

METACOGNITION: THE EFFECTS OF COGNITIVE STRATEGY INSTRUCTION  
ON THE PROBLEM-SOLVING SKILLS OF HIGH SCHOOL ALGEBRA 2  
STUDENTS

by

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In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to others under the specified rules of the MSSE program.

Luke Beall

July 2012

## DEDICATION

This is dedicated to my beautiful wife, Liz, and our awesome son, Dominic. Without both their support and love, I would not be able to do what I do.

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## ABSTRACT

This study investigated the effects of cognitive strategy instruction on the problem-solving skills of 24 Algebra 2 students. The students used a metacognitive approach to solve word problems in linear systems, matrices and quadratic equations. Various data collection instruments, including pre and postassessments, survey, interviews and observations, were used to determine the effects on students' cognitive achievement, long-term memory, motivation and attitude along with the motivation and attitude of the teacher. The study found an increase in students' achievement and long-term memory with the treatment. The study also yielded mixed results for the attitude and motivation of both the students and teacher.

## INTRODUCTION AND BACKGROUND

The following is a typical scene in a high school math class. The teacher directs the class, “Students, we are going to practice our new concepts with the following word problems.” With little hesitation one student will say, “I do not like word problems.” Another student adds, “Word problems are so confusing.” “Why do we have to do word problems?” a third student interjects. “I never know what to do with word problems,” an anxious fourth student states. Over the years I have seen that solving word problems is often met with resistance by high school mathematics students.

The past year, 2011, was my first year teaching at Fairview High School in Fairview, PA, though it was my third year as a mathematics teacher. Fairview High School has 560 students in grades 9 through 12. Over 96% of those students are white, and 14% of the students are eligible for free or reduced lunches. The district has one elementary school and one middle school in the district. The high school is based on semester-long courses with 80 minutes of instruction per class per day. I teach Algebra and Geometry courses to freshmen, sophomores and juniors. My project focused on Algebra 2 students, which consisted of 11 freshmen, 8 sophomores, and 5 junior students.

As a teacher, my observations of students during assessments, particularly those utilizing open-ended questions, indicate a strong deficiency in problem solving. I noticed students have trouble applying content knowledge to applied mathematics problems. The skill of problem solving is a vital part of learning and understanding mathematics and the success of a student depends of his or her ability to logically think through problems. Therefore, it is my goal to aid and encourage students to develop their problem-solving

skills. I used this project to gain insight as to what affects my students' problem-solving skills, which, in turn, improved my effectiveness as a teacher.

Logical reasoning and problem solving are helpful skills for students both in and out of school. My goal was to use cognitive strategy instruction (CSI) to improve the problem-solving skills of my students. CSI is an instructional approach, which emphasizes the development of thinking skills and processes as a means to enhance learning. The goal of CSI is to enable all students to become more strategic, self-reliant, flexible, and productive in their learning (Scheid, 1993).

The focus of my project was to study the problem-solving skills of my students while determining the effects of CSI on the problem-solving skills of high school Algebra 2 students. The project subquestions were: what are the effects of CSI on students' long-term memory of Algebra 2 concepts; what are the effects of CSI on students' attitudes and motivations; and, what are the effects of CSI on the teacher's attitudes and motivations? This topic is significant to me because I noticed the deficiency of problem-solving skills and its negative effects in my former students. I observed that students tended to struggle more in mathematics classes when they lacked adequate problem-solving skills.

To aid the development of this project, I assembled a support team from close friends and colleagues. The first member of my support team was my wife, Liz Beall. She is not an educator by profession, but she has a keen eye and a great outside perspective upon which I can rely. She also edits all of my writing and helps me put my thoughts onto paper. The second member of my support group was a fellow math teacher, Mike Parmeter. Mike has 25 years experience teaching math. The third support

team member was Gerald Drabina, a physics teacher. Gerald has 15 years experience teaching math and 20 years experience teaching physics. The final member of my support team was Dale Lewis. Dale is the assistant principal at my high school and has 17 years experience as a social studies teacher. In addition to this support team, I had a math content reader from Montana State University Mathematics Department, Terrill Paterson and my MSSE project advisor, Jewel Reuter, Ph.D.

### CONCEPTUAL FRAMEWORK

Many students experience difficulties solving applied mathematics problems (Pol, Harskamp, Suhre, & Goedhart, 2008). These difficulties are the result of deficiencies in the knowledge needed to solve problems (De Jong & Ferguson-Hessler, 1996). The deficiencies can either be in content knowledge or in problem-solving practices. Good problem solvers are better able to regulate, or direct, actions than weak problem solvers (Pol, Harskamp, Suhre, & Goedhart, 2009). This conceptual framework discusses the components and effectiveness of CSI, the effects of metacognitive strategies on problem-solving skills, and the attitudes and motivation of students and teachers using CSI. Finally, the conceptual framework presents the methodologies in evaluating problem-solving skills and measuring the attitudes and motivation of teachers and students.

Before a student is prepared to solve problems in a given domain, he or she must develop a foundation of content knowledge. Moreno (2006) indicates that in the introductory stage of a new domain, demonstration of examples with decreasing instruction is an effective teaching strategy. Pol et al. (2008) indicated that once students have gained content knowledge and are asked to apply this knowledge to new problems,

demonstration by solving examples was no longer an effective method. This knowledge the students gain influences which problem-solving strategies they will use (Ferguson-Hessler & De Jong, 1990), and the strategies used by a student will influence the knowledge that student gains from problem solving (Leonard et al., 1999). The more content knowledge a student gains, the more likely he or she is to use the proper problem-solving strategies. Students gain more from a favorable problem-solving experience. Mathan and Koedinger (2005) claim that it is often not a lack of content knowledge that inhibits problem solving, but a lack of strategic knowledge. Strategic knowledge allows students to analyze a given problem, find relevant content knowledge, and make a plan to solve the problem (De Jong & Ferguson-Hessler, 1996). Mathan and Koedinger (2005) hypothesized that the main cause of failure in problem solving is the lack of strategic knowledge.

Sherin (2001) and Tuminaro and Redish (2007) demonstrated in their research of high school and college math and physics students that problem solving involves a complex process of mapping conceptual and procedural knowledge to problem states. Problem states are like checkpoints along the path to the solution. At each problem state, the solver is able to verify how and why he or she arrived at this conclusion. Throughout the problem, the solver manipulates the problem state through a procedure that intends to meet the goals of the problem (Litzinger & Van Meter, 2010). A student needs a firm foundation of content knowledge from which he or she can effectively navigate through the problem states. The content knowledge a student brings to solving a problem influences the success of that student. The lack of content knowledge will inhibit a

student from properly mapping and performing the necessary procedures in problem solving.

In studying the interactions between tutors and college and high school students during problem solving of applied mathematics problems, VanLehn, Siler, Murray, Yamauchi, and Bagget (2003) concluded that the acquisition of new knowledge was most likely to occur when students were at an impasse. The study concluded that impasses are distinguished by students' error detection, expressions of uncertainty, or an inability to move forward. Impasses can occur when students are on both correct and incorrect solution procedures. When a student comes to an impasse, he or she will make a decision to move forward in the problem-solving process and at this point acquire new knowledge about the process, whether he or she is on the correct path or not. The authors discovered that impasses could not guarantee new learning, but students following an impasse were much more likely to acquire new knowledge than those who did not.

Dole, Nokes, and Drits (2007) summarized cognitive strategy instruction as a byproduct that came about during the end of behaviorism, when cognitive psychologists turned their focus solely to the mind. Psychologists and researchers focused on how the mind thinks about human processes and how it organizes and stores information in memory. Dole et al. (2007) also summarized a study done by Greeno, Collins, and Resnick stating researchers and psychologists developed two different strategies: cognitive strategies for mental processing that occurs in the mind for incoming information and metacognitive strategies for monitoring and evaluating the understanding of that information. A cognitive strategy is simply a routine or procedure the mind uses to complete a task or goal. During problem solving, strategies are used to categorize

problems, focus attention, and integrate information (Schraw, Crippen, & Hartly, 2006). The strategies facilitate learning and knowledge transfer (Weinstein, Husman, & Dierking, 2000), which is a critical part of problem solving.

Metacognition is a process of evaluating understanding and thinking about how one thinks. Dole et al. (2007) stated that metacognition refers to the awareness and regulation of learning and problem-solving actions. Students use metacognition when they simply ask themselves, “Do I understand the material discussed in class?”, “Are there any areas where I need further explanation to better understand the content?” or “What helps me to learn this best?” These self-reflective questions help the students further their understanding by forcing them to think about how they think. Students who use metacognitive strategies are more aware of the cognitive resources they have to accomplish goals. They are able to review the outcomes of previous problem-solving experiences and evaluate the effectiveness of previous procedures for learning, and they develop routines to use when comprehension breaks down (Dole et al., 2007).

One of the goals of metacognition and CSI is to encourage higher-order thinking by the students. When students become more aware of how they think and understand the way in which they learn, they are better able to answer higher order thinking questions. Ferguson-Hessler and De Jong (1990) found, in their study of high school physics students, that students who were better performers on higher-order problem solving tended to be more aware of how they thought. In other words, these students possessed more highly-developed metacognitive skills. The more metacognitive skills a student possesses, the more likely he or she can perform better on higher-order problem solving.

Selcuk, Sahin, and Acikgoz (2009) summarized research of Wittrock where metacognitive strategies were found to be effective in storing successful problem-solving strategies into long-term memory of middle and high school math students. Because the students were able to develop metacognitive strategies to better understand how they think, the students were able to increase their comprehension and better store their experience into long-term memory. Rampp and Guffey (1999) supported this conclusion with their research on metacognition of high school students by concluding that metacognition is a method for improvement of long-term memory. With an increase in comprehension and memory skills, the students became more confident and therefore increased their motivation to learn, which caused the students to be more attentive to future lessons.

Students' attitudes toward problem solving are typically negative. This attitude can negatively affect their success in the classroom. A lack of understanding and inability to properly use cognitive strategies could contribute to their negative attitude toward problem solving. Mason and Singh (2010) found that high school students had much better attitudes while solving problems that were within their level of difficulty and were able to be solved independently, but had negative attitudes toward problems which they felt they could not solve on their own. I believe rectifying the attitudes of students can lead to an increase in students' motivations, which is an integral part of student success in education.

Another key to the success of students' learning is the attitude and motivation of the teacher. Selcuk et al. (2009) stated that teachers are initially reluctant to introduce and use new learning strategies in their classroom because of limited time and

concentration of curriculum, but the motivations of the teachers were positively affected in their research. Shawer, Gilmore, and Banks-Joseph (2008) found in their research on high school math and science students that teachers noticed an increase in motivation when increasing the cognitive and effective development of their students. By increasing the cognitive skills of students, the teacher's motivation will increase, which fosters an environment beneficial to learning.

The most-used method of evaluating the problem-solving skills of high school students was to simply put their skills to the test by solving sample problems. Many researchers, such as Selcuk et al. (2009), used preunit and postunit questions that measured the progress of a skill after a specific treatment or strategy was implemented with students. Using similar evaluative questions after an extended period of time, Rampp and Guffey (1999) assessed and evaluated the problem-solving skills stored in students' long-term memory. To evaluate the attitudes and motivations of students and teachers toward problem solving, all researchers reviewed herein used some type of survey or questionnaire. This methodology uncovered the attitudes toward problem solving and the effectiveness of different cognitive strategies on the attitudes and motivation of teachers and students.

The research shows the primary source for failure in problem solving is not the lack of content knowledge, even though this is an integral component, but the lack of cognitive strategies and strategic knowledge needed to properly perform problem-solving procedures. These deficiencies lead to many of the problems observed in problem-solving skills. It was also suggested that the possession of such problem-solving skills allows students to better perform on higher-order thinking problems and better store

content in long-term memory. In addition, research presents the positive effect of metacognitive strategies on the attitudes and motivations of students and teachers. In order to positively affect the motivation and problem-solving skills of students, they must develop an awareness of their cognitive strategies and strategic knowledge.

## METHODOLOGY

### Project Treatment

For this project, three units were observed. The nontreatment unit was Solving Systems of Linear Equations and Inequalities. In this unit, students learned to solve systems of linear equations and inequalities both graphically and analytically. Treatment was not applied to the unit and students were taught in a typical teacher based instruction. The next two units were Matrices and Quadratic Functions. The matrices unit allowed students an alternative approach to solving systems while the quadratic functions unit introduced a new family of functions and its properties. These two units were taught with cognitive strategy instruction. The nontreatment unit was used to compare with the treatment units to determine the effects of cognitive strategy.

For the nontreatment unit, students were presented new material through book reading or teacher-instructed notes. These concepts were reinforced through hands-on activities in which students collaborated with their peers. Sample problem solving was modeled by the teacher and practice examples were performed by the students in class with the aid of the teacher. Additional practice problems were completed by students independently and solutions to these problems were discussed in class. In all of these problem-solving experiences, the main focus was arriving at the correct solution and not

focusing on the method in which the solution was found. Sample problems the students solved can be found in Appendix A.

The following two units, Matrices and Quadratic Functions, were taught using cognitive strategy instruction strategies and using the GUESS model. The GUESS model is an acronym for: given, unknown, equation, substitution, and solution. The treatment consisted of six different stages. First, students activated prior knowledge and developed new content knowledge through teacher-demonstrated examples and student practice. Second, the teacher discussed the strategy of the GUESS model with the students. Third, the GUESS model was demonstrated for the students by the teacher. Fourth, students became familiar with the acronym and the process of using the model. Fifth, the strategy was supported through scaffolding and hands-on activities. Sixth, the students performed the strategy independently. The students first learned this model on word problems containing content already covered in the course and then students had the opportunity to apply this model to new material.

Students continued to learn the new concepts through reading the text and teaching-instructed notes. This activated prior knowledge and developed background knowledge, which is a necessary foundation to cognitive strategy instruction. Content was supplemented by additional activities and classroom discussion of the concepts. Once background knowledge was created, introduction of the GUESS model began. The GUESS model was explained to the students as a model used to solve problems. The first step was to identify and list the given information from the problem and identify any unknown values that the solver intends to find. The problem solver then used their background knowledge to identify an equation that precisely connected the given

information and the unknown. Students then used this equation to substitute the given values in order to solve for the unknown. This strategy was discussed in detail and then modeled for the students. The teacher then “thought aloud” while solving and explained the cognition, or thought processes, involved. The students completed metacognitive activities, such as journal entries or responding to prompts about how they drew their conclusions and how they thought during their problem-solving process. Students recorded these processes and occasionally shared them with their peers. Students were encouraged to reflect upon their problem-solving process and determine which parts were helpful and which parts were not. Along with the reflections, students completed document problem solving classroom assessments that required them to not only solve problems but to explain their thought process throughout the experience. An example of one of these assessments can be found in Appendix B.

After the strategy was introduced, students became familiar with the model through hands-on learning activities. Students practiced using the GUESS model while solving sample problems in class with partners and with the aid of the teacher. The teacher gave support and corrective feedback, while stepping back and allowing more student autonomy over time. Once students were able to “think aloud” themselves and explain the steps they used to solve correctly, they were ready to pursue solving problems and used the strategy independently. The teacher still monitored the students to ensure they were using the strategy correctly. If the student(s) had continual issues with using the GUESS model, the teacher would give the student(s) additional examples of how to “think aloud” or show the student(s) different ways to approach metacognition in order to work up to using the GUESS model. An example of an alternative approach was to have

students write down the first thing they thought of after reading a problem and to slowly build up to implementing the GUESS model. The teacher also provided feedback to each student on his or her use of the GUESS model, giving positive reinforcement to those who did well and additional instruction to those who had difficulty.

In one of the treated lessons from first treatment unit, students worked to activate the prior knowledge needed for the new lesson. The teacher gave notes on solving systems of linear equations using inverse matrices. At this point in the unit, students were already familiar with the GUESS model and were able to apply it. The teacher modeled a problem using the application of a linear system and solved the system using inverse matrices. In this demonstration the teacher explained the cognition of each step and used the GUESS model to aid in the set up and solution of the problem. Students then had an opportunity to practice similar sample problems with partners and with the corrective feedback of the teacher. One of the sample problems is shown in Appendix C. Along with using the GUESS model, students were asked to give short reflections of their problem solving process. They would explain how they used the GUESS model as an aid in problem-solving and reflect on its usefulness. Once students reached mastery of applying the GUESS model for this section of the unit, students were able to perform independently.

In one of the treated lessons from the second treatment unit, Quadratic Functions, students continued to use the GUESS model and use metacognition while solving word problems. In this lesson students were split into two groups, A and B. Each group was given a separate real-life problem using quadratic functions. Each student wrote a plan of how to solve their problem but not how to derive a solution. In this plan, each student

wrote the mental process they would go through in order to solve the problem. In this activity they used an adaptation of the GUESS model where they stated the given information; stated what was unknown; suggested equations needed; specified any substitutions required; and specified what needed to be solved. The difference in this application was that students wrote this in essay form, without rewriting the original problem. It was more of a commentary of their thought process that described how the problem would be solved. Once the students completed this task, each found a partner from the opposite group and switched essays. The students then used their partner's essay to solve the problem without seeing the original word problem. An example of this is shown in Appendix D.

#### Data Collection Instruments

The students who participated in the treatment were 11 freshmen, 8 sophomores, and 5 juniors in one section of Algebra 2, 7 of which were male and 17 female. The class was the last class of the day from 12:52 to 2:12 PM each day. The semester ran from January 23, 2012 to June 7, 2012. Fairview High School has 560 students in grades 9 through 12. Over 96% of those students are non-Hispanic white, and 14% of the students are eligible for free or reduced lunches. The school services a small town and rural communities on the shores of Lake Erie, 13 miles west of downtown Erie, Pennsylvania. The students have a wide range of learning abilities and are required to have a sufficient level of mathematical skills in order to enroll in this class. Each student in the class had a prerequisite of successfully completing Algebra 1 and some students have completed

Geometry, although not required. Because of these prerequisites, some students had very effective problem solving skills. However, there were some students who were still deficient in their problem-solving skills, or at least did not possess the higher level problem-solving skills needed in Algebra 2. These deficiencies were observed through students practicing problem solving in class.

In order to answer the focus question and subsequent questions effectively, data were collected using three different sources for each question. This allows for data triangulation and a better comparison of results. The data triangulation matrix can be found in Table 1. By using this triangulation matrix, data were collected from various perspectives including student, teacher, and colleague. This provided both quantitative and qualitative data along with an appropriate mix of perspectives to adequately answer the focus question and subquestions, especially the questions concerning attitudes and motivation of the students and teacher. When assessing the attitudes and motivation, bias was minimized because outside data sources were used for comparison.

Table 1  
*Data Triangulation Matrix*

Focus Question	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. What are the effects of cognitive strategy instruction on the problem-solving skills of high school Algebra 2 students?	Preunit Assessment and Postunit Assessment	Pre and Postunit Concept Interviews with concept mapping	Pre and Postunit -Surveys
<i>Secondary Question:</i> 2. What are the effects of cognitive strategy instruction on students' long-term memory of physics concepts?	Post and Delayed Unit Assessment	Post and Delayed Unit Interviews	Post and Delayed Unit Surveys
3. What are the effects of cognitive strategy instruction on students' attitudes and motivation?	Student survey with open-ended questions before and after intervention	Teacher observations during both nontreatment and treatment units	Student interviews before and after intervention
4. What are the effects of cognitive strategy instruction on the teacher's attitudes and motivations?	Teacher survey (pre and postunit)	Reflection journal	Colleague observation

Before treatment was administered, the students completed a preunit assessment of the concepts they later learned and an initial Documented Problem Solving (DPS) classroom assessment technique (Angelo & Cross, 1993). The preunit assessments are shown in Appendix E, F, and G. Along with the unit assessment, students completed concept interviews with concept maps. These concept interviews contributed to answering the primary focus question. The concept interview for each unit is shown in Appendix H, I, and J. The comparison of the pre and postunit assessments answered the first three questions concerning the problem-solving skills, long-term memory, and the higher-order thinking skills of the students. To continue assessing the long-term memory, students completed a delayed assessment 14 days after they completed the postunit assessment.

To assess the attitudes and motivation of the students, a preand posttreatment survey was administered. A sample of the survey can be found in Appendix K. All students completed this survey after the nontreatment unit and after both treatment units were completed in order to create a comparison of their attitudes and motivations. A few additional questions were added for the posttreatment survey to ask the students about their perception of the treatment. During the treatment units, observations of their attitudes and motivation were conducted. Prompts for these observations are shown in Appendix L. These data were used to triangulate with the student surveys to get an appropriate comparison. In addition to the surveys, six selected students were interviewed. Two were students that the teacher felt were very successful in their problem-solving experiences, two were students the teacher felt had a good understanding of problem solving but could use additional help, and the last two were

students who struggled with problem solving. Each student was interviewed individually during the tutorial period of the school day. The questions asked for this interview can be found in Appendix M.

Three instruments were used to assess the attitude and motivation of the teacher: teacher survey, journal reflection, and colleague observations. The teacher survey, shown in Appendix N, was completed by the teacher before and after each unit. These data were compared to see the effects of the treatment. The teacher also kept a daily journal using the prompts shown in Appendix O. The journal entries were compared through the treatment and nontreatment unit to also study the effects of the treatment. Finally, the teacher invited a colleague into the classroom for three observations, one per unit, using the prompts in Appendix P. These observations were an additional data source to observe the effects of the treatment on the attitudes and motivations of the teacher.

The data collected from the surveys and interviews were compiled yielding both qualitative and quantitative data. Both the qualitative and quantitative data from these instruments were compared to see the effects of CSI on attitudes and motivation, higher-order thinking skills, and long-term memory. The preunit and postunit assessments were compared quantitatively to see the effects of CSI on problem-solving skills and higher-order thinking skills. The delayed assessment was compared to the postunit results to see the effects on long-term memory.

This project began in February of 2012. The nontreatment unit, Solving Systems of Linear Equations, lasted one week. The treatment units, Matrices and Quadratic Equations, lasted for one and a half weeks and two weeks, respectively. The project was

completed by March 28, 2012. A general timeline for the implementation of these three units can be found in Appendix Q.

## DATA AND ANALYSIS

Data were collected in one nontreatment and two treatment units to determine the effect CSI had on the problem solving skills of Algebra 2 students. Data were collected in accordance with the triangulation matrix such that each focus question and subquestion had subsequent data to support the effect of CSI.

The data collected from the unit pre and postassessments allowed calculations of the percent change for the nontreatment and treatment units. The average scores, percent change and normalized gain scores can be found in Table 2. In general, students showed gains in all three units, however, the gains in the treatment units were greater than the gain in the nontreatment unit.

Table 2  
*Average Scores of Unit Preassessments and Postassessments (N = 24)*

Unit Data	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Preassessment	12.6	7.8	6.9
Postassessment	24.9	26.7	25.5
Percent Change (%)	98	237	269
Normalized Gain Score	0.71	0.85	0.81

*Note.* All Assessments Out of 30 Points.

When comparing the three units, the two treatment units had higher gains than the nontreatment with the second treatment unit having the highest gains. This shows a positive association of the intervention on the students' assessment; however, one should notice that both treatment units had much lower preassessment scores than the nontreatment unit. This was because the nontreatment contained concepts the students have encountered in their previous course history where the two treatment units contained more material that was new to the students. Because of their lower preassessment scores, the two treatment units had more opportunity to show higher gains. Therefore, a normalized gain score yields a better picture by showing the fraction of available improvement obtained. When comparing the units with the normalized scores, the data confirms a increase in the improvement for the two treatment units as compared to the nontreatment unit.

Data were also collected to determine the effects of CSI on problem-solving skills through concept interviews including concept maps. These results are found in Table 3.

Table 3  
*Average Scores of Preunit and Postunit Concept Interviews with Concept Maps (N=24)*

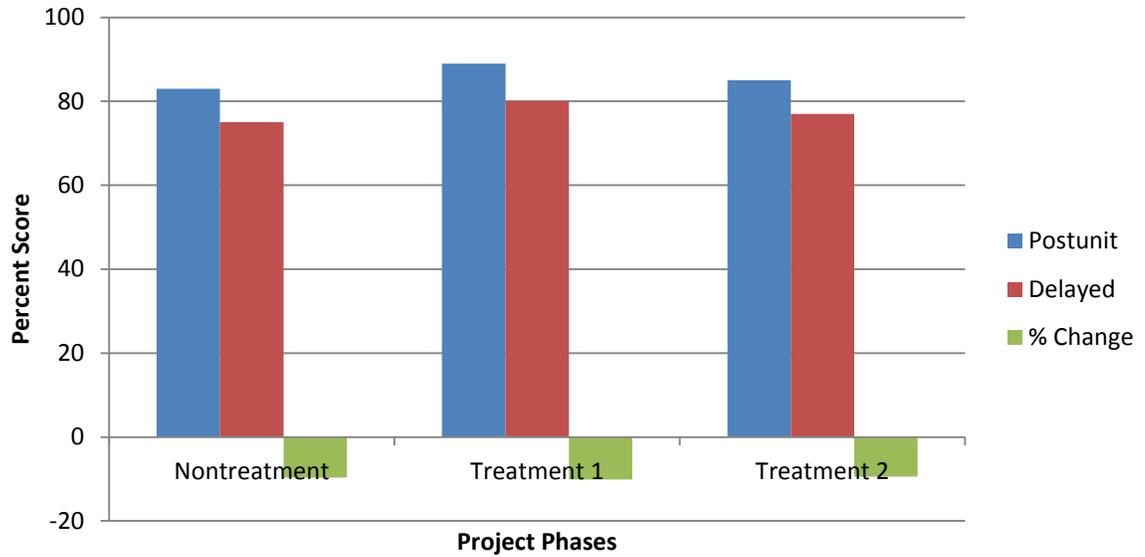
Concept Interview	Nontreatment Unit	Treatment Unit 1	Treatment Unit 2
Preunit	7.8	5.4	5.1
Postunit	9	9.3	8.9
Percent Change (%)	15	72	75
Normalized Gain Score	0.55	0.84	0.78

*Note.* All interviews scored out of 10 points.

These data further supports the analysis of the preassessment and postassessment data above. Students showed higher gains in the two treatment units than the nontreatment unit, and the preassessment scores were much lower for the two treatment

units than the nontreatment unit. This was, once again, due to the amount of unfamiliar material in each unit. The nontreatment unit consisted of systems of equations which are covered in detail in Algebra 1, a prerequisite for Algebra 2. The first treatment unit consisted of matrices, which students had very little exposure to prior to Algebra 2. Students were exposed to the second treatment unit concepts, quadratics, in previous courses; however, students minimally investigated quadratics in Algebra 1 compared to Algebra 2. The students scored the highest on the postunit concept interview in the first treatment unit. The normalized gain score yields the significance of the increase for the two treatment units compared to the nontreatment unit. In the nontreatment unit, students improved on 55% of the available content. Where the students improved on 84% and 77% of the treatment unit 1 and treatment unit 2 respectively.

In addition to determining the effects CSI had on content knowledge through the assessment and concept interviews, students' ability to retain the content long term captured my interest. To determine the effects on long-term memory of the concepts for each of the three units, 14 days after the conclusion of the unit, students completed a delayed assessment and concept interview. The results of the delayed assessment compared to the post assessment can be seen in Figure 1. The data show that students decreased in all three units and the percent decrease was the greatest for the first treatment unit and was the least for the second treatment unit. However, the data show that the percent decrease for all three units was about 10. This indicates that students retained about 90% of the content for all three units and that the use of CSI did not have much effect on long-term memory.



*Figure 1.* Average scores from postunit assessment to delayed assessment, ( $N = 24$ ).

In addition to the delayed assessment, students completed a delayed concept interview including the construction of a concept map. The results for this are shown in Figure 2. The data, once again, show that the students decreased comprehension in all three units and the percent decrease was the greatest in the nontreatment unit and the least in the second treatment unit. The first treatment unit also had a percent decrease lower than the nontreatment. This indicates that there was an increase in concept retention in the two treatment units compared to the nontreatment unit.

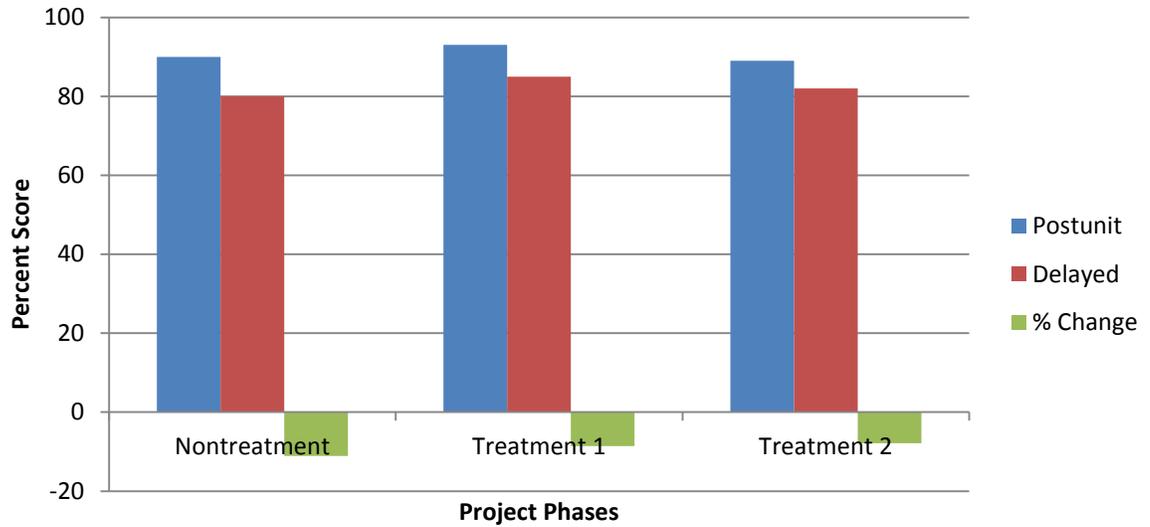
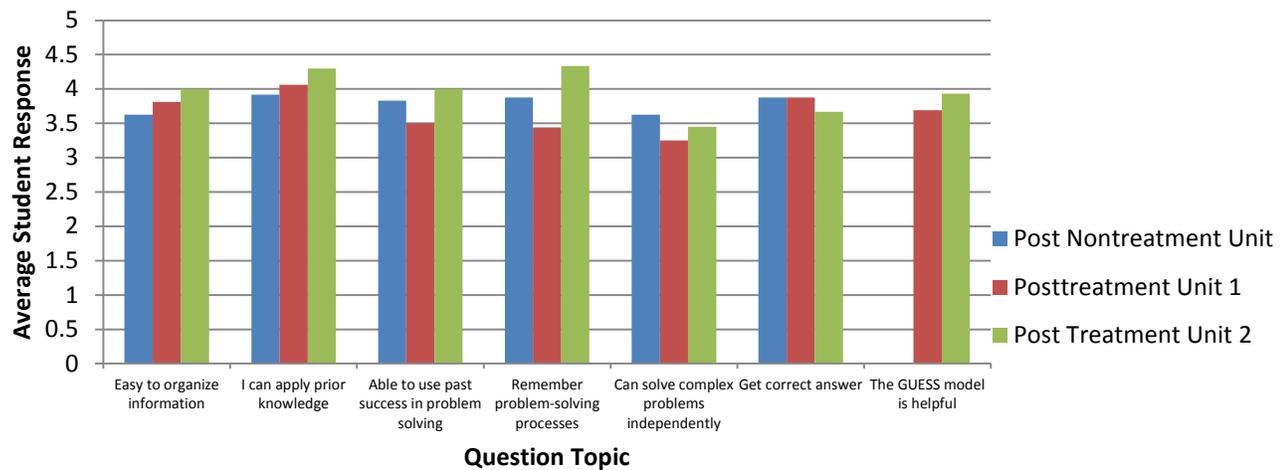


Figure 2. Average scores from postunit concept interviews and delayed concept interviews, ( $N=24$ ).

At the beginning and conclusion of each unit, students completed a survey containing both Likert scale and open-ended questions. The results of select Likert scale questions from the surveys given to the students after the nontreatment and the two treatment units are shown in Figure 3.



*Figure 3.* Average student response for select survey questions. ( $N= 24$ ). *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

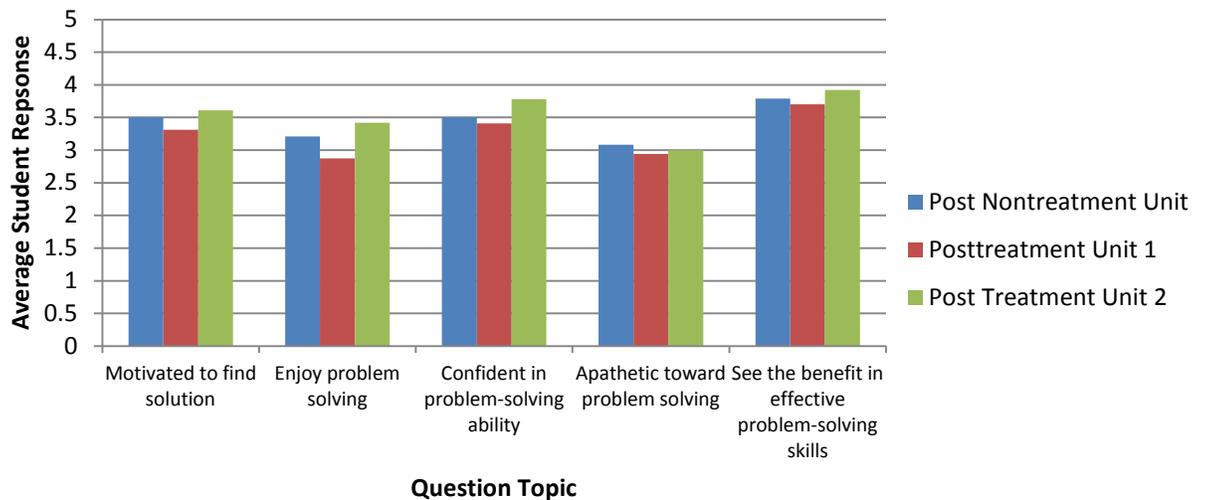
These particular questions in Figure 3 pertain to the students' ability to use prior knowledge, organize a problem and properly arrive at the correct solution. The data show improvement in two areas during the intervention. Both ease of organization and applying prior knowledge increased for each unit. The students' ability to organize information could have increased due to the intervention or just simply because students received more opportunity to solve problems and they became more comfortable in organizing the information. Therefore, this data cannot determine if the increase is due to the intervention.

These survey data show that the students' perception of their ability to use past success in problem solving and ability to remember problem-solving processes both decreased for the first treatment unit as compared to the nontreatment unit. However, the second treatment unit increased in these two categories more than the nontreatment unit. Because the intervention introduced in the first treatment unit was new and unfamiliar to the students, one could expect a temporary decrease in the students' ability to remember past success and the problem solving process. Once the students became familiar with the GUESS model, they showed an increase in their abilities.

Students' perception of their ability to solve complex problems and arrive at correct solutions when problem solving either stayed the same or decreased from the nontreatment to both treatment units. Both treatment units contained more complex problems and higher degrees of difficulty, therefore a decrease in the number of students arriving at correct answers would be natural. The complexity and degree of difficulty

increased for these units solely by the nature of the material not be the intent of the teacher. The higher degree of difficulty would also influence the students' ability to solve complex problems. The students showed an increase in their ability to solve complex problems and in their opinion of the helpfulness of the GUESS model from the first treatment unit to the second, most likely because of their comfort using the GUESS increased with more practice.

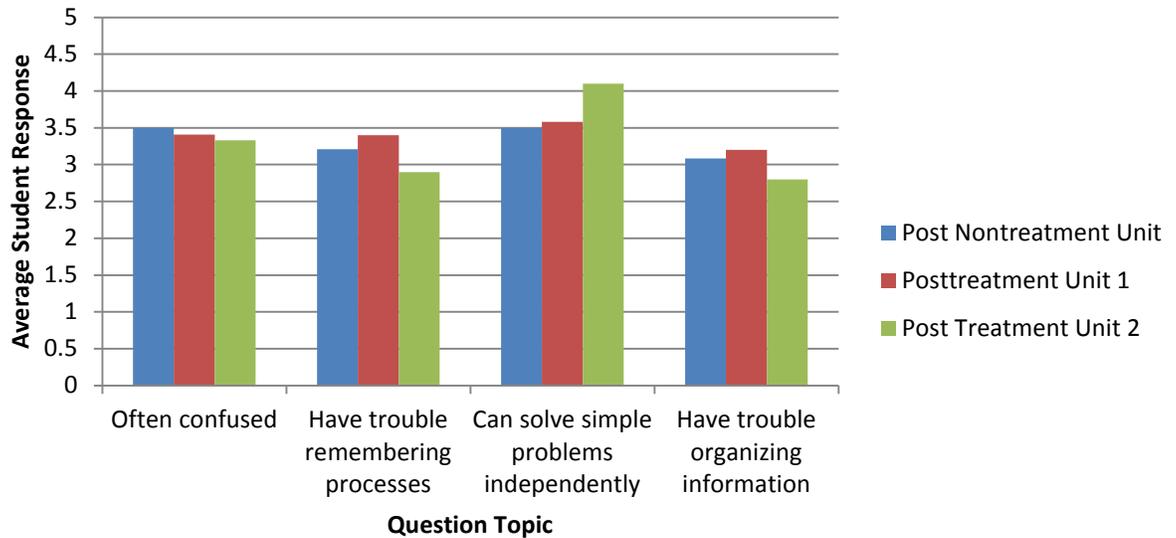
In the student survey, students responded to questions concerning their attitude and motivation toward problem solving. The results of these Likert scale questions from the surveys given to the students after the nontreatment and the two treatment units are shown in Figure 4.



*Figure 4.* Average student response for select survey questions concerning attitudes and motivation, ( $N = 24$ ). *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

These data show that students decreased in all categories from the nontreatment unit to the first treatment unit. However, in the students' motivation, enjoyment of problem solving, confidence and seeing the benefit of problem solving, students increased to a mark higher than the nontreatment unit during the second treatment unit. Once again, the uncertainty of the new problem solving process during the intervention showed some negative effects at first but showed positive effects once the students became comfortable with the GUESS model during the second treatment unit.

Student also responded to questions concerning the identification of possible areas in which the students are deficient with concern to problem solving. The results are shown in Figure 5. The data show that the students felt slightly less confused in the two treatment units than in the nontreatment unit and showed an increase in the ability to solve simple problems independently. The data also show that students had an increase in both having trouble remembering the problem-solving and organizing information from the nontreatment unit to the first treatment unit, but then had a decrease to the second treatment unit. The unfamiliarity of the intervention could have contributed to this increase. The decrease to the second treatment unit indicates that the intervention, once familiar, was helpful in decreasing confusion, remembering the problem-solving process, solving simple problems independently and organizing information in a given problem.



*Figure 5.* Average student response for select survey questions concerning problem solving skills and organization, ( $N = 24$ ). *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

Before and after intervention, six students were chosen to participate in the interview located in Appendix M. There were two of each achievement level: low, moderate, and high. A summary of their responses is listed in Table 4. There was an overall increase in all three categories, meaning more students felt they were effective problem solvers, had a positive attitude toward problem solving and were more motivated to solve problems after the intervention. One low-achieving student responded in the negative after the intervention for all three categories.

These data suggest that the intervention had a positive effect on the students' opinion of their effectiveness as a problem solver, their attitude and motivation toward problem solving. When one high-achieving student was asked if she felt she was an effective problem solver, she responded "I think I am more effective when I know what I am doing. When I am comfortable with the way to solve problems I am effective."

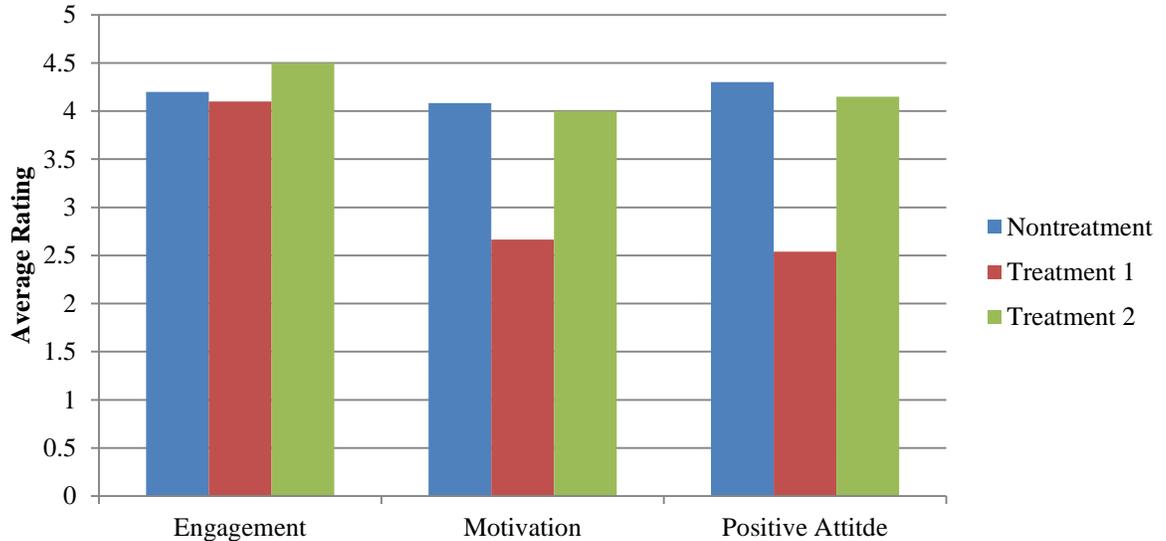
Another student responded to his attitude and motivation by saying, “I have a good attitude with problem solving because I usually want to find the answer and, more often than not, get the answer right so that makes me feel good.” When this student was asked why he wanted to find the answer to problems he answered, “I like the challenge and it makes me think.” These two students’ responses demonstrated that their effectiveness, attitude and motivation are directly affected by their success during the problem-solving experience along with the intrinsic reward of facing a challenge.

Table 4  
*Number of Students that Responding in Positive Affirmation to Interview Questions Concerning Effectiveness, Attitude and Motivation Before and After Intervention, (N=6)*

Students	Effective problem solver		Positive attitude toward problem solving		Motivated to solve problems	
	Before	After	Before	After	Before	After
Low-Achieving ( $n=2$ )	1	1	0	1	0	1
Moderate-Achieving ( $n=2$ )	1	2	0	2	1	2
High-Achieving ( $n=2$ )	2	2	1	2	1	2
Total	4	5	1	5	2	5

During the three units, I conducted observations of the students to determine their attitudes and motivation toward problem solving and the use of cognitive strategy instruction to aid in the problem-solving process. The prompts for the student observation can be found in Appendix L. The rating for student engagement, motivation and attitude were average according to each unit and the results are displayed in Figure 6.

There were six days observed for the nontreatment unit and the first treatment unit and seven days for the second treatment unit.

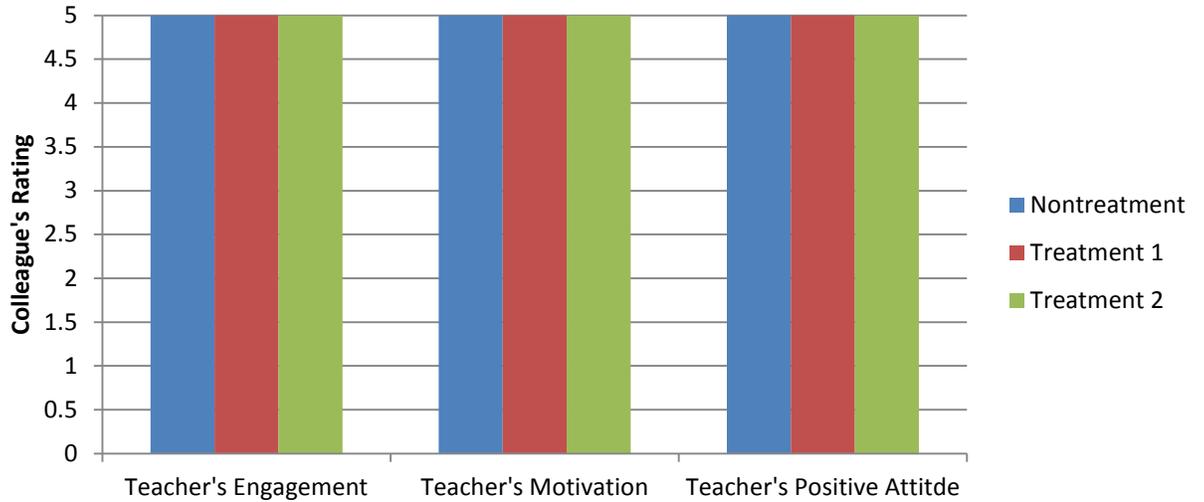


*Figure 6.* Average teacher rating during unit of students' engagement motivation and positive attitude. *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

These data show that the level of student engagement was fairly consistent with the second treatment unit slightly higher than the other two units. These data also show a steep decrease in both the students' motivation and attitudes from the nontreatment unit to the first treatment unit. However, the students' motivation and attitudes increased just as drastically from the first treatment unit to the second treatment unit but did not reach the nontreatment level. This large discrepancy could be due to the unfamiliarity of the intervention during the first unit. During the first treatment unit, I wrote a comment on the observation form stating, "Students are very discouraged with the new GUESS model. They are having trouble remembering the method and do not see its purpose. This is negatively affecting their attitudes and motivation toward class. However the

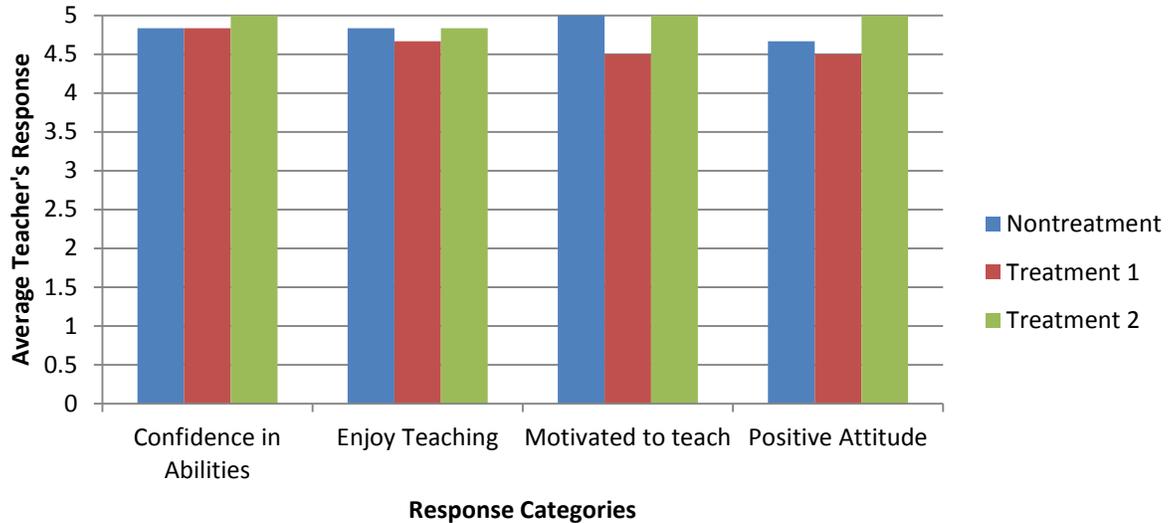
students are still engaged and willing to learn.” The data suggest that CSI had little effect on student engagement, however had a negative effect on the students’ motivation and attitude at first. The data also suggest that once the methods of CSI used in the intervention became familiar to the students during the second treatment unit, the students’ motivation and attitudes returned to a level almost consistent with the nontreatment unit.

To determine the effects of CSI on the teacher’s attitude and motivation, a colleague conducted an observation of the classroom during the nontreatment unit and each of the treatment units using the prompts listed in Appendix P. The results for the colleague’s rating of student engagement, teacher’s motivation, and attitude are displayed in Figure 7. The data show that the teacher’s engagement of the students, motivation or attitude was not affected by the intervention. The colleague rated the teacher at the highest level for all three observations in each of the three categories. During the second treatment unit, my colleague wrote, “The teacher demonstrates enthusiasm and connects to all students in the class... his positive attitude leads to positive attitudes of the students...motivates the unmotivated” This shows that during the lesson, with the teacher’s motivation and attitude positive, the students shaped their motivation and attitude after the teacher’s and were also positive.



*Figure 7.* Colleague's Rating During Unit of Students' Engagement, Teacher's Motivation and Teacher's Positive Attitude. *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

In addition to the colleague observation, the teacher completed daily teacher surveys which are located in Appendix N. Six surveys were completed for the nontreatment unit and the first treatment unit and seven were completed for the second treatment unit. The averages for each unit were found and the results are displayed in Figure 8.



*Figure 8.* Average teacher's rating for daily teacher survey. *Note.* 5 = Strongly Agree, 4 = Agree, 3 = Indifferent, 2 = Disagree, 1 = Strongly Disagree.

These data show that my enjoyment of teaching, motivation to teach and positive attitude decreased from the nontreatment unit to the first treatment unit. This could be a reflection of the decrease in the students attitude and motivation during their period of unfamiliarity of the new intervention. However, the data also show that my confidence, enjoyment, motivation and attitude all increased from the first treatment unit to the second treatment unit. The second treatment unit was greater than or equal to the nontreatment unit in all four categories. This suggests that the intervention had a positive or null effect. Notably, even though there was a difference in the three units for these four categories, all three units remained at a high standard for each category and the differences may not be considered significant.

To triangulate the data in determining the effect of CSI on my attitude and motivation, I also completed a daily journal using the prompts in Appendix O. Since the survey and journal were typically completed about the same time, the data for the Likert

scale motivation, attitude and effectiveness was consistent with those of the teacher survey above. I recorded in the journal that during the nontreatment unit, the want for my students to succeed in Algebra 2 was my primary motivation. My attitude stayed positive throughout the unit and both my attitude and motivation noticeably affected the students' attitudes and motivations positively.

During the first treatment unit, I maintained my high level of motivation and positive attitude. At the beginning of the unit, my excitement was shown in my first reflection stating, "Today, I was highly motivated and had a great attitude because I was excited to start the new intervention of the GUESS model and teach my students to become a more metacognitive problem solver." However, there were moments of discouragement. In a reflection during the first treatment unit, I wrote, "Both my attitude and motivation suffered today, because the students had trouble understanding the method and usefulness of the new GUESS model. This however, has become a new drive in my motivation to increase the understanding of my students and to give my students the needed resources to succeed in problem solving." These reflections show the effect of the intervention on my motivation and attitude as first being positive because of the excitement, then negative because of the discouragement, but the discouragement was then used to increase my motivation and attitude to become a better teacher.

In the second treatment unit, my motivation was higher and my attitude was more positive. I wrote in a reflection,

Now that the students are getting the hang of the GUESS model and becoming more introspective in their problem solving, they are having more success and therefore increasing their attitudes and motivation. This

positively affects my attitude and motivation. I enjoy seeing the students succeed and I want to continue to become a better teacher so that I can continue to see more success.

This showed that the intervention was showing a positive effect on the students which then caused a positive effect on my attitude and motivation.

### INTERPRETATION AND CONCLUSION

The goal of this project was to determine the effects of CSI on the problem-solving skills of Algebra 2 students. Both the assessment and the concept interview data show an increase during both treatment units than in the nontreatment unit. In this regard, CSI clearly had a positive effect on the problem-solving skills of the students. The survey data confirms this with increases in almost all areas of the problem-solving process by the end of the second treatment unit. However, the survey data also show a decrease in many areas for the first treatment unit. I can confidently say that this is due to the unfamiliarity of the intervention and that the student's resolved these issues once the intervention became familiar. The student interviews and observations created the confidence for this reasoning. From these data I can conclude that CSI had a positive association with the degree of competence of the problem-solving skills of my students.

The purpose of this project was to also investigate the deeper effects of CSI. I first wanted to see how CSI affected the long-term memory of my students. The data show that there was little effect on students' long-term retention from the delayed assessments; however the students did show a slightly higher level of retention in the concept interviews during the treatment units. The survey data also show that the

students perceived that they remembered problem-solving processes better after the treatment. Therefore, CSI had a positive effect on the students' long-term memory in that they retained more concepts and remembered problem-solving processes better with the treatment than they did without.

My next goal was to see the effect on the students' attitude and motivation toward problem-solving. The data from all three sources, survey, interview, and observation, show a sharp decrease in the attitudes and motivation of the students from the nontreatment unit to the first treatment unit. However, all data also show an even larger increase in the attitude and motivation of students from the first treatment unit to the second. As stated earlier, the students' unfamiliarity to the intervention could be the cause for this sharp decrease into the first treatment unit. When compared from the nontreatment unit to the second treatment unit, or the end of intervention, the data show an increase in the attitudes and motivation of the students. When CSI was first used with students, there was clearly a negative effect on the attitudes and motivation, but once CSI had enough time to become familiar to the students, it positively affected the students' attitudes and motivation.

Along with the students' attitudes and motivation, this project set out to determine the effect of CSI on the teacher's attitude and motivation. Through the reflective journal, teacher survey, and colleague observation, the data show that CSI affected my attitude and motivation similarly to the students. My attitude and motivation noticed a small decrease during the first treatment unit but then increased to the second treatment unit. The students decrease in motivation had a negative effect on my motivation during this period. Like the students, my attitude and motivation was higher by the end of the

intervention than during the nontreatment unit. At first, CSI affected my attitude and motivation negatively but over time affected positively.

This project yielded conclusive data that CSI had a positive effect on the competence of the problem-solving skills of Algebra 2 students. Even so, this project could be improved to become more conclusive. For my first improvement, I would make more specific survey and interview questions. Now knowing that CSI caused a slight decrease in several areas initially, I would like to have specific questions to determine what about CSI and the GUESS model caused these decreases. I would also expand the concept interview. The concept maps worked well, but I would include more specific concept questions to more closely examine the true effects of CSI on content knowledge and long-term retention. I would also like to examine the spread of each result whether it is a standard deviation or simply a range of scores. The spread of data may shed light on a hidden change. For instance, since the delayed assessments showed around the same retention, the treatment may seem to have no effect. However, if the spread after the treatment were smaller than the nontreatment, this would mean there is a positive effect since the lower students achieved at a higher level. Finally, it would be beneficial to conduct this same project on three independent units with approximately equal prior knowledge. This would assist in eliminating latent variables and contribute to a clearer picture of the effect of CSI.

## VALUE

Problem solving will always be a challenge for students and teachers alike. This project has allowed me to see how the teaching techniques of CSI can positively affect

students' problem-solving skills. These results help to show both me and my students the importance of the metacognitive process of problem solving and when a student is reflective of his or her problem-solving process improvements are made. This shows that the current method of teaching problem solving may not be the best method possible for students.

This will lead me to consider including more types of CSI in my future teaching and ultimately become a more effective teacher.

The results of this project are not limited to the high school mathematics classroom. Problem-solving skills are necessary in almost all content areas and every level of education. These results can be applied to any level from elementary to postsecondary education and any content area. The idea that a student, who is more aware of his or her problem solving process, is a more successful problem solver, can be applied almost anywhere. A science teacher can use this when teaching students to develop hypotheses and ways to test hypotheses in the lab. A social studies teacher can use this when students are trying to answer questions or conduct a social experiment. The applications are endless. Anywhere a student is presented with a problem, mathematical or not, and asked to solve, problem-solving skills are needed.

The research could be applied into many different directions. This same or similar study could be done in other content areas to see the effects of CSI in content other than math. One could also use other techniques of CSI to determine the effects. This project focused on self-reflection and the use of the GUESS model. One could use other metacognitive activities and techniques to see if they have the same effect. This

could help determine if it is CSI in general that has a positive effect or the specific techniques used in this study.

In addition, one could expand on this study. One could stratify the study sample into achievement levels and conduct the same study but analyze the effects of CSI in the separate achievement levels as well as the class as a whole. This may provide more valuable or conclusive information than only looking at the class as a whole. One may discover that CSI has a much greater effect on one level than another or even determine that the effect on a particular level is negative when the class as a whole is positive. This would help teachers to appropriately use CSI in their differentiated instruction. Just because CSI has a general benefit for the entire class, it may not be a benefit for every student in the class.

I think that this project was beneficial for my students for two reasons. First, they became more effective problem solvers. Second, they learned the importance and effectiveness of self reflection. Students saw that when they are more aware of the process they use, the more effective these processes can be. This can be applied to many areas of my students' lives, whether in academics or outside of school. If my students continue these practices, they will continue to be effective problem solvers in the classroom as well as being more effective decision makers in life.

This study also taught me, as the teacher, to be more reflective of my teaching in general. When I make a point to take time and reflect on my teaching, I am better able to identify both my effective and ineffective practices. This helps me to develop an action plan in which I can promote more use of the effective practices and attempt to eliminate the ineffective. This project has taught me to continue these practices to help improve

my effectiveness as a teacher and improve my students' learning. This also forced me to think about what affects my students' problem-solving skills. Until this research, I never considered what affected their skills, I just observed their deficiencies. By studying and knowing what affects their problem-solving skills, I can better help my students become more effective problem solvers.

This study also helped me learn more about myself. During the study I encountered challenges, especially when beginning the intervention and experiencing resistance from the students initially. This adversity negatively affected my motivation as a teacher, which in a way was disappointing that I can be that easily affected. However, the disappointment quickly became motivation because of my determination to improve my students' problem-solving skills and to persevere in determining the effects of CSI. I learned both my strengths and weaknesses.

This capstone gave me insight to my students' problem-solving abilities that will have a lasting effect on my teaching throughout the rest of my career. However, I do not believe this will be the full impact of this study. More importantly I have learned to be a more reflective teacher. In addition, I have found the importance of not only identifying the deficiencies of my students, but to also determine the reason behind the deficiencies. This project was not able to identify why my students have trouble with problem solving, but it was able to show me how CSI affects their problem-solving skills and this leads me to wonder what the underlying cause is. I feel that these lessons are important because they require action on my part, as the teacher, and this action will continue to make me a more effective teacher. After all, becoming a more effective teacher is the ultimate goal of action research.

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APPENDICES

APPENDIX A

NONTREATMENT UNIT SAMPLE PROBLEMS

Appendix A  
Nontreatment Unit Sample Problems

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

Algebra 2 Linear Programming Problem Solving

**Use Linear Programming to solve each of the following.**

1. A juice company makes two kinds of juice: Orangeade and Berry-fruity. One gallon of Orangeade is made by mixing 2.5 quarts of orange juice and 1.5 quarts of raspberry juice, while one gallon of Berry-fruity is made by mixing 3 quarts of raspberry juice with 1 quart of orange juice. A profit of \$0.50 is made on every gallon of Orangeade sold, and a profit of \$0.40 is made on every gallon of Berry-fruity sold. If the company has 150 gallons of raspberry juice and 125 gallons of orange juice on hand, how many gallons of each type of juice should the company make to maximize profit?
  
2. An office manager is purchasing file cabinets and wants to maximize storage space. The office has 60 square feet of floor space for the cabinets and \$600 in the budget to purchase them. Cabinet A requires 3 square feet of floor space, has a storage capacity of 12 cubic feet, and costs \$75. Cabinet B requires 6 square feet of floor space, has a storage capacity of 18 cubic feet, and costs \$50. How many of each cabinet should the office manager buy?
  
3. You are stenciling wooden boxes to sell at a fair. It takes you 2 hours to stencil a small box and 3 hours to stencil a large box. You make a profit of \$10 for a small box and \$20 for a large box. If you have no more than 30 hours available to stencil and want at least 12 boxes to sell, how many of each size box should you stencil to maximize your profit?

APPENDIX B

DOCUMENTED PROBLEM SOLVING CAT

Appendix B  
Document Problem Solving CAT

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

Algebra 2 Documented Problem Solving

**For the following problem, in addition to finding a solution, write a short essay describing the thought process in which you used to arrive at your solution. Explain the mental processes you went through in solving the problem.**

A baton twirler tosses a baton into the air. The baton leaves the twirler's hand 6 feet above the ground and has an initial vertical velocity of 45 feet per second. The twirler catches the baton when it falls back to a height of 5 feet. For how long is the baton in the air?

APPENDIX C

TREATMENT UNIT ONE WORD PROBLEM

Appendix C  
Treatment Unit One Word Problem

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

Algebra 2 Solving Systems with Inverse Matrices

For the following word problem, use the GUESS model to organize the information and solve using inverse matrices.

You have \$10,000 to invest. You want to invest the money in a stock mutual fund, a bond mutual fund, and a money market fund. The expected annual returns for the funds are 10%, 7% and 5% respectively.

You want your investment to obtain an overall annual return of 8%. A financial planner recommends that you invest the same amount in stocks as in bonds and the money market combined. How much should you invest in each fund?

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Once the problem is solved, write a sentence or two for each of the sections of the GUESS model describing your thought process and stating why you chose to write what you did.

APPENDIX D

TREATMENT UNIT TWO ACTIVITY

Appendix D  
Treatment Unit Two Activity

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

Algebra 2 Quadratic Functions in the Real World Activity

In this lesson students split into two groups, A and B. Each group is given a separate problem using quadratic functions in real life. Each student writes a plan of how to solve their problem but does not derive a solution. In this plan, each student puts the mental process they would go through, in order to solve the problem, on paper. The students are to use an adaptation of the GUESS model in essay form, without rewriting the original problem. Once this task is complete, the students find a partner from the opposite group and switch essays. The students then use their partner's essay to solve the problem without seeing the original word problem.

**Group A** (only shown to group A)

The equation  $h = 0.019s^2$  gives the height  $h$  (in feet) of the largest ocean waves when the wind speed is  $s$  knots. How fast is the wind blowing if the largest waves are 15 feet high?

**Group B** (only shown to group B)

The aspect ratio of a TV screen is the ratio of the screen's width to its height. For most TVs, the aspect ratio is 4:3. The measurement of a TV is the length of its diagonal. What are the width and height of the screen for a 27 in TV?

APPENDIX E

NONTREATMENT PRE AND POSTUNIT ASSESSMENT

Appendix E  
Nontreatment Pre and Postunit Assessment

1. Describe the process of solving a system of linear equations in two variables using substitution.
2. Use elimination to solve the linear system 
$$\begin{array}{r} 3x - 2y = 10 \\ 5x + 3y = -15 \end{array}$$
3. During a recent telethon, people pledged \$25 or \$50. Twice as many people pledged \$25 as \$50. Altogether, \$18,000 was pledged. How many people pledged \$25?
4. Postcard stamps are \$0.29 each, while letter stamps are \$0.44 each. If you have 50 stamps worth \$18.85, how many of each type do you have?
5. You work at a grocery store. Your hourly rate is greater after 6:00 PM than it is during the day. One week you work 20 daytime hours and 20 evening hours and earn \$280. Another week you work 30 daytime hours and 12 evening hours and earn a total of \$276. What is your daytime rate? What is your evening rate?

APPENDIX F

TREATMENT UNIT ONE PRE AND POST UNIT ASSESSMENT

Appendix F  
Treatment Unit One Pre and Postunit Assessment

1. Solve  $\begin{bmatrix} 12 & 7 \\ 5 & 3 \end{bmatrix} x = \begin{bmatrix} 2 & -1 \\ 3 & 2 \end{bmatrix}$
2. Describe what an inverse matrix is and its purpose in solving systems of linear equations.
3. Use a determinant to find the area of the triangle formed by the following vertices: (0,0); (5,-2); (2,6)
4. You have \$18 to spend for lunch during a 5-day work week. It costs you about \$1.50 to make a lunch at home and about \$5 to buy a lunch. How many times each work week should you make a lunch at home? Use inverse matrices to solve the system.
5. Use Cramer's rule to solve the following: Macadamia nuts cost \$0.90 per ounce, peanuts cost \$0.30 per ounce, and cashews cost \$1.30 per ounce. You want a 20-ounce mixture of macadamia nuts, peanuts, and cashews that cost \$0.68 per ounce. If the combined weight of the macadamia nuts and cashews equals the weight of the peanuts, how many ounces of each nut should be used?

APPENDIX G

TREATMENT UNIT TWO PRE AND POST UNIT ASSESSMENT

Appendix G  
Treatment Unit Two Pre and Postunit Assessment

1. Explain what a zero of a function is. What are the zeros of the function:  
$$f(x) = 4x^2 - 25$$
  
2. Find the discriminant of the function  $f(x) = 2x^2 + 6x - 21$ . What does this tell you about the number and type of solutions of  $f(x) = 0$ ?
  
3. A football is released into the air at an initial height of 9 feet and an initial velocity of 30 feet per second. The football is caught at a height of 10 feet. Use the vertical motion model  $h = -16t^2 + vt + s$  where  $h$  is the height,  $t$  is the time in motion,  $s$  is the initial height, and  $v$  is the initial velocity, to find how long the football is in motion.
  
4. Niagra Falls is 167 feet high. How long does it take for water to fall from the top to the bottom?
  
5. An insurance company charges a 35-year-old nonsmoker an annual premium of \$118 for a \$100,000 term life insurance policy. The premiums for a 45-year-old and 55-year-old nonsmoker are \$218 and \$563, respectively. Write a quadratic model for the premium  $p$  as a function of age  $a$ .

APPENDIX H

CONCEPT INTERVIEW: NONTREATMENT UNIT

Appendix H  
Concept Interview: Nontreatment Unit

Concept Map

Create a concept map using the materials provided: poster paper, cards with vocabulary words and terms.

You will be given cards with the following words or terms: system of two linear equations in two variables; substitution method; elimination method; systems of linear inequalities; linear programming; three-dimensional coordinate system; ordered triple; system of linear equations in three variables.

Arrange these cards on the poster paper in a logical order with the starting word: systems. If you would like to add any cards with your own words or phrases, feel free. Connect each of the cards with connections phrases.

You will present your concept map to me.

Concept question: Using your concept map, explain how both substitution and elimination are used to solve linear systems of equations and inequalities in both two and three variables.

APPENDIX I

CONCEPT INTERVIEW: TREATMENT UNIT ONE

Appendix I  
Concept Interview: Treatment Unit One

Concept Map

Create a concept map using the materials provided: poster paper, cards with vocabulary words and terms.

You will be given cards with the following words or terms: matrix; equal matrices; scalar; scalar multiplier; determinant; Cramer's rule; identity matrix; inverse matrix.

Arrange these cards on the poster paper in a logical order with the starting word: matrices. If you would like to add any cards with your own words or phrases, feel free. Connect each of the cards with connections phrases.

You will present your concept map to me.

Concept question: Using your concept map, explain how matrices are used to solve systems of equations in both two and three dimensions.

APPENDIX J

CONCEPT INTERVIEW: TREATMENT UNIT TWO

Appendix J  
Concept Interview: Treatment Unit Two

Concept Map

Create a concept map using the materials provided: poster paper, cards with vocabulary words and terms.

You will be given cards with the following words or terms: quadratic function; parabola; factoring; quadratic equation; zero of a function; square root; complex number; completing the square; quadratic formula; discriminant.

Arrange these cards on the poster paper in a logical order with the starting word: quadratic functions. If you would like to add any cards with your own words or phrases, feel free. Connect each of the cards with connections phrases.

You will present your concept map to me.

Concept question: Using your concept map, explain how quadratic functions are solved and what the solutions of a quadratic function means.

APPENDIX K

STUDENT SURVEY

Appendix K  
Student Survey

This survey is voluntary and has no effect on your grade

1 = Strongly Disagree 2 = Disagree 3 = Indifferent 4 = Agree 5 = Strongly Agree

- |  |         |
|--|---------|
| 1. I find it easy to organize information when given a problem to solve.   | 1 2 3 4 |
| 5  |         |
| 2. I often find the correct answer when I am problem solving.              | 1 2 3 4 |
| 5  |         |
| 3. I am often confused when I am problem solving.                          | 1 2 3 4 |
| 5  |         |
| 4. I am able to use past success in problem solving to solve new problems. | 1 2 3 4 |
| 5  |         |
| 5. Once I discover how to solve a problem, I always remember the process.  | 1 2 3 4 |
| 5  |         |
| 6. I have trouble remembering how to solve problems.                       | 1 2 3 4 |
| 5  |         |
| 7. I can solve simple problems without assistance.                         | 1 2 3 4 |
| 5  |         |
| 8. I can solve complex problems without assistance.                        | 1 2 3 4 |
| 5  |         |
| 9. When presented with a problem, I am motivated find the solution.        | 1 2 3 4 |
| 5  |         |
| 10. I enjoy problem solving.   | 1 2 3 4 |
| 5  |         |

11. I am confident in my problem solving ability. 1 2 3 4  
5
12. I have trouble organizing information when presented with a problem. 1 2 3 4  
5
13. I am apathetic toward problem solving. 1 2 3 4  
5
14. I do not see the benefit in having effective problem-solving skills. 1 2 3 4  
5
15. Posttreatment: I find the GUESS model helpful in solving problems. 1 2 3 4  
5
16. I can apply my prior knowledge to new problems presented to me. 1 2 3 4  
5
17. Why is it important to understand the method of problem solving? How does it help you in future problem solving experiences?
18. What strategies in class help you learn to solve problems the best? Explain.
19. What are the biggest challenges you face when solving an applied math problem? Explain. How can you address these problem(s)?
20. What discourages you about problem solving? What encourages you about problem solving? Explain.

APPENDIX L

STUDENT OBSERVATION PROMPTS

Appendix L  
Student Observation Prompts

Date \_\_\_\_\_ Phase of class for observation \_\_\_\_\_

Prompts for when the teacher observes the students during both treatment and nontreatment units. With each of these prompts an explanation is not always necessary, but encouraged.

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

- |  |       |
|--|-------|
| 1. Students are engaged in the lessons<br>4 5<br>Explain.                    | 1 2 3 |
| 2. Students are showing motivation to learn new material.<br>4 5<br>Explain. | 1 2 3 |
| 3. Students are showing motivation to solve problems.<br>4 5<br>Explain.     | 1 2 3 |
| 4. What seems to motivate students? What does not?                           |       |
| 5. The students' motivation is a help to their learning.<br>4 5<br>Explain.  | 1 2 3 |
| 6. Do any students have negative attitudes toward the lesson?                |       |
| 7. Do any students have negative attitudes toward solving problems? Why?     |       |
| 8. What seems to promote a positive attitude in the classroom?               |       |
| 9. What seems to promote a negative attitude in the classroom?               |       |

10. The students' attitudes are a help to their learning?  
4 5  
Explain.

1 2 3

APPENDIX M

STUDENT NONCONCEPT INTERVIEW QUESTIONS

Appendix M  
Student Nonconcept Interview Questions

1. What parts of problem solving do you find most challenging? Explain.
2. Pre and Post: Do you feel you are an effective problem solver? Explain. Post: How does using the GUESS model help in solving a problem? Explain.
3. Pre and Post: What is your attitude toward problem solving? Explain. Post: How does using the GUESS model affect your attitude toward problem solving? Explain.
4. Why is it important to understand the method of solving problems? Explain.
5. When do you feel motivated to solve a problem? Explain.
6. Post: How has the Guess model affected you higher order thinking? Explain.
7. Post: Do you feel that the GUESS model has improved your long-term memory? Explain.
8. Post: What is the biggest change that you notice in your attitude or motivation toward problem solving after using the GUESS model? Explain.

APPENDIX N

TEACHER SURVEY

Appendix N  
Teacher Survey

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

- |  |         |
|--|---------|
| 1. I am confident in my teaching abilities.<br>5<br>Explain.   | 1 2 3 4 |
| 2. I enjoy teaching my students.<br>5<br>Explain.  | 1 2 3 4 |
| 3. I feel motivated to come to school each day.<br>5<br>Explain.   | 1 2 3 4 |
| 4. I have a positive attitude toward teaching my students problem solving.<br>5<br>Explain.                            | 1 2 3 4 |
| 5. My motivation is driving me to become a better teacher.<br>5<br>Explain.  | 1 2 3 4 |
| 6. My attitude contributes to the learning of my students.<br>5<br>Explain.  | 1 2 3 4 |
| 7. What is my motivation to teach? How does my motivation affect my teaching and the learning of my students? Explain. |         |

8. What is contributing to my attitude toward teaching? How does my attitude affect my teaching and the learning of my students? Explain.

APPENDIX O

JOURNAL REFLECTION PROMPTS

Appendix O  
Journal Reflection Prompts

The following are prompts for the teacher's daily journal entries. It is not necessary for the teacher to answer every prompt daily, nor give an explanation for each. However, it is encouraged to answer as many and explain as much as possible.

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

My attitude today was positive. 1 2 3  
4 5  
Explain.

How did my attitude affect my students' learning?

What shaped my attitude today?

I was motivated to teach today. 1 2 3  
4 5  
Explain.

How did my motivation affect my students' learning?

What motivated me to teach today?

My students have a better understanding of the concepts after my lesson. 1 2 3  
4 5  
Explain.

What improvements could I make to the lesson?

What is my plan for tomorrow?

APPENDIX P

COLLEAGUE OBSERVATION PROMPT

Appendix P  
Colleague Observation Prompt

Date \_\_\_\_\_ Phase of  
class \_\_\_\_\_

The following are prompts for a colleague to use during an observation. The colleague is not limited to the list below.

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

The teacher shows motivation for teaching. 1 2 3  
4 5  
Explain.

How does this affect the students?

The teacher is engaging the students in the lesson. 1 2 3  
4 5  
Explain.

The teacher has a positive attitude toward teaching. 1 2 3  
4 5  
Explain.

How does this affect the students?

How does the attitude of the teacher change with the attitudes of the students?

How does the motivation of the teacher change with the motivation of the students?

Where could you see improvement in the teacher's attitude or motivation?

APPENDIX Q

GENERAL TIMELINE

Appendix Q  
General Timeline

Timeline:

February 15 - Nontreatment preunit assessment and concept interview, Solving systems of linear equations by graphing

February 16 - Solving system of linear equations algebraically

February 21 - Graphing systems of linear inequalities

**1<sup>st</sup> Observation by colleague**

February 22 - Linear programming

February 23 - Solving systems of linear equations in three variables

February 24 - **Nontreatment postunit assessment and concept interview, Treatment Unit 1: Matrices preunit assessment and concept interviews**

**Nontreatment postunit surveys and nonconcept interviews**

February 27 - Matrix properties

February 28 - Finding determinants of matrices

February 29 - Cramer's rule for solving systems

March 1 - Using inverse matrices in real life

**2<sup>nd</sup> observation by colleague**

March 2 - Solving systems using inverse matrices

March 5 - **Treatment Unit 1: Matrices postunit assessment, Treatment Unit 2: Quadratic Functions preunit assessment**

**Treatment unit 1 postunit surveys and interviews**

March 6 - Graphing quadratic functions

March 7 - Solving quadratics by factoring

March 8 - Solving quadratics by square roots and complex numbers

March 9 - Completing the square, **nontreatment unit delayed assessment nontreatment unit**

**3<sup>rd</sup> observation by colleague**

March 12 - Quadratic formula and graphing quadratic inequalities

March 13 - Modeling data with quadratics

March 14 - **Treatment Unit 2: Quadratic Functions post unit assessment, Unit 1 Treatment unit 2 postunit surveys and interviews**

March 19 - **Treatment unit 1 delayed assessment, surveys and interviews**

March 28 - **Treatment unit 2 delayed assessment, surveys and interviews**