell me the purpose of composite functions.

## DAY 16

Daily Learning Intention: **Understand and explain composite functions and name the domain of these functions.**

Daily Success Criteria:

- **I can explain what the composition of functions means and use that knowledge to solve problems.**
- **I can find the domain of a composite function.**

Pre-Lesson – What do you remember from the last lesson about the Difference Quotient?

Do you remember it being difficult for you to understand? Why?

During-Lesson – How is your learning of composite functions going so far? What makes you think this?

Post -Lesson (Exit Ticket) – Create a problem similar to one that we did in class today and solve it. What would your domain of this function be?

Appendix E

Addendum: Daily Metacognitive Questions – Learning Intentions, Success Criteria, & Lesson Questions

<h2>DAY 1</h2>
Daily Learning Intention: <b>Solve one-variable linear equations, identify types of linear equations, and solve a literal equation for a specified variable</b>
Daily Success Criteria: <ul style="list-style-type: none"><li>• <b>I can solve one-variable linear equations with both integers and fractions</b></li><li>• <b>I can identify the types of equations – identity, conditional, and contradiction</b></li><li>• <b>I can justify how I know the three types of linear equations</b></li><li>• <b>I can solve a literal equation for a specified variable</b></li></ul>
<u>Pre-Lesson</u> – What do I already know and remember about linear equations? What do I think that “equality” means in terms of linear equations?
<u>During-Lesson</u> – How do I feel about the Success Criteria so far? What makes me think this?
<u>Post –Lesson (Exit Ticket)</u> – Is there anything specific that I think I might need to work on after today’s lesson?



## DAY 2

Daily Learning Intention: **Solve a literal equation for a specified variable & understand and perform operations with the imaginary unit  $i$ .**

Daily Success Criteria:

- **I can explain what the imaginary unit  $i$  actually is**
- **I can write solutions that involve the imaginary unit  $i$  in  $a + bi$  (complex) form**
- **I can simplify and perform operations with square roots involving  $i$**

Pre-Lesson – What do I remember about imaginary numbers? Do I remember having trouble with imaginary numbers?

During-Lesson – As of right now, am I confident about the Success Criteria, or am I confused about something?

Post-Lesson (Exit Ticket) – Name two things that I feel are important from today's lesson that I need to remember?

## DAY 3

Daily Learning Intention: **Solve a literal equation for a specified variable & understand and perform operations with the imaginary unit  $i$ .**

Daily Success Criteria:

- **I can solve quotients using complex conjugates**
- **I can explain the repeating cycle of  $i$**

Pre-Lesson – What is something from yesterday’s lesson that stood out to me? What should I make of note of from yesterday’s lesson?

During-Lesson – What is something new that I have learned in today’s lesson so far?

Post -Lesson (Exit Ticket) – Did I understand everything in today’s lesson? Is there a Success Criteria that I am still confused about?

## DAY 4

Daily Learning Intention: **Perform operations with the imaginary unit  $i$  and factor quadratic equations using various methods**

Daily Success Criteria:

- **I can solve quotients using complex conjugates**
- **I can explain the repeating cycle of  $i$**
- **I can factor quadratic equations into two binomials**
- **I can use the zero-factor property to find the solutions to a quadratic equation**

Pre-Lesson – Make a conjecture about today’s lesson. How do I think that yesterday’s lesson can connect to today’s Success Criteria?

During-Lesson – Was my conjecture correct? Explain further how I was correct or incorrect.

Post -Lesson (Exit Ticket) – Create your own problem similar to one that we did in today’s lesson and solve it. How can I prove to someone that my answer is correct?

## DAY 5

Daily Learning Intention: **Perform operations with the imaginary unit  $i$  and factor quadratic equations using various methods**

Daily Success Criteria:

- **I can use the zero-factor property to find the solutions to a quadratic equation**
- **I can use the square-root property to find the solutions to a quadratic equation**
- **I can use the quadratic formula to find the solutions to a quadratic equation**

Pre-Lesson – List two or three things that you remember from Friday’s lesson.

During-Lesson – The most difficult thing about the math concepts that I am learning today is... (I need to be specific)

Post –Lesson (Exit Ticket) – What would I say to describe what I learned today in class to an absent classmate? (Be as specific as possible.)

## DAY 6

Daily Learning Intention: **Factor quadratic equations using various methods and factor cubic equations**

Daily Success Criteria:

- **I can factor quadratics into two binomials**
- **I can use the quadratic formula to find the solutions to a quadratic equation**
- **I can complete the square to solve quadratic equations \*I can factor quadratic equations using the square-root method**
- **I can factor a sum and difference of cubes**

Pre-Lesson – I think that today's success criteria will be...(easy, difficult, etc.). Why do I think this?

During-Lesson – Am I seeing any patterns so far that can help me better understand today's success criteria? What are they?

Post -Lesson (Exit Ticket) – What have I learned today so far about one of the Success Criteria listed above? What do I still need to know?

## DAY 7

Daily Learning Intention: **Factor quadratic equations using various methods and factor cubic equations**

Daily Success Criteria:

- **I can complete the square to solve quadratic equations \*I can factor quadratic equations using the square-root method**
- **I can factor a sum and difference of cubes**

Pre-Lesson – What do I think might be the most difficult section for the first test? Why do I think this?

During-Lesson – What – in my own words – does completing the square for a quadratic equation mean?

Post -Lesson (Exit Ticket) – What do I need to do to prepare for my test next week? What do I know the best? What do I know the least?

## DAY 8

Daily Learning Intention: **Solve absolute value equations and inequalities and write solutions in interval notation**

Daily Success Criteria:

- **I can solve an absolute value equation in one variable**
- **I can solve an absolute value inequality in one variable and represent the solution in interval notation**

Pre-Lesson – What do I already know about absolute value in general?

During-Lesson – How well do I understand absolute value equations so far? What makes me think that?

Post -Lesson (Exit Ticket) – Create your own problem similar to one that we did today in class and solve it. How could you verify that your solution is correct?

## DAY 9

Daily Learning Intention: **Solve absolute value equations and inequalities and write solutions in interval notation; solve special cases of absolute value, and solve one-variable inequalities**

Daily Success Criteria:

- **I can solve an absolute value inequality in one variable and represent the solution in interval notation**
- **I can solve special case absolute value equations and inequalities**
- **I can solve a linear inequality in one variable and represent the solution on both a number line and in interval notation**

Pre-Lesson – Describe a misunderstanding that I had in class yesterday. What did I learn from the mistake?

During-Lesson – Where do I think that I could make a careless mistake? What could I do to avoid this careless mistake?

Post -Lesson (Exit Ticket) – How has my understanding of the Success Criteria improved today compared to yesterday?



# DAY 10

Daily Learning Intention: **Solve one-variable, three-part, and quadratic inequalities**

Daily Success Criteria:

- **I can solve a linear inequality in one variable and represent the solution on both a number line and in interval notation**
- **I can solve a three-part linear inequality in one variable and represent the solution on both a number line and in interval notation**
- **I can solve a quadratic inequality in one variable and represent the solution on both a number line and in interval notation**

Pre-Lesson – How do I think that yesterday’s lesson will connect with today’s Success Criteria? (Can I make a conjecture about how they connect?)

During-Lesson – Was my conjecture correct about how today connected to yesterday? What was something specific that I noticed that I want to note here?

Post -Lesson (Exit Ticket) – What is something that I am still struggling to understand? What can I do to help me understand this math concept better for tomorrow?

# DAY 11

Daily Learning Intention: **Solve quadratic and rational inequalities**

Daily Success Criteria:

- **I can solve a quadratic inequality in one variable and represent the solution on both a number line and in interval notation**
- **I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation**

Pre-Lesson – Describe a difficulty I may have had in the past with fractions. Why do I think that fractions have been so difficult for me to understand?

During-Lesson – How have today's problems been similar to ones that I have already solve before? How have the problems been different from ones that I have already solved before?

Post -Lesson (Exit Ticket) – How well do I think I understand the Success Criteria after today's lesson? Why do I think that?

# DAY 12

Daily Learning Intention: **Solve rational inequalities**

Daily Success Criteria:

- **I can solve a rational inequality in one variable and represent the solution on both a number line and in interval notation**

Pre-Lesson – What questions do I have about yesterday’s lesson?

During-Lesson – Am I seeing any patterns so far that can help me be successful with today’s Success Criteria?

Post -Lesson (Exit Ticket) – What do I need to prepare for my test next week? What do I need to do differently from how I prepared for the last test?

## DAY 13

Daily Learning Intention: **Solve Rational Equations that lead to linear and quadratic equations; solve equations with rational exponents and with squared and cubed roots**

Daily Success Criteria:

- **I can solve a rational equation that gives a linear solution and verify if the solution is true**
- **I can solve a rational equation that gives a quadratic solution and verify which solutions are true**

Pre-Lesson – What do I already know from my last two tests about rational equations or rational inequalities? (I need to remember that these are problems with fractions)

During-Lesson – What have you noticed about this lesson so far that reminds you of what we investigated during last week's lesson?

Post-Lesson (Exit Ticket) – What were some of the connections among all of the Success Criteria that I noticed after today's lesson? (Were there similar methods to solve certain problems, patterns that I noticed, etc.?)

# DAY 14

Daily Learning Intention: **Solving equations with rational exponents and with squared and cubed roots**

Daily Success Criteria:

- **I can solve simple equations with fractional exponents by using the reciprocal of the exponent**
- **I can solve square root and cubed root equations by using the reciprocal of the exponent and verify which solutions are true**

Pre-Lesson – What do I remember from the last lesson when I explored solving rational equations that produced both one and two solutions? Why does this memory stand out for me?

During-Lesson – Is there anything in this lesson so far that is confusing to me? Why do I think that I need to ask my teacher that could help me clarify what I'm not understanding clearly?

Post -Lesson (Exit Ticket) – Create a problem similar to one that we learned in class today. Solve the problem to prove that I know my solution is correct.

## Appendix F

### Addendum: Student Survey Questions – Group 1

#### Test 1

**The daily sheets covered the following 7 days - 1/14, 1/15, 1/16, 1/17, 1/22, 1/23, & 1/24**

1. How many sheets did you answer for this test?
2. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?
3. Do you think that you answered the daily questions as honestly as you could?
4. Do you feel that you wrote about what you knew, understood, and didn't understand as well as you could?
5. Do you feel that you could have written more on your sheets than you did?
  - a. Why do you feel this way?
6. Do you feel that the daily sheets were helpful to you?
  - a. Why do you feel this way?
7. Was the written feedback that I gave you helpful or not helpful?
  - a. Why do you feel this way?
8. Did writing on the sheets and reading the written comments each day make you feel good?
  - a. Did the sheets and the comments help you want to continue to write on the sheets each day?
  - b. Did the sheets and the comments cause you to not want to write on the sheets each day?
9. Do you enjoy writing on the sheets every day?
  - a. Do you write notes to yourself as a normal part of your learning?
  - b. Do you like to make notes to yourself to help you keep up with what you're learning in class?
10. What suggestions to you have for me about my written feedback to you?
  - a. What should I change to help you improve?

#### Test 2

**The daily sheets covered the following 7 days: 2/1, 2/3, 2/6, 2/7, 2/8, 2/15, & 2/19**

1. How many sheets did you answer for this test?
2. Did you answer more, less, or the same number as Test 1?
  - a. More - Why do you think you wrote on more sheets this time?
  - b. Less - Why do you think that you wrote less sheets this time?
  - c. Same Number - Why do you think that you wrote the same number of sheets?
3. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?
4. Do you feel that you were as honest and descriptive as you could have been?
5. Did you write more on this test than you did on your first test?
  - a. If you wrote more, what made you want to write more during this test?
  - b. If you wrote less, why do you think that you didn't write as much on this test?
6. Do you feel that the daily sheets helped you?
  - a. Why do you feel this way?
7. How did you feel about receiving only verbal feedback during the second test?
  - a. Do you think that it helped you or hurt you?
8. Do you enjoy writing on the sheets every day?
  - a. Do you write notes to yourself as a normal part of your learning?
  - b. Do you like to make notes to yourself to help you keep up with what you're learning in class?
9. What suggestions to you have for me about my written feedback to you?
  - a. What should I change to help you improve?

## Appendix G

### Addendum: Student Survey Questions – Group 2

#### Test 1

**The daily sheets covered the following 7 days - 1/14, 1/15, 1/16, 1/17, 1/22, 1/23, & 1/24**

1. How many sheets did you answer for this test?
2. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?
3. Do you think that you answered the daily questions as honestly as you could?
4. Do you feel that you wrote about what you knew, understood, and didn't understand as well as you could?
5. Do you feel that you could have written more on your sheets than you did?
  - a. Why do you feel this way?
6. Do you feel that the daily sheets were helpful to you?
  - a. Why do you feel this way?
7. Was the written feedback that I gave you helpful or not helpful?
  - a. Why do you feel this way?
8. Did writing on the sheets and reading the written comments each day make you feel good?
  - a. Did the sheets and the comments help you want to continue to write on the sheets each day?
  - b. Did the sheets and the comments cause you to not want to write on the sheets each day?
9. Do you enjoy writing on the sheets every day?
  - a. Do you write notes to yourself as a normal part of your learning?
  - b. Do you like to make notes to yourself to help you keep up with what you're learning in class?
10. What suggestions to you have for me about my written feedback to you?
  - a. What should I change to help you improve?

#### Test 2

**The daily sheets covered the following 7 days: 2/1, 2/3, 2/6, 2/7, 2/8, 2/15, & 2/19**

1. How many sheets did you answer for this test?
2. Did you answer more, less, or the same number as Test 1?
  - a. More - Why do you think you wrote on more sheets this time?
  - b. Less - Why do you think that you wrote less sheets this time?
  - c. Same Number - Why do you think that you wrote the same number of sheets?
3. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?
4. Do you feel that you were as honest and descriptive as you could have been?
5. Did you write more on this test than you did on your first test?
  - a. If you wrote more, what made you want to write more during this test?
  - b. If you wrote less, why do you think that you didn't write as much on this test?
6. Do you feel that the daily sheets helped you?
  - a. Why do you feel this way?
7. How did you feel about the written feedback that I gave you during the second test?
  - a. Do you think that it helped you or hurt you?
8. Do you enjoy writing on the sheets every day?
  - a. Do you write notes to yourself as a normal part of your learning?
  - b. Do you like to make notes to yourself to help you keep up with what you're learning in class?
9. What suggestions to you have for me about my written feedback to you?
  - a. What should I change to help you improve?

## Appendix H

### Addendum: Student Survey Responses – Group 1

#### Group 1 - Test 1 – Questions 1 - 5

St. #	1. How many sheets did you answer for this test?	2. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?	3. Do you think that you answered the daily questions as honestly as you could?	4. Do you feel that you wrote about what you knew, understood, and didn't understand as well as you could?	5. Do you feel that you could have written more on your sheets than you did? a. Why do you feel this way?
19	7	I did not have any missing sheets	Yes	Yes	No I was very honest
20	7	I have not missed any sheets	Yes, I do	Yes. I do	Maybe a little I did not know how to fully explain what I wasn't understanding
21	7	I have not missed any sheets	Yes, I do	Yes. I did	No I wrote everything I was having trouble with
22	7	I wasn't missing any	Yes	Yes	No not really. I was honest with my responses
23	6	I had one missing sheet because I may have forgotten to turn it in at the end of class	Yes, I do	I did	On the days that I was rushing to finish, the questions were probably not as lengthy as I wanted them to be. Somedays I did not get to finish
24	6	I was either not here that day or I forgot to fill them out before the bell rang	Yes, I do	Yes. I do	On some I feel like I could have explained it better I was in a hurry
25	4	I missed 3 sheets because I was sick at the time	Yes	Yes	I feel like I definitely could have written more I didn't see the need to draw out my sentences and make them extra-long, but maybe I should have done more.
26	6	If I forgot any I either didn't turn it in because I had no questions, or I may have just packed it in my bag	Yes, I do	Yes, I tried to as best as I could even if I wasn't sure what I was asking.	Maybe on the days I did not understand I could have but I tried to ask questions if I did not answer. I was straight forward
27	6	I have not missed any sheets	Yes, I do	Yes, I do	Yes



					I didn't want to spend too much time on them
28	7	NA	Yes	Yes	Probably Because I tend to shorten my sentences on paper.
29	7	I have answered all of my sheets.	I believe that I have answered honestly.	Yes.	I probably could have written an essay on it. I feel this way because I tend to not think as much until after class.
30	7	I have not missed any sheets	Yes, I do	Yes, I do	Yes, I do I can't always describe what I'm thinking (what I don't understand) into words
31	7	I have not missed any sheets	Yes, I do.	Yes, I do.	No not really. I was straight forward.
32	7	I have not missed any sheets.	Yes	Yes	No I tried to answer as honestly as possible.
33	7	I have not missed any sheets	Yes, I believe that I did.	Yes, I do.	I believe I did. I was straightforward and honest with my answers.
34	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
35	7	I have not missed any sheets	Yes, I do	Yes, I do	No not really I was straight forward (sic)
36	6	I was absent on 1/23	Yes	Yes, I do	No not really I was straight forward

### Group 1 – Test 1 – Questions 6 - 10

<b>St. #</b>	<b>6. Do you feel that the daily sheets were helpful to you? a. Why do you feel this way?</b>	<b>7. Was the written feedback that I gave you helpful or not helpful? a. Why do you feel this way?</b>	<b>8. Did writing on the sheets and reading the written comments each day make you feel good? a. Did the sheets and the comments help you want to continue to write on the sheets each day? b. Did the sheets and the comments cause you to not</b>	<b>9. Do you enjoy writing on the sheets every day? a. Do you write notes to yourself as a normal part of your learning? b. Do you like to make notes to yourself to help you keep up with what you're learning in class?</b>	<b>10. What suggestions to you have for me about my written feedback to you? a. What should I change to help you improve?</b>
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			<b>want to write on the sheets each day?</b>		
19	It wouldn't change me. I still would get the information and understand it Examples help me more than discussion	Yes Even though the discussion does not help me, it's nice to know what I do right or wrong	I didn't really need it Not really Not really	It doesn't affect me No No not really	Nothing Nothing
20	It helped me think about what I was or wasn't understanding	It was helpful I was told whether I was wrong or not and reassured that I can always ask for help	Yes, it allowed me to express my difficulties without telling the whole class Yes No	Yes Yes Yes	No Nothing
21	Yes I like knowing that you know what I am struggling with	Yes You told me what I was right about and what I was wrong about	Yes Yes No	Yes No No	Keep doing what you're doing Nothing
22	Yes It helped me with what I was struggling with since you broke it down more.	Yes. Your feedback helped explain it more in depth.	Yes, because when I was struggling with something you made it more clear. Not really No	Yes Sometimes when it's something that can be confusing Sometimes	None Nothing
23	Yes I got to ask questions that I did not ask in the class and it helped me understand the criteria better	Yes I was given good answers to my questions	It did. It would be nice to continue because it was something to fall back on when I did not understand everything in class that day. No	Yes, I do Yes, I do Yes, I do	Nothing Nothing
24	Yes It helped make me feel I was going in the right direction	Yes I was told whether I was wrong or not	Yes On some days I didn't but mostly yes No	Yes No No not really	Nothing Nothing

25	I'm really indifferent to them I personally am not helped by the sheets, but I understand how they help others and I figured it wouldn't hurt me to do them as well	Yes It was encouraging to have positive feedback on what I write down	It was good positive reinforcement Yes No	I don't enjoy it, but it doesn't exactly bother me either. Yes It depends on the importance of the information	Nothing at the moment This doesn't have anything to do with the sheets, but I personally like having people go up to the front and working problems out their own way if they do it differently than what you show us. It allows me to see other ways of doing problems and helps me come up with my own better way, if needed.
26	Yes It helped me ask questions I was afraid to out loud it helped to reassure me if I was unsure about a question	Yes I was told whether I was wrong or not	Yes, it helped me to realize that I understood a lot more than I thought I did. Yes No	Yes Yes Yes, all the time	Nothing Nothing that I know of; I just need to get back to studying my note every night instead of trying to cram.
27	Yes It helped make sure my info was right	Yes I was told whether I was wrong or not	Yes, because it gave me confidence on the test for that week Yes No	Sometimes Sometimes Sometimes	Nothing Nothing
28	Yes Because the sheets asked me the questions that I need to ask myself that I typically would not ask myself.	It was helpful. It gave me reassurance about what I was writing.	Yes. Yes. No.	Not every day, but I still did because it benefitted me. Sometimes. Yes.	Keep doing it. Noting I like the way you teach, and I learn very well from you.
29	Very helpful. It gave me a different way on how to view the lesson.	Always. The feedback gave me confident (sic) and explained why what I	Yes, it did very much. Honestly, it really did. No.	Most of the time yes. Sometimes. Every now and then.	I have none. I honestly cannot think of anything.

		put down was correct or important.			
30	Yes It helped me understand the smaller things in problems that benefitted me when it was time to take the test	Yes, the feedback was very honest and very encouraging Your feedback helped me and encouraged me to feel good about myself when attempting different things in math and prevented me from getting involved in a very high level of stress	It made me very confident Writing is not something I have a lot of interest in but, I am very confident that if I ever have a question or maybe something that I don't understand, I know she will do her best to help e in any way you can No	Most of the time No Yes, I do that quite often to study over a little bit	Nothing, you are doing a great job for me and helped me excel in math much better than before Nothing
31	Yes It helps me explain what I need from my teacher better	Yes Because I articulate things better when it's written out for me to study and review as much as I need.	Yes	Yes No	Nothing Nothing specific but I think you should thing about doing a closing practice problem on the metacognition paper
32	Yes. It helped me reassure what I was writing.	Yes. It cleared up some areas that were hazy to me.	Yes, the information was helpful. Yes. No.	Yes. Depends on the class. Usually I do in math. Yes.	None. None.
33	I believe they were helpful. It helped me to be able to discuss any problems I was having with my	Yes, it was very helpful. It helped me be reassured and answered	I almost forgot to some days, but yes, they made me feel much better about the class. Yes, they very much did.	Yes. I usually write some side notes on the worksheets, but I see the worksheets as my	No. No.

	teacher in a way that felt protected. It also felt like I was getting a weight off my shoulders.	any questions that I had about class.	No, the comments are always helpful and do not dismay me.	notes that I need to look over. No.	
34	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
35	Yes It helped make sure my info was right	Yes You gave me a different look at it, and helped me learn how to do it	Yes, it was a confidence boost. It helped having a 2 <sup>nd</sup> opinion on it. Not really No	Yes No No no really	Nothing Nothing
36	Yes It helped make sure my info was right	Yes It reassured me that I was right	Yes Not really No	Yes No Yes	Nothing Nothing

### Group 1 - Test 2 – Questions 1 - 5

St. #	1. How many sheets did you answer for this test?	2. Did you answer more, less, or the same number as Test 1? More - Why do you think you wrote on more sheets this time? Less - Why do you think that you wrote less sheets this time? Same Number - Why do you think that you wrote the same number of sheets?	3. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?	4. Do you feel that you were as honest and descriptive as you could have been?	5. Did you write more on this test than you did on your first test? a. If you wrote more, what made you want to write more during this test? b. If you wrote less, why do you think that you didn't write as much on this test?
19	7	Same I keep up with my work	I had all my sheets	Yes	No. It was about the same to me
20	7	Same Same number I received the same number of sheets	I wasn't missing any	Yes	No. I thought the test was about equal
21	7	The same Same number I always write on every sheet you give (sic) me	No Answer	Yes	I think I wrote about the same

22	7	The same Same number Because I didn't miss any for test 1 and 2	No Answer	Yes	I wrote about the same amount
23	6	It was about the same Same number It's the usual amount of stuff I write daily. (honestly depends on the extra time I have in class as well)	I may have forgotten to turn it in, or I missed that day for a school event	Yes	I didn't (same amount)
24	2	Less Less because this was the week that I was sick some	I wasn't here every day	Yes	No. I didn't know anything about that test so I didn't have much to say. I didn't know what to write.
25	7	More I didn't miss any days and was here for all of the review days for this test	I didn't miss any sheets	I was honest, but I probably was not as descriptive as I could have been.	The first test, in my opinion, required more work for me
26	All	More	I was more confused on a certain thing on test 2	Yes	Yes I think I put myself more reminders
27	7	More Cause I realized how much they helped	Didn't have any missing sheets	Yes	Yes The more the better Yes
28	7	Same Because it helped me last time.	N/A	Yes	Yes. Because the more I wrote the more I remembered
29	Seven	More I think I started to understand the importance of writing down on the sheets.	No missing sheets.	Yes.	Yes. It gave me a better understanding.
30	6	Less Busy bee I am	Senior stuff or band	Yes	No. I thought the test was about equal
31	7	Yes	No answer	No I write about the same for all	Yes Because I get feedback from

		Because this is something that helps both me and you			the simple notes I make
32	7	Same amount. The sheets helped me on the first test.	None.	Yes.	No, I tried to take the same approach.
33	7	Same Always wanted to turn a sheet in.	No missing sheets.	Yes	No, less I'm being more straightforward
34	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
35	7	Same Same number Because it helped last time, so why stop now.	NA	Yes	No. I thought the test was about equal.
36	7	More I got used to them and I got comfortable with it	NA	Yes	No. I thought the test was about equal

### Group 1 – Test 2 – Questions 6 - 9

St. #	6. Do you feel that the daily sheets helped you? a. Why do you feel this way?	7. How did you feel about receiving only verbal feedback during the second test? a. Do you think that it helped you or hurt you?	8. Do you enjoy writing on the sheets every day? a. Do you write notes to yourself as a normal part of your learning? b. Do you like to make notes to yourself to help you keep up with what you're learning in class?	9. What suggestions to you have for me about my written feedback to you? a. What should I change to help you improve?
19	No. I did not affect what I learned	Good Neither	Yes No No	Nothing Nothing
20	Yes It helped me understand what I had right or wrong	Good Helped	Yes Yes Yes	None Nothing
21	Yes It helps me know whether I'm right or wrong	Good Helped	Yes No No	I like what you are doing. I think what you are doing right now is helping me
22	Yes Helped explain stuff more	Good Helped	Yes It depends No	Nothing Nothing
23	No Answer	Yes You answered the questions I had very well	Good Helped	Nothing Nothing

24	Yes My grades have improved	Good Helped	Yes No No	Nothing Nothing
25	I'm indifferent about the sheets. They don't help me personally.	I appreciated it. They don't do anything to me really.	Sure Yes Yes	Nothing Nothing
26	Yes Reassurance	Okay, somedays I felt like I may have needed more, but I ended up coming to your desk to ask questions Helped	Yes Yes Yes	Nothing Nothing
27	Yes Let me know how I was doing up till test day	Good Helped	Sometimes Sometimes Sometimes	Nothing Nothing
28	Yes Because it makes me ask myself if I feel confused about anything	It was good Helped	Not every day but I do it anyway because it helps me. Usually Yes	None. None.
29	Yes. It helped me understand the lesson better.	It was different from other feedback I have gotten before. Helped me.	Yes. Sometimes. Sometimes.	Nothing. Can't think of anything off the top of my head.
30	Yes My info was right	Good Helped	Yes No No	Nothing Nothing
31	Honestly, I don't remember	Yes Yes Yes	No Answer	No Answer
32	Yes. I was able to keep up with my information.	I didn't feel much different. Neither.	Yes. Depends on the class. Usually I do in math. Sometimes.	Nothing Nothing
33	Yes	Blank	Blank	blank
34	Didn't do	Didn't do	Didn't do	Didn't do
35	Yes Because I could refer back to them, and it made me think during the lesson	Good Helped	Yes Yes, so if I get confused, I can go back and look at it Yes	Nothing Nothing
36	Yes I was reassured on my thoughts	Good Helped	Yes No Yes	Nothing Nothing



Appendix I

Addendum: Student Survey Responses – Group 2

**Group 2 – Test 1 – Questions 1 - 5**

St. #	1. How many sheets did you answer for this test?	2. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?	3. Do you think that you answered the daily questions as honestly as you could?	4. Do you feel that you wrote about what you knew, understood, and didn't understand as well as you could?	5. Do you feel that you could have written more on your sheets than you did? Why do you feel this way?
1	All of them	No Answer	Yes, I kept my answers succinct and honest.	I suppose it wasn't necessarily the best I could, but it did easily convey the message.	Oh, most definitely. As I have previously stated, I have kept my answers very short, sweet, and to the point.
2	7	No missing sheets	I try my best too (sic). Some sheets probably not.	Yes; I believe I wrote about what I knew and if I ever needed any help to the best of my ability.	Yes There is just so much mathematics that I could go on and on a lesson.
3	6	I think that I answered the questions, I just forgot to turn it in before leaving.	Yes	Most days	Yes I did write a lot, but I feel like I kept most of my explanations pretty general.
4	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
5	7	No Answer	Yes	I wrote when I understood, or if I did not, I usually said I need more practice on this	I wrote and explained all my answers pretty well so far, but there are a few questions here and there I could explain more. I felt like the response was too vague.
6	5	I most likely answered two out of 3 questions and just kept the paper since I wasn't finished.	Yes, unless I was tired then I may have just wrote (sic) some stuff down but not much	Yes, however I had a lot of trouble during the first few tests.	Most likely I am tired most mornings so sometimes I tend to not put much as much effort.

7	6	I was absent	Yes	Yes	No I feel that I get my point across each time
8	6 sheets	I don't remember filling one out for 1/17	Yes	I felt like I knew what I was writing about.	No. Because I suck at writing
9	I answered 7 Metacognition sheets for Test 1	I answered all of my sheets	I believe I could have answered them more honestly	No ma'am	I usually wait until the end of class to fill out these sheets so I'm usually pressed for time, so I write very little. I could have written more.
10	I answered all seven sheets	I did not have any missing sheets	I do believe I answered them honestly. I may have had a little more confidence in myself than I should have at times, but I did believe I understood when I said that I did.	I tried to, yes. I never hesitated to write down when I was confused or did not understand how to do certain problems.	I do feel like at times, I could have. Sometimes I feel like I could've gone more in depth with what exactly I didn't understand.
11	7	I don't have any missing sheets	I think I was fairly honest. At the beginning of the semester I was totally lost and frustrated, but I think I was pretty honest about it.	I felt like I did	I was as honest as I could be and I feel like I wrote enough. You can only explain so much
12	Seven	I wasn't absent any of these days	Yes, because math is my best and favorite subject, so when I don't understand something, I make it a point to ask, and these daily sheets help so much!	Sometimes, but not every day because sometimes I would get in a hurry, so I know I could've asked better questions.	Some days I definitely could have, but other days, I feel like I got my point or question across pretty well. Because I know some days that I was tired and was probably just trying to get something wrote down, but other days, I really took time to write out my questions.
13	Seven	I am not missing any of them	Yes, when I really wanted help with something, I did my best to answer the questions as honestly as I can.	Yes, I feel like after taking Algebra 3, I am more prepared for this class than I ever will be.	Yes. I probably could have put more details into what I needed help with.

14	All seven of them.	I don't have any missing sheets that I know of, and if I did it would be due to a school trip because I haven't missed any days otherwise.	Yes, I always tried to answer as best I could so that you would know how I felt about the lesson.	Yes, occasionally, it was hard to explain what I needed help with, but I think I did a pretty good job answering the questions to let you know overall.	It honestly depends on the question. On some of them, my answers were pretty lengthy, but there may have been others I could have answered in more detail. Looking through my pages, I made a good bit of notes and usually filled up the space in between questions.
15	All 7 of them	I had missing sheets.	Yes, I feel like I answered all of the questions honestly	Yes, I feel like I did	Yes, I could have wrote (sic) more but I feel like what I wrote answered all the questions honestly. Because you can always write more when writing as long as you have room on the paper left.
16	7	I have not missed any sheets.	Yes, I do.	Yes, I do.	No not really I was straight forward.
17	7	There were no missing sheets.	I tried but I think I had some trouble realizing what I didn't understand.	Not. Completely.	Yes, but not much. I think I could've been slightly more specific.
18	I answered all of them.	I do not have any missing sheets.	Yes	Yes, in the amount of time that we had.	No. Because sometimes, especially on the last question, we do not have a lot of time. I feel like I have written as much as I can.

### Group 2 – Test 1 – Questions 6 - 10

<b>St. #</b>	<b>6. Do you feel that the daily sheets were helpful to you?</b>	<b>7. Was the written feedback that I gave you</b>	<b>8. Did writing on the sheets and reading the written comments each</b>	<b>9. Do you enjoy writing on the sheets every day? a. Do you write notes to yourself as</b>	<b>10. What suggestions to you have for me about my written feedback to you?</b>
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	<b>a. Why do you feel this way?</b>	<b>helpful or not helpful? a. Why do you feel this way?</b>	<b>day make you feel good? a. Did the sheets and the comments help you want to continue to write on the sheets each day? b. Did the sheets and the comments cause you to not want to write on the sheets each day?</b>	<b>a normal part of your learning? b. Do you like to make notes to yourself to help you keep up with what you're learning in class?</b>	<b>a. What should I change to help you improve?</b>
1	I feel they weren't helpful to me. I answered the question point blank and didn't put much thought into it.	I'll say between no and somewhat. Your answers helped me to recognize how shortly I answered the questions.	No; it felt more like a formality than a helpful mode of guided thinking. No No. I felt ultimately indifferent	No I do when the notes pertain entirely to the advancement of the topic knowledge and standards. No. I feel as though I am a visual and auditory learner	I have none; I'm sure that this question-answer is very helpful to many people, but not I. Nothing at all should be changed.
2	Yes Doing the daily sheets that we do keeps my mind engaged at all times. I like the idea of being able to write down my thoughts to my teacher which allow him/her to write their ideas and support to their students' questions and responses.	Yes. I feel this way because you always made sure if I was ok with the content, even if I said I was. It made me feel as if I finally had a teacher that cared about everyone's education and did not just give you the math and expect you to learn it yourself.	It did. It made me feel like I was getting somewhere with my math. Especially when you respond to my examples. Yes No	Yes Yes Yes, because even if I'm not sure about what I am learning, I can look back at what I wrote later and then understand it better.	Write some tips or tricks you would or have already shared with us. That way we have it on paper just in case we were to forget. Everything is fine with me. I enjoy doing the sheets every day. Thank you.
3	Yes I was able to go back and look to see what I had questions on and what I was the most confused about, so I could spend more time on those questions that	Most of the time. Sometimes they were just compliments and questions back to me that I never got to answer.	Yes Yes Not at all	Yes, when I remembered to do them during class instead of getting it all done right before the bell rings. Yes Yes, but sometimes I write more notes on the worksheets we work in class	On some of my answers, their (sic) were questions that I never got to answer. The positivity is great though because it doesn't bother me to write down everything when I know that you are

	others that I understood more.			rather than on these papers.	taking time to read it and comment back.
4	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
5	I think they were very helpful It allows me to state what I need more practice on or if I'm comfortable.	The notes you wrote back were very helpful. By mentioning that I am making good notes and points helps me feel better going into the test	Yes, it did Yes No	I think it is helpful I don't make a lot of notes, but if it's something I missed or a formula I will write it over. Small notes sometimes.	It has helped so far and makes me feel more comfortable. The daily questions are good. The bell ringers in the morning are helpful. Starting with one or two problems helps get class started.
6	Yes, however I feel the practice problems at the beginning of class are far more effective for me. They helped me reflect on what I learned	Kind of It can help in certain situations, but after I get the paper back, how can I respond to the questions you ask me on there?	Nothing at school makes me feel good lol Yes, if it benefits my learning Not really	I don't enjoy much at school so no I am not a note taker, I have to just practiced to get good at something, and I am most definitely not an auditory learner. Every now and then.	Nothing. Bring back the warm up problems at the beginning of class
7	Yes It made me self-aware to what I didn't understand about class and I get feedback	It was helpful It clarified my confusion from time to time	Yes Yes No	Yes Yes, all the time Yes	Non Nothing I think everything is good the way it is.
8	Yes, it kept a thought of what we learned the day before there for me	Very helpful. It helped me go back and study on the things what were more difficult	Yes. Yes. No.	Not really but I will because it helps me. Yes. Yes.	None. None, you're doing a great job at teaching me! You're the best teacher I ever had to be honest.
9	If I would have answered honestly, they would have been helpful, but I wrote very little, so they were very little help to me.	The feedback was helpful on questions that I answered openly	Yes, they gave me confidence. Yes, because they gave me a since of pride in the subjects that I learned, understood, and knew. No ma'am	Some days I did not feel like filling out the sheets. Yes ma'am Yes ma'am	Please be straightforward with me on how to correct my work if I do not understand a lesson. Explain to me, in detail, what I did wrong and how I should correct it.

10	I do feel like the daily sheets were helpful to me. I sometimes write notes on them, make points for me to for sure look over to study, and they contain direct feedback on my thoughts and notes.	It was helpful. I appreciate that if I have quick questions, you can answer them in word form on the papers, and I've even asked about how I should study for the test before on the sheets and got feedback on that.	It did. Especially when I knew that I understood. The comments were especially encouraging to keep filling out the sheets.	I don't know that I "enjoy" them persay (sic), but I do appreciate them and want to continue doing them. I do write notes to myself. I have a hard time remembering things sometimes, so I make notes to ensure I don't forget what I need to look over, etc....  Yes	I don't have any specific suggestions.  I'm not sure what will help me improve. I like that we take time to go over the different topics on the tests, don't rush into tests, and that we have the opportunity to work practice tests, but I still do not perform well on tests. Most of that I attribute to nerves, which I'm not sure you can do anything to help
11	I found it helpful sometimes, but most of the time it kind of felt like it was just an extra task. I didn't usually understand anything better, but it was nice to know that you knew what I was struggling with.	The feedback was only helpful sometimes There is only so much that you can give feedback on. It is really just on me to figure it out.	Yes, they did make me feel good. For the first two weeks it was comforting to have daily feedback. Not through the first test it didn't.	I don't particularly enjoy it and sometimes it stresses me out. Sometimes I do write a helpful side-note or two, but I rarely look back on them. I don't mind it, but like I said, I rarely look back on them.	The feedback was comforting, and I think to be giving feedback on every paper, it is fine the way it is. I think the feedback is fine.
12	Yes!! Because they give me a chance to ask my questions without having to talk in front of the class because sometimes that can be intimidating.	Yes!! Because when I had questions, you answered them, and when I gave a vague answer, you would ask questions back that got me to think about it a little more and better understand things.	Yes, because I knew that they weren't just busy worksheets and that you actually used them. Yes, because it helped me out a lot. No.	Yes!! Yes, because I have put things into a way I understand. Yes!	None, I think it's great how it is. If we started doing warm up problems again, that would help!
13	Yes. The sheets help me put more thought into what	Yes. The day after we turn in the sheets, you would go over	It makes me feel more confident in Math. Yes, since I would always get	Even though it feels repetitive, I don't mind writing on those sheets. Not really.	You could probably take off the questions referring to other classmates, since,

	we learn every day.	what people were confused about.	feedback for what I wrote. No, they did not.	It doesn't bother me, but I don't do it that much.	during first block, not that many people will like to talk to each other. I don't think any changes should be made. I think it is just fine how it is.
14	Yes The sheets allowed me to let you know when I needed more practice or didn't understand a concept and helped me make notes to myself.	Yes I enjoyed hearing what you had to say, and it made me feel better when you said things like "Nice" and "Good, I'm glad you remembered that."	Yes, I always feel better having down my thoughts so that I can remember them. Yes, the nice comments and the help you gave when I requested in on the sheets made me want to continue using them. No, I enjoyed them.	Yes, it's fun to get creative with my notes and get feedback. Yes, all of my notebooks are nearly full for my other classes. Notes really help me. Yes, because I can always look back and see how I felt during the lesson and see what I need to work on using the sheets.	I don't really have many. If you were to add a little to our notes if we were missing something, it would help. Maybe giving us more questions where we make up our own problems or a small example to work on the sheet would help when looking back.
15	Yes, I feel like they were very helpful. Because it gives you an idea of what we are having trouble in and then you explain it more or go over it again the next day.	I felt like the feedback was helpful. Because, it gives me an idea of what you think about my notes/ answers.	Yes Yes No, because it was always positive feedback	I did not enjoy it but I knew it would help me later on Yes Yes	I have no suggestions because everything you say is always positive Nothing because the sheets help me and your feedback helps me.
16	Yes. It helped make sure my info was right.	Yes. I was told whether I was wrong or not.	It was simple, but I didn't really need it. Not really. No.	No. No. No not really.	Nothing. Nothing.
17	Yes, somewhat. I got some info from it but understood most of the test from experience.	It was helpful. It reinforced what I knew in the past.	I felt okay about them. Not really, I felt alright with it as I did the first time. No, I still had something to say.	Not necessarily enjoy but like the feedback. Sometimes. Sometimes.	I have none. It is good as is.
18	Sometimes they have been. Sometimes they remind me on what I need to work on.	Yes. We go over the stuff that we have problems with in class.	It was more of a neutral feeling. Yes, to an extent. Vary rarely	I don't enjoy it, but I don't hate it. Yes. Yes.	Nothing. Nothing.

## Group 2 – Test 2 – Questions 1 - 5

St. #	1. How many sheets did you answer for this test?	2. Did you answer more, less, or the same number as Test 1? More - Why do you think you wrote on more sheets this time? Less - Why do you think that you wrote less sheets this time? Same Number - Why do you think that you wrote the same number of sheets?	3. If you had any missing sheets, why do you think you didn't answer the sheets on those missing day(s)?	4. Do you feel that you were as honest and descriptive as you could have been?	5. Did you write more on this test than you did on your first test? a. If you wrote more, what made you want to write more during this test? b. If you wrote less, why do you think that you didn't write as much on this test?
1	All of them	I felt obligated to complete them to fill time in class	No answer	Pertaining to honesty, I was. Pertaining to descriptiveness, I wasn't in the slightest.	I had realized that the metacognition didn't really help not hurt me all that much.
2	7	I had became (sic) more experienced and I started to have more questions and responses	No missing sheets	Yes	I kind of developed a habit of starting to ask more questions. I believe this is another good reason as to why we should do sheets.
3	All but one	Same Because I probably just forgot one day.	Probably just didn't turn it in on accident.	Yes	More Because I saw how I could go back and see what I needed to work on.
4	Didn't do	Didn't do	Didn't do	Didn't do	Didn't do
5	7	Same number I was not absent any days	No Answer	I was accurate in how I felt, but I could have been more descriptive.	Yes Getting used to the questions and having more practice
6	4	Less Less – I probably didn't complete them	Most likely didn't finish them so I didn't turn them in	Probably not, just as most people	I should have but no Didn't put forth enough effort
7	6	Same Number I honestly think that I just misplaced one.	I think I have misplaced it	Yes	Yes I wasn't satisfied with my first test, so I wanted to make sure I



					understood everything
8	I only answered 1 more. More – I think I was here that’s why	NA	I always could do more	It was about the same NA NA	Yes It helped me study
9	I answered 7 sheets for Test 2	I answered the same amount. Same number. I believe I was held back with my answers, just like test one because I did not have faith in myself and didn’t want to receive negative feedback	No Answer	No ma’am	Yes ma’am My grade did not reflect what type of student I truly am
10	I had all seven.	I wrote about the same, but sometimes on the “Post-Lesson” I answered slightly less. Less - I know that sometimes I was rushed to finish the last question, but it was never really an issue. The answers are just slightly smaller.	I didn’t have any missing sheets.	Sometimes I wasn’t as detailed as I could’ve been but I was honest.	I don’t think I wrote much more or less for test 2.
11	7	Same number. We almost spent the same amount of time on them.	I didn’t have any missing sheets.	I feel like I was pretty honest	I think I wrote less I think once I got more comfortable with the class, the sheets became a task rather than a comfort.
12	Seven	The same Because I really try not to miss school especially college classes	I wasn’t absent any of these days.	Honest: Yes, because if I don’t understand something, I want someone to explain it to me, I’m not going to pretend like I know something that I don’t. Descriptive: No, not always, because I would get in a hurry	Yes Because I didn’t understand absolute value on the second test as well as I did imaginary numbers on the first test, so I had more questions.

				and wouldn't write as much.	
13	Seven	Same number. I showed up to class every day.	I don't have any missing sheets.	Yes, I did.	Yes, I did. There was more to this test than the last one.
14	Blank	Blank	Blank	Blank	Blank
15	All 7 of them	Same Number Because I did all of them	No Answer	I may could have been more descriptive, but I was always honest	I feel like I wrote the same amount.
16	6	Less Busy bee I am	Senior Stuff or band.	Yes.	No. I thought the test was about equal.
17	7	Same Number I wanted to get feedback as I did the first.	There were none missing.	Yes, I was.	Yes. There seemed to be more to understand on this test.
18	All of them.	The same number. It just became routine.	I had no missing sheets.	Yes, in the amount of time that we had.	Yes. I started to feel more relaxed with it.

### Group 2 – Test 2 – Questions 6 - 9

St. #	6. Do you feel that the daily sheets helped you? a. Why do you feel this way?	7. How did you feel about the written feedback that I gave you during the second test? a. Do you think that it helped you or hurt you?	8. Do you enjoy writing on the sheets every day? a. Do you write notes to yourself as a normal part of your learning? b. Do you like to make notes to yourself to help you keep up with what you're learning in class?	9.. What suggestions to you have for me about my written feedback to you? a. What should I change to help you improve?
1	No. I learn by seeing and hearing, self-reflection doesn't help me very much in my educational career.	Eh. It neither helped nor hurt me.	No When the notes pertain entirely to the source material.	I neither like nor dislike it.
2	Yes Because I have become	The low key made me feel that I did not give a full response	Yes Yes. It is a habit of mine	I feel find with the responses that I'm getting. I like longer

	more engaged in my mathematical education.		Yes	responses, but I would rather get a response than not one at all. Everything is fine with me.
3	Yes. The first time, I didn't look at them as much and I made higher on the second time	I don't think that mine were that limited, there was still enough feedback	Yes Yes Yes	It makes me feel better that there are so many comments on my paper, but if something is wrong or questionable, I want to know. Same answer as the previous one.
4	Didn't do	Didn't do	Didn't do	Didn't do
5	Yes It shows what are good notes and some specifics I need to note.	It was very helpful Helped.	Yes Occasionally Yes, I write things that I need to remember or did not understand.	None Everything is good, pointing out specifics and good notes is very helpful.
6	Yes, a little bit It helps with my memory recall	I don't think that really helps	Not enjoying lol No, I do not Nope	Maybe more descriptive There isn't really anything
7	Yes It helped me clarify things	I felt that it made me work harder Helped	Yes Always Yes	None I think everything is fine.
8	I think it helped me.	Not Really but it helps Yes Yes	None I think you're doing great	
9	Yes ma'am It helped me keep up with my learning if I did not understand something I could come back and figure out what I needed o do to fully understand what I didn't	It helped me because it brought me to the realization what you are doing this to benefit us, and by limiting your response it made me be thankful for your long descriptive responses	Most of the time Occasionally Occasionally	Tell me where I can go if I do not understand something. Be more harsh and descriptive. Constructive Criticism
10	I feel that, in the end, they did somewhat benefit me. Feedbacks and the notes	I always appreciate the feedback. It didn't 100% hurt me. It did help how I felt about everything.	I wouldn't say I enjoyed them persay (sic), but they do help. Yes. Yes.	I don't know that I have any. Nothing that I can think of.

	I made helped me.			
11	Somewhat I kind of feel like I was just writing because I had to at test two	I don't feel like it affected me	Not particularly, but some days it does help I take less notes on the sheets as time goes on. Sometimes	The feedback is short, but I know you had to go through many sheets and wouldn't have had time so I think the feedback is fine. I think the feedback is fine.
12	Yes! Because they gave me the chance to ask all of my questions without taking up class time.	I don't feel like the feedback was more limited. I don't think your feedback ever hurt me. Whether there was a lot or not as much, it still helped me.	Yes Yes Yes	None, I think it's great how it is. If we started doing warm up problems again, that would help!
13	Yes, they did. I made a good grade on the test.	It didn't bother me. It didn't really affect me as a whole.	It is repetitive, but I don't mind. No, I don't. I wouldn't mind writing notes to myself.	Again, you could probably take off the questions referring to other classmates, since, during first block, not that many people will like to talk to each other. None.
14	Blank	Blank	Blank	Blank
15	Yes, I feel like the (sic) helped me Because it gives you an idea on what I need more explanation	I feel like it helped me. Helped me.	I did not enjoy but I feel like it helped me in the long run. Yes. Yes.	I have no suggestions because it is helping me right now. Nothing
16	Yes. My info was right.	Good. Helped	Yes No. No.	Nothing. Nothing.
17	I thought nothing of it.	I think it helped.	I wouldn't say enjoy but I like getting the feedback from it. Sometimes.	I would just suggest feedback with maybe more tips. Just more tips for the test.

Appendix J  
School Consent Form

2/2/2018

Mail - Letter



Shawna Robinson <shawnarobinson@mcsd.us>

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**Letter**

1 message

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**jeff brooks** <jeffbrooms@mcsd.us>

Fri, Feb 2, 2018 at 7:41 AM

To: Shawna Robinson <shawnarobinson@mcsd.us>

To Whom It May Concern:

This email is to confirm that I am aware that Ms. Shawna Robinson is conducting a research study here at the Monroe County Advanced Learning Center. I am also aware that she is attending the University of Mississippi pursuing her Ed.D in mathematics education. Her study involves using metacognitive questioning with her college algebra students on a daily basis. I am aware that she is giving the students questions every day to ask themselves throughout the block as they go through the lesson. She has written and sent out parent consent forms, and all students are participating in the study.

Sincerely,

Jeff Brooks

Principal, Monroe County Advanced Learning Center

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Jeff Brooks

Monroe County Advance Learning Center

## Appendix K

### Parental Consent Form

#### Consent for Your Child to Participate in Research Study

**Study Title:** *Can Helping Students Learn to Become More Reflective on Their Learning Improve Their Achievement in College Algebra?*

**Investigator**

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**The purpose of this study**

The purpose of this study is to see if having students think and reflect daily on what they are learning in the classroom can improve their test scores in college algebra. I want to know if providing students with a few specific questions throughout the lesson will help them understand the math that I am teaching and improve their achievement this semester.

**What your child will do for this study**

Your child will receive a sheet of paper from me daily that will describe what I want the students to learn each day and several statements to help them assess where they are in their learning for the day. I will also write questions for your child to answer before the lesson, during the lesson, and after the lesson to help him or her think about what he or she knows, how he or she feels so far, what he or she might still be struggling to understand, and what he or she has learned in his or her own words. At the end of each day, I will collect the reflection sheets, read through your child's self-assessments, and comment back to your child. I will return the reflection sheets to your child at the beginning of the next class to keep.

**Time required for this study**

This study will take place daily over a period of approximately two to four weeks.

**Possible risks from your participation**

There are no anticipated risks to your child from participating in the study.

**Benefits from participation**

Neither you nor your child should expect benefits from participating in this study. However, your child could develop self-assessing and self-understanding skills to improve his/her learning in the mathematics classroom. Developing these skills will help your child for many years beyond the classroom.

### **Confidentiality**

The records of this study will be kept private. Only I will have access to your student's information. Members of the Institutional Review Board (IRB) – the committee responsible for reviewing the ethics of, approving, and monitoring all research with humans – have authority to access all records. However, the IRB will request identifiers only when necessary. I will not release identifiable results of the study to anyone else without your written consent unless required by law.

### **Right to Withdraw**

Taking part in this study is completely voluntary. Your child does not have to participate, and there is no penalty if he/she refuses. If your child does not want to answer the reflection questions every day, just tell the teacher. Your child may also choose at any point to no longer answer the questions at any point during the research period. Participating or not participating **will not** affect your child's relationship to the teacher or his/her grade in the college algebra course.

### **Student Participants in Investigators' Classes**

Special human research subject protections apply where there is any possibility of coercion – such as for students in classes of investigators. Investigators can recruit from their classes but only by providing information on availability of studies. They can encourage you to participate, but they cannot exert any coercive pressure for you to do so. Therefore, if you experience any coercion from your instructor, you should contact the IRB via phone (662-915-7482) or email [irb@olemiss.edu](mailto:irb@olemiss.edu) and report the specific form of coercion. You will remain anonymous in an investigation.

### **IRB Approval**

This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by the state and federal law and University policies. The researcher conducting this study is Shawna Robinson. If you have any questions of concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) at (662) 915-7482 or [irb@olemiss.edu](mailto:irb@olemiss.edu).

Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, then decide if you want your child to be in the study or not.

**IRB Approval**

This study has been reviewed by The University of Mississippi's Institutional Review Board (IRB). The IRB has determined that this study fulfills the human research subject protections obligations required by the state and federal law and University policies. The researcher conducting this study is Shawna Robinson. If you have any questions of concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) at (662) 915-7482 or [irb@olemiss.edu](mailto:irb@olemiss.edu) .

Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, then decide if you want your child to be in the study or not.

**Statement of Consent**

I have read the above information. I have been given an unsigned copy of this form. I have had an opportunity to ask questions, and I have received answers. I consent to allow my child to participate in the study.

Furthermore, I also affirm that the teacher explained the study to me and told me about the study's risks as well as my right and my child's right to refuse to participate and to withdraw, and that I am the parent/legal guardian of the child listed below.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Printed name of Parent/Legal Guardian  
\_\_\_\_\_

Printed name of Child  
\_\_\_\_\_



## VITA

Shawna Hill-Robinson

- Philosophy:** My philosophy of education has remained unchanged in all of the years that I have been in education – All students are capable of learning, and I feel that I should do everything that I can to help them be successful. I advocate Dweck’s growth mindset. I tell my students every day that mistakes are welcomed, valued, and investigated together. I want my students to not be afraid to make an error; I want them to understand that if we never made a mistake, we would not have opportunities to learn new things. I am always reflecting on my own teaching practice; I am an example of a life-long learner for my students. If not me, then who?
- Education:** **Ed.D** in Education – Emphasis in Secondary Mathematics Education  
University of Mississippi, Oxford, MS  
Graduation date – May 10, 2019
- Master of Education, Curriculum & Instruction – Mathematics  
University of Texas Arlington, Arlington, TX  
Graduation date – December 2014
- National Board Certification  
National Board for Professional Teaching Standards, Arlington, VA  
Certification date – November 2012
- Endorsement – Mathematics (7 - 12)  
Mississippi State University, Starkville, MS  
Completion date – July 1999
- Bachelor of Arts, Secondary Education – English (7 – 12)  
Mississippi University for Women, Columbus, MS  
Graduation date – May 1996
- Licensure:** English 7 – 12 (119)  
Mathematics 7 – 12 (154)
- Experience:** Mathematics Teacher (August 2013 to present)  
Monroe County Advanced Learning Center  
Amory, MS
- Currently teaching Algebra III and Calculus

- Currently an adjunct professor through ICC teaching Dual-Credit College Algebra
- Previously taught Pre-calculus, Trigonometry, Advanced Algebra, and AP Calculus
- Mu Alpha Theta Sponsor (2013 – present)
- Comfortable using Google for Education applications
- Currently using Plickers with students
- Familiar with Go Formative
- Advocate for daily formative assessment
- Actively differentiate openers, assignments, and assessments

**Mathematics Teacher (August 2000 – May 2013)**

Hamilton Attendance Center  
Hamilton, MS

- Taught Algebra I, Algebra II, Geometry, 8<sup>th</sup> Grade Algebra I, and 8<sup>th</sup> Grade English
- Senior Beta Club Sponsor (2003 – 2013)
- Junior Beta Club Sponsor (2011 – 2013)
- Class Sponsor (2000 – 2013)
- Yearbook Sponsor (2007 - 2008)
- Cheerleading Sponsor (2007 – 2008)

**Special Education Teacher (August 1999 – May 2000)**

Amory Middle School  
Amory, MS

- 6<sup>th</sup> Grade Inclusion and Tutorial
- Wrote IEP's and met with parents

**Reading and English Teacher (August 1996 – May 1997)**

Alexander Attendance Center  
Starkville, MS

- Taught middle school reading
- Taught 9<sup>th</sup> grade English
- Taught high school African-American Literature

**Honors/Awards/Memberships:**

- STAR teacher – 2002, 2006, 2009, 2015, & 2016
- Teacher Council member with Mississippi Department of Education, 2017 - present
- Mississippi Council for Teachers of Mathematics member
- National Council for Teachers of Mathematics member
- Delta Kappa Gamma Society member
- ASCD member

- MPE member
- Participated on the Instructional Support Committee with Mississippi Department of Education
- C.H.A.M.P.S. Participant through MUW – 2012
- T.E.A.M.S. Participant through MUW – 2009