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Using Graphic Organizers, Cooperative Learning, and Written Reflection to Improve Mathematics Problem Solving Skills

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USING GRAPHIC ORGANIZERS, COOPERATIVE LEARNING AND WRITTEN REFLECTION TO IMPROVE MATHEMATICS PROBLEM SOLVING SKILLS

by

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CHAPTER ONE

Introduction

Problem Solving in My Classroom

Problem solving is a major component of any math classroom. In my mathematics classroom, problem solving is the process of working through the details of a problem to reach a solution. The act of problem solving consists of applying previous knowledge to a new situation to develop conclusions and develop an answer. The ability to problem solve is a skill all students must learn to be successful in math classes, other disciplines, college, and future careers. As an algebra and geometry teacher, I know not all of my students will choose careers where they will apply the math concepts I am teaching them. Students will not need to know how to graph a line or find trigonometry ratios, but they will need to find solutions to problems they encounter in their future careers. I repeatedly tell my students I am teaching them problem solving skills and I am preparing them for the future. I believed I was achieving these goals by teaching the algebra and geometry concepts.

However, watching my students work on challenging problems made me realize I was not adequately teaching my students the skills they would need for the future. My students were not good problem solvers and something needed to change. I needed to do a better job at teaching skills for problem solving for the benefit of my students and colleagues. My textbooks contain brief problem solving strategies scattered throughout the book, but it has not been enough to adequately teach my students the skills they need.

I need to supplement my curriculum with other problem solving strategies and teach my students how to use these strategies. How can cooperative learning, graphic organizers, and writing improve eighth grade advanced geometry students' problem solving skills?

Overview

This chapter takes a closer look at the beginnings of this capstone project. I first reflect on why I teach math and my beliefs on the purpose of mathematics education. After giving my students a challenging assignment and watching their reactions, I reflected on the assignment and realized I am not adequately teaching what I preach to my students about the importance of math education. I realize I need to do more to teach students problem solving skills and in this chapter, I explain the importance of these skills and the stakeholders in our students having good problem solving skills. The last section of this chapter offers a summary of the chapter and a preview of chapter two.

Why I teach math

Every math teacher, including myself, dreads the question, "When are we going to use this in real life?" It always comes up in my algebra and geometry classes during the first half of the school year. Initially, I respond by asking them, "Isn't this real life?" The students do not like my answer and proceed to ask about situations outside of school. I tell them about several jobs that use math daily. More importantly, I convey to them I am teaching them skills they need for future classes, college, and any job they hold. I am teaching them critical thinking and problem solving skills, skills all employers look for when hiring new employees. Not all my students will need to know how to solve a

system of equations or the properties of a parallelogram, but everyone needs to know how to problem solve. I truly believed I was preparing my students with these vital skills until I started teaching geometry to my advanced eighth graders.

The Challenge Assignment

My school decided to push geometry down to eighth grade because our advanced learners were no longer reaching their growth targets on state and other testing. I knew geometry would be a good fit for our advanced students and could not wait to challenge them with the geometric concepts. Math comes so naturally to most of my advanced students. I thought most of them would be happy to have an assignment where they were challenged. From a teacher's perspective, this means requiring students to extend their thinking beyond the typical book assignments. From the student's perspective, a challenge is any problem they do not know how to do right away. After the first few weeks of the course, I decided to give my students a challenge assignment. The challenge assignments consist of four higher-level thinking questions. Higher-level thinking questions require students to analyze, explain, and synthesize multiple concepts to find a solution (Thomas & Thorne, 2009). Each question requires students to utilize several current concepts and algebra concepts they learned the previous year. A challenge assignment is given at the end of each chapter as a way to bring together all the sections in the chapter and to help the students review for the upcoming test. The students work in groups to solve these problems so they can share ideas and collaborate to reach a solution.

As an advanced math student myself, I loved having to work through a difficult problem in the various math classes I took throughout my education. I saw math problems as a big puzzle, and I would not give up until I had the solution. I liked reasoning through the different ways I could solve a problem and I knew I would eventually find a way to answer the problem correctly. Additionally, I felt pride in myself for sticking with the problem and for successfully solving the problem. I also felt pride in being one of the students who could answer the difficult problems correctly, and my competitiveness made me want to be the first one to find the correct answer. I thought my students would get the same satisfaction out of challenging problems as I did. I hoped they would appreciate a change from the basic skills practice I assigned throughout the chapter from out of the book.

Students' reactions. Unfortunately, my students were not as excited about being challenged as I was about challenging them. The day of the first challenge assignment, I sorted the students into groups and passed out the assignment. I instructed them to work with each other, share ideas, and use their notes and books if they came to a dead end on a problem. After giving the instructions, I went to my desk to take attendance. When I looked up from my computer, I was surprised to see several hands in the air. When I asked the students what they needed, they responded they did not know how to do the problem and needed help. When I looked at their papers, I saw they were blank and I knew they had not put much thought into the problem. They wanted me to tell them how to do the problem even though they had only been working on the problem for a few minutes! I was shocked at how easily the students gave up on the problems. Where was

the perseverance now that things were tougher? I spent the rest of the class period frantically rushing around the classroom trying to give the students hints and ideas to get them on the right track for each problem. About half way through the hour, I knew the students would not be able to complete any unfinished questions at home by themselves, so I had to get to as many students as possible. Once the bell rang, I was exhausted from running around the classroom.

Reflections on the assignment. As I drove home from school that day, I reflected on my challenge assignment and why it went so poorly. I began to realize my students' biggest struggle was getting started on the problem. Once they had an idea on how to solve the problem, they usually could come to a correct solution without much assistance. They knew how to do the math. They lacked the ability to reason and think logically through the problem if they did not know how to solve it after the initial reading of the problem. My reflections on the challenge assignment brought me to the conclusion that my students were poor problem solvers. I needed to do something to help remedy the problem. I did not want to spend another class period like the one I just had.

The challenge assignment also made me realize I was failing at one of my main goals as a math teacher. I had been telling my students all along the purpose of math class was to teach them how to think critically and problem solve. After the challenge assignment, I realized I was not teaching these skills well and was not adequately preparing my students for the future. I do not want to be the teacher who preaches about the importance of a skill, but does nothing to help my students improve upon the skill. I

knew I needed to do more about problem solving, but I did not know how. Problem solving comes so naturally for me. How do I take my skills and make them into teachable concepts? I knew I would need to do more research on the topic to develop a worthwhile plan for teaching problem solving.

Importance of Problem Solving

The development of problem solving skills is a topic not only important to me, but also my colleagues and students. Problem solving is important to me and my math classroom because it is a skill that is crucial to solving higher order questions in math. For students to be successful in a math class, they need to be able to problem solve. When students have strong problem solving skills, they can apply previous knowledge to a problem and work from that knowledge to obtain an answer. Students will no longer need to memorize the process of how to solve several different types of math problems, but will be able to work to a solution using their knowledge base. Theoretically, this should result in improved achievement on state testing. Problem solving is also a skill college professors will expect of their students. It is my job as a middle school math teacher to start practicing and developing these skills so my students are ready for the future.

Stakeholders in good problem solving. Additionally, this is a skill that will transfer over into other disciplines and teachers will see the benefits in their subject area. Every teacher presents either a problem or activity where students need to produce a final product. In science class, students need to develop hypotheses and create an experiment

to prove or disprove their prediction. In history, students determine why beliefs have shifted across a generation. Even in shop class, students experiment and problem solve to determine the best design for a CO_2 car. If students can become better problem solvers, then all teachers will be able to increase the rigor of their courses and continually challenge students. Teachers will be able to go beyond asking students to just memorize or understand the material. They will be able to ask higher-level questions, have students synthesize material, or apply the concepts to create something. Teachers will be more willing to do these kinds of activities in their classrooms when they know the students have the skills and ability to work through a challenging situation. As a result, students will learn and achieve much more.

Employers are also stakeholders in this research as they desire and need employees who are good problem solvers. Any occupation, whether it is a doctor or a sanitation engineer, will face problems that need solutions. When I have this discussion with my students, I often tell them, "Your boss is going to fire you if you run to them for the answer to every problem you encounter." Students need to learn strategies to conquer problems, practice using them, and gain confidence in their ability to come to a good, logical solution. Employers also want problem solvers because our world today is constantly changing due to the technology and information we now have at our fingertips. They will be expecting their employees to be able to adapt and find solutions to an ever changing world. Since most of the jobs my eighth graders will hold do not even exist right now, I cannot teach them the specific skill set they will need for that job. However,

I can teach them to reason and problem solve; skills they will undoubtedly need in any occupation.

Conclusion

Students need to become better problem solvers to be successful in school and their future careers. It is my job as a math teacher to teach these skills and provide opportunities for my students to practice these skills. Not all my students will need to use the math I teach them in the future, but every single student will benefit from becoming better problem solvers. These skills are the reason educators teach their students mathematics. I thought I was teaching these skills until the challenge assignment in my geometry class showed me how poorly my students were at using problem solving to reach a solution to a difficult problem. After watching my students' reactions to the challenging assignment and reflection on the class period, I knew I needed to do more to help my students become better at problem solving. Problem solving is an important part of a mathematics education as it teaches students how to make connections and better understand the mathematical concepts. The students, other teachers, future college professors and employers are all stakeholders of teaching problem solving as they will all benefit from our students having better problem solving skills.

Preview of chapter two. The next chapter will review the literature from prominent voices in math education, the National Council of Mathematics Teachers, and many others. The chapter first looks at the definition of problem solving and then moves to the history of problem solving in the mathematics classroom and curriculum. The history of

problem solving begins in the 1940s and moves through curriculum reforms caused by world events such as *Sputnik* to *An Agenda for Action* and finally to today's problem solving standards from the National Council of Mathematics, NCTM. The literature review then looks at the differences between successful and unsuccessful problem solvers. From there, the literature review examines various strategies that can be used in the classroom to improve problem solving. Finally, the literature review concludes with the benefits of problem solving and its positive effects on student thinking.

CHAPTER TWO

Literature Review

Introduction

The following literature review seeks to discover a solution to the question: How can cooperative learning, graphic organizers, and writing improve eighth grade advanced geometry students' problem solving skills? This research will be used to develop an action research plan for this capstone. It combines information from published teachers and experts in mathematics education as the research goes through a wide spread of information on mathematical problem solving.

Overview

This chapter digs into the research on mathematics problem solving. The first section explores the definition of problem solving. The following section looks at its role in mathematics education starting in the 1940s and working through various reform efforts, *An Agenda for Action*, and finally the problem solving standards used today. The difference between successful and unsuccessful problem solvers is then investigated as well as the skills needed to become a successful problem solver. Additionally, various methods of improving problem solving in the mathematics classroom are described. The literature review then explores the importance of problem solving including the benefits it has on student thinking and creativity and why teachers struggle to incorporate problem

solving into their curriculum. The last section of the chapter provides a summary and a preview of the upcoming chapter.

Definition of Problem Solving

Problem solving can have many different meanings. Those who do not enjoy mathematics usually think of problem solving as any task involving math. Conversely, those who enjoy mathematics often feel like problem solving is an integral part of mathematics. It is used in word problems, to find patterns, to prove theorems, etc. (Wilson, Fernandez, & Hadaway, 1993). More commonly, people take a general, non-mathematical approach and define problem solving as the work done to obtain a solution for a problem. According to The National Council of Mathematics Teachers (NCTM), problem solving is, "Engaging in a task for which the solution is not known in advance" (2014, p. 1). Therefore, the topic of problem solving is not its own separate concept or chapter of a math textbook. It is intertwined into the subject as a means to better learn and understand the curriculum.

History of Problem Solving

This section of the literature review sheds light on the history of problem solving in the mathematics classroom in the United States. The first notable discussion of problem solving was started by George Pólya in 1945 when his book, *How to Solve It*, was published. However, Pólya's ideas about problem solving were not put into practice until much later. Worldwide events, such as *Sputnik*, created a surge in mathematics curriculum reform as the United States saw a drastic need for improving math, science,

and technology in the country. The focus of the mathematics classroom shifted to more abstract ideas. Unfortunately, the pendulum swung too far to one side and due to the new curriculum, students now lacked the basic skills needed to perform well in mathematics. This spurred a back to the basics movement in the curriculum. The changes in the curriculum did not provide the results the United States desired as students were now scoring poorly in problem solving. This caused the National Council of Mathematics Teachers, NCTM, to recommend problem solving to become the focus of mathematics education. Today, problem solving is still a large focus of the mathematics curriculum as the NCTM has made it one of their mathematics process-based standards.

The beginnings of problem solving in classrooms. Problem solving in the mathematics classroom has had a long history. George Pólya was the first to shed light on the topic of problem solving with the release of his book, *How to Solve It,* in 1945. His book set the groundwork for problem solving in the math classroom. For Pólya, teaching students to think was of primary importance (Wilson, Fernandez, & Hadaway, 1993). Pólya describes problem solving as a practical skill such as swimming. We learn to swim by imitating others and then practicing it by ourselves (Pólya, 1957). Mathematics gives students the opportunity to learn how to problem solve by imitating their teachers and classmates and provides the chance for students to practice on their own.

Pólya's describes four steps or phases of problem solving. The first step is to understand the problem. Students should be able to state the unknown, the data, and the condition or question. The second phase is to devise a plan. Pólya (1957) states, "We

have a plan when we know which calculations, computations, or constructions we need to perform in order to obtain the unknown" (p. 8). The time between understanding the problem and developing a plan may be long because the plan may emerge gradually or after unsuccessful trials. The third phase is to carry out the plan. This includes performing all calculations to find the solution. The last and fourth stage is looking back. This stage is more than just double checking the answer. Looking back consists of reexamining the path that led to the answer. Reflecting upon the problem builds knowledge and problem solving skills (Pólya, 1957).

Mathematics curriculum reform. George Pólya's four steps to problem solving would later become the basis for problem solving in most U.S. mathematics textbooks. However, a reform movement for mathematics curriculum did not occur until late 1957 (Schoenfeld, 1992). The Soviet Union's launch of *Sputnik* sparked the discussion of the mathematics curriculum across the nation. A new curriculum, later to be called "New Math," was developed by the School Mathematics Study Group which was a think tank made up of mathematicians and scientists. The curriculum became widespread in the 1960s but it was later viewed as a failure (Schoenfeld, 1992). The students were not able to learn the abstract ideas in the new math and they were missing the basics skills, like arithmetic, that had been removed from the New Math curriculum (Schoenfeld, 1992).

The lack of basic skills brought a "back to the basics" movement to the 1970s. However, it was not long before the movement was declared a failure (Schoenfeld, 1992). Students had now learned the basic skills through rote memorization but were doing

poorly on measures of thinking and problem solving (Schoenfeld, 1992). After assessing the current state of mathematics education, the National Council of Teachers of Mathematics, NCTM, produced *An Agenda for Action* in 1980 (NCTM, 1980).

Problem solving to the forefront. *An Agenda for Action* created the first big push for problem solving in mathematics. The document is broken up into eight recommendations to improve the math curriculum in the United States. The first recommendation calls for problem solving to be the focus of mathematics in the 1980s. The other seven recommendations involve other areas of the math curriculum (NCTM, 1980). The document states several reasons why problem solving needs to become a focus for math education. The first reason is because problem solving is part of routine and non-routine tasks we encounter in our day-to-day lives. It is a skill students need because every single student will use problem solving in some capacity in their future careers. Additionally, the document states problem solving is crucial to not only mathematics careers but emerging sciences and fields yet to be discovered (NCTM, 1980).

Steps to implement problem solving. *An Agenda for Action* (1980) provided six action steps that would need to be completed for problem solving to become a major focus of mathematics. The first action was to organize the mathematics curriculum around problem solving. The mathematics curriculum of the time focused around computational skills and taught them apart from applications. The recommended action was to create a balance between the two. The curriculum should require students to formulate questions, recognize patterns, seek out data, transfer skills, and draw on

background knowledge. It should also contain the use of imagery, visualization, and spatial concepts (NCTM, 1980).

Action steps two and three ask the teacher to incorporate specific elements of problem solving into their classrooms. The second action calls for a development of problem solving vocabulary. Doing word problems could no longer be considered problem solving. Educators were also asked to make problem solving strategies a priority in their classrooms and use "good problems" throughout their curriculum. The third action calls for teachers to create an environment where problem solving could flourish. Instead of lessons using algorithms, routines, and formulas, teachers are to make lessons involving problem solving as an open, creative activity where students can experiment, ask questions, make estimates, and explore. Educators are also asked to incorporate problems of different forms into their teaching. Students should see problems in the written form, hear problems presented orally, by viewing a diagram, or observing a phenomena (NCTM, 1980).

The fourth and fifth action steps call for a change to the mathematics curriculum. The fourth action asks for appropriate curricular materials to be developed to promote problem solving. This was to be done at all grade levels. Textbooks at the time did not contain real-life problems, only drill and kill type of problems. Most of the problems did not allow for a full range of strategies or abilities to be used. Instead, the problems required students to use an algorithmic approach to the problems. The fifth action calls for problems students could see in their day-to-day lives. NCTM wanted to create

curriculums which incorporate problems used in social sciences, business, engineering, and the natural sciences. Additionally, the fifth action statement called for reform at the college level for prospective teachers. College curriculums for pre-service teachers were asked to provide opportunities for their students to learn how to model problem solving strategies (NCTM, 1980).

The sixth action statement called for more research on problem solving. Throughout the 1980s, NCTM wanted to see research on effective strategies, the identification of effective teaching methods, new programs to prepare teachers for teaching problem solving, the attitudes of good problem solvers, and development of curriculum (NCTM, 1980).

Creating problem solving standards. NCTM believed if students' performance in problem solving improved so would test scores and overall competency in math. This was not the case. The 1987 report, *The Underachieving Curriculum*, found US students to be lagging behind their international counterparts (NCTM, 1989). After analyzing the data from the report, NCTM developed the document *Curriculum and Evaluation Standards for School Mathematics* in 1989. This document contained the first set of national standards for mathematics education.

While *An Agenda for Action* outlined what needed to be done to improve problem solving, not all schools were following the outline. NCTM hoped a set of well-defined standards would make math teachers more aware of what they were expected to teach (NCTM, 1989). Problem solving became one of the many standards developed by

NCTM. Since the release of *Curriculum and Evaluation Standards for School Mathematics*, NCTM has continued to examine, evaluate and revise their standards for mathematics education to remain relevant to the current advances and technology (NCTM, 1989). The current NCTM standards on problem solving call for instructional programs from pre-kindergarten to twelfth grade to build new mathematical knowledge through problem solving, solve problems present in math and other contexts, apply various strategies to solve problems and to monitor and reflect on the problem solving process (NCTM, 2000). These standards have been and will continue to be the driving force in the current movement to improve problem solving skills in math classrooms across the nation.

Differences Between Successful and Unsuccessful Problem Solvers

With the big push in mathematics education to improve students' problem solving abilities, teachers are trying harder to make their students good problem solvers. However, teachers cannot develop students into good problem solvers if they do not know what skills are needed to solve problems and what makes a student a successful or unsuccessful problem solver.

Skills needed for good problem solving.

Problem solving is complex and it requires the student to have many different skill sets (Kauer, 1997). First, the student must have good mathematical knowledge. However, they need to know when and how to utilize this knowledge (Kauer, 1997). Students also need linguistic knowledge so they can understand the problem and what it is asking. Additionally, students must know

strategies for solving problems in order to create a plan for the problem (Kaur, 1997, p. 102). This could be Pólya's four steps or other problem solving heuristics. Lastly, students must have good metacognition skills (Kaur, 1997, p. 103). Metacognition refers to the ability to control one's thinking process (Livingstone, 1997). It is the process of reflecting on and assessing one's thought process. In problem solving, students should use metacognition to pick a plan and assess if their plan is working or if they need to try a different method to solve the problem (Kauer, 1997).

According to Kauer (1997) researchers found several common characteristics and abilities of good problem solvers that poor problem solvers lacked. These include the ability to distinguish between relevant and irrelevant information in the problem, the ability to see the mathematical structure of the problem, the ability to relate it to a range of problems and the ability to remember the structure of similar problems solved earlier. The mathematical structure refers to the underlying concept in the problem. The structure of the problem helps the reader determine if they need to make an equation, use a formula, or make a graph to solve the problem.

Differences between problem solvers. Other research by Schoenfeld (1992) found good and poor problem solvers differ in five distinct ways. The first distinction is how students connect information learned in the classroom. Good problems solvers have the ability to connect new information with previous knowledge while poor problem solvers often see each concept as idea disjointed from previous content. These connections will help a good problem solver formulate a plan for solving the problem.

The second difference is good problem solvers tend to focus their attention on structural features of the problem while poor problem solvers focus on surface features such as math words or units. The third distinction is good problem solvers are more aware of their strengths and weaknesses. If they know they are weak in a specific mathematical area, they will work around it and find another way to solve the problem.

The fourth difference between good and poor problem solvers is good problem solvers are better at monitoring and regulating their problem solving efforts. Through their monitoring process, they are more likely to discover where they solution has gone wrong and correct the mistake. The final difference is that good problem solvers want to produce "elegant" solutions (Kaur, 1997). They want to have a logical, systematic way of finding the solution instead of using "messy" methods like guess and check.

In the 1990s, Foong studied the problem solving skills of pre-service mathematics teachers in an attempt to distinguish characteristics of successful and unsuccessful problem solvers. Kaur's summary of Foong's study states successful problem solvers translated the problem statement more correctly than unsuccessful problem solvers (Kauer, 1997). Foong also noticed unsuccessful problem solvers paid more attention to obvious details and tended to translate the problem word by word instead of looking at the problem as a whole (Kaur, 1997). For example, if unsuccessful problem solvers saw the phrase "more than" in a problem, they would immediately think of addition instead of looking at the phrase in the context of the whole problem.

Another difference Foong noted was successful problem solvers planned their solutions in more detail (Kaur, 1997). Poor problem solvers were impulsive in executing a solution and they often returned to their impulsive action several times, even if it was incorrect. Successful problem solvers also used more metacognition processes. They knew where they were in their plan for solving the problem and were able to judge the effectiveness of the plan. The last observation was the unsuccessful problem solvers tended to have more negative emotions such as frustration (Kaur, 1997).

Strategies to Improve Problem Solving

There are many different methods and strategies teachers can use to teach problem solving. Teachers hope these methods and strategies will turn unsuccessful problem solvers into successful ones by developing the skills researchers have found in good problem solvers. Some of these strategies include creating lessons around problem solving, problem solving with heuristics, cooperative learning, using graphic organizers, and writing in mathematics.

Creating lessons around problem solving. Many teachers believe the answer to improving students' problem solving skills is by creating lessons around a central problem or question, also known as problem-based learning (Goldthrop, 2013). When a lesson is designed around a specific problem, students have to use problem solving to complete a given task or answer a question. On the journey to answer the given question, students discover and learn about a specific mathematical concept. Proponents of this strategy argue that a problem-based classroom is essential to actively engage students

(Goldthrop, 2013). It forces students to use problem solving, critical thinking, and interpersonal skills. They have to use problem solving to come up with a solution to answer the question and meet the learning objectives.

There are many benefits to problem-based learning, but there are many views against this strategy. First, problem-based learning cannot be done with every single mathematical concept. Some concepts do not lend themselves to an activity typical to those used in problem-based learning. Additionally, it is difficult for teachers to come up with an activity that will lead the students to the desired concept to be learned (Weimer, 2009). Developing problem-based lesson plans take time and energy. Teachers do not have time to develop a problem-based lesson for every concept to be taught. Also, some students may not be able to make the connection between the activity and the learning target (Weimer, 2009). Many students could go through the activity and have no idea what they are supposed to be learning.

Problem solving with heuristics. Many mathematics textbooks support problem solving through the use of heuristics. Heuristics refer to different strategies that can be used to solve non-routine math problems. The common mathematical heuristics are grouped into four categories shown below in Table 1 (Marshall Cavendish Education, 2014).

Table 2.1

Problem Solving Heuristics

Make a representation	Make a calculated guess	Go through the process	Change the problem
• Draw a picture • Make a diagram • Make a list • Use equations	• Guess and check • Look for patterns • Make a supposition	• Act it out • Work backwards	• Restate the problem • Make it simpler • Solve part of the problem

These heuristics work as aids to help produce a solution (Wilson, 1993). They can be applied to a variety of problems and introduced in whole class instruction. Teachers have support from textbooks for teaching problem solving through heuristics. Most textbooks highlight one of these strategies when showing how to work out an example (Wilson, 1993). Therefore, teachers have a problem solving resource at their fingertips. Students are usually taught these at a primary level and have success with them at an early age (Wilson, 1993). One of the drawbacks of heuristics is that students do not always know which one to use for a given problem. For example, students will try to work backwards when it makes more sense to draw a diagram. Studies have shown students do better when there are task specific heuristics instructions rather than general heuristics instruction (Wilson, 1993). This suggests students can complete the problem correctly when they know which heuristic to use. However, just because students know which

heuristic they should use does not mean they have the skills necessary to complete the problem.

Cooperative learning. Another approach to teaching problem solving is through cooperative learning. Cooperative learning is defined as a teaching arrangement where people work together in order to achieve a common goal, usually solving a problem (Barczi, 2013). Through the group work, students learn how to work together and trust each other. Their success depends on their ability to cooperate. Cooperative learning is effective for learning and improving problem solving skills because the group setting promotes discussion, explanation, and justification (Lynch, Lynch, & Bolyard, 2013). When students have to discuss, explain and justify their procedure or answer to a problem, they actually learn the material better. Justifying a solution or procedure to their group also allows students to practice their metacognition skills. Students are forced to think about how they would solve the problem and once the problem is completed, if their solution worked (Lynch, Lynch, & Bolyard, 2013). Development of metacognition skills is crucial to becoming a successful problem solver.

Students learn more through cooperative learning because they can see how their peers approach problems. The students become problem solving role models for each other and can emulate the problem solving strategies their group members use. Additionally, sharing ideas and thought processes through cooperative learning provides students with the potential to make connections between mathematical concepts and make connections between different problem solving procedures (Lynch, Lynch, &

Bolyard, 2013). Cooperative learning effectively improves problem solving skills in students because it forces them to discuss their problem solving strategies with one another.

I-THINK framework. Another method to improve problem solving is by using the I-THINK framework (Lynch, Lynch, & Bolyard, 2013). This method is used in tandem with cooperative learning. The I in the I-THINK framework is the first step in the process and stands for individual thinking about the problem being presented. Once students start group work, they go through the THINK process which is guided by the following prompts:

- Talk about the problem.
- How can it be solved?
- Identify a strategy to solve the problem.
- Notice how your strategy helped you solve the problem.
- Keep thinking about the problem. Does it make sense? Is there another way to solve it? (Lynch, Lynch, & Bolyard, 2013, p. 10).

By using the I-THINK method, students do not solely focus on the solution. They learn to focus on thinking about how they solved the problem, why their solution worked, and how to communicate their ideas. The thought processes and discussions of students through the I-THINK prompts develop greater metacognition and problem solving skills (Lynch, Lynch, & Bolyard, 2013). The I-THINK model forces students to practice

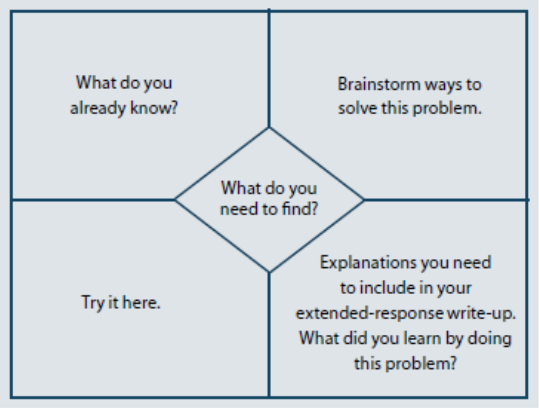
thinking about how to solve a problem and monitor its progress, skills successful problem solvers possess.

Graphic organizers. The use of graphic organizers in the math classroom is another strategy teachers use to improve problem solving. A graphic organizer is a tool to organize information and promote thinking about the relationships between the concepts (Zollman, 2009). Common graphic organizers are Venn diagrams and flow charts. Graphic organizers allow students to see what information is missing and classify the information as essential or nonessential. When students are working on solving a mathematical problem, their initial thinking is not linear. Good problem solvers brainstorm different ideas when first viewing a problem (Zollman, 2009). Some of these ideas will be useful, some of them will not. The graphic organizer allows students to record these ideas, but not process them. The student can later reflect on their ideas and determine if they will be useful in solving the problem. The most common graphic organizer used in the math classroom is the four corners and a diamond mathematics graphic organizer in figure 2.1 (Zollman, 2009). This organizer was modified from the four squares writing graphic organizer. The organizer contains five areas:

1. What do you need to find?
2. What do you already know?
3. Brainstorm possible ways to solve the problem.
4. Try your ways here.

5. What things do you need to include in your response? What mathematics did you learn while you were solving this problem?

Figure 2.1 Four Corners and a Diamond Organizer



The four corners and a diamond organizer was designed to model Pólya's four steps to solve a problem (Zollman, 2009). However, they do not need to complete the four steps in order, as Pólya suggests, but can write down any ideas as they occur. For example, they could start by putting the correct units in the solutions box and then work to find the whole solution.

There are many benefits of using graphic organizers to aid the problem solving process. The organizer encourages students to persevere with the problem (Zollman, 2009). Students know all boxes of the organizer should contain information. If they have an empty box, they keep working to find an idea to put in the box. In Zollman's (2009) research on graphic organizers, nine middle school teachers started using graphic organizers to teach problem solving. All the teachers found the organizers to be effective

and efficient for mathematical problem solving (p. 8). According to the teachers' data, the graphic organizer used for mathematical problem solving significantly helped students coordinate ideas, methods, thinking and writing.

Improvements in problem solving were seen across all mathematical ability levels in the classroom when using the graphic organizer. Previously, lower-ability students would hardly even attempt the problems. With the organizer, they started to get partial solutions. For average-ability students, the four squares and a diamond organizer helped shape and clarify their thinking. The use of the organizer also led to an increase in the high-ability students' problem solving communication skills (Zollman, 2009). However, for the four corners and diamond graphic organizer to be effective, students must be taught how to use it properly. If teachers introduce it as a linear process, much like Pólya's four steps, the graphic organizer will not be as successful (Zollman, 2009).

Problem solving through writing. Another effective strategy to improve problem solving skills is through writing. Writing is effective for several reasons. In mathematics, writing requires students to demonstrate what they know as well as how and why they know it (Bicer, Capraro, & Capraro, 2013). Writing strengthens student knowledge as it forces students to reflect on their learning, organize and clarify their thoughts, and make connections between various topics. Making connections between mathematical topics is a key aspect of problem solving. Students need to be able to connect the problem with a previously learned concept to create a plan to solve the

problem. Writing in a math classroom gives students the opportunity to practice making these connections.

Additionally, writing promotes the development of metacognition behaviors, a key factor in problem solving abilities. According to Kuzle (2013), various studies have reported improvements in problem solving abilities are dependent on mathematical knowledge, cognitive and metacognitive abilities (p. 44). When students write about their math knowledge, they are forced to organize their thoughts into new structures of ideas, thus developing their metacognitive abilities (Kuzle, 2013). Another benefit of writing in the math classroom is the ability for writing to give a visual image to an abstract problem. Writing about the problem makes it more concrete and less abstract (Kuzle, 2013). Finally, writing gives teachers a window to view their student's thinking when solving a problem. Teachers can identify any gaps in conceptual or problem solving knowledge and work with the student to close the gap.

Using the strategies with students. There are many different strategies to improve problem solving in the classroom. Each strategy has advantages and disadvantages. However, for any strategy to be successful, the teacher must have student buy-in. If students do not see the point to the activity, tool, or strategy, they will not fully engage in the chosen method. Teachers can create student buy-in by explaining the importance of problem solving, why the strategy will help them, and show enthusiasm for the strategy and problem solving.

Benefits of Problem Solving

There are many lifelong benefits of learning and improving problem solving skills. Problem solving is a skill used in all areas of life (NCTM, 2000). Problems are always going to arise and a solution needs to be discovered. Providing students with problem solving activities in their math classes gives them opportunities to learn and practice how to problem solve. When students learn how to problem solve in the classroom, they are also learning how to make effective decisions throughout the course of their day and into the future (Salleh & Zakaria, 2009). Goldthorp (2013) states, "Those students who learn problem solving as well as interpersonal skills and critical-thinking skills will be the most successful" (p. 70).

Problem solving's effects on student thinking. Problem solving also develops cognitive abilities in the area of mathematics. Cognitive thinking is the act of comprehending, solving, or calculating when solving a problem (Livingstone, 1997). Cognitive abilities are enhanced through problem solving because problem solving allows students to form calculations, solidify what they have learned, apply various strategies and extend their learning (Cai & Lester, 2010). Problem solving also drives students to make connections between mathematical concepts in their search for a solution (Cai & Lester, 2010). These connections are hard, if not impossible, to make in a classroom that only uses the drill and kill method to practice new concepts.

Problem solving also improves creativity. In a traditional math classroom, the teacher introduces a new skill, models the skill, and gives the students an assignment for them to

practice the new skill. This method does not provide opportunities for creativity as there is usually an algorithm or step-by-step instructions for how to solve the problems (New Zealand Ministry of Education, 2010). Activities based around problem solving give children the opportunity to explore ideas and extend their creativity (New Zealand Ministry of Education, 2010). Learners often think of confusing or unusual ways to solve problems. These solutions show the ingenuity and creativity of young minds (Buschman, 2004).

Problem solving creates positive outcomes. Additionally, problem solving can make math more interesting and enjoyable. Most problem solving activities are story problems or real-world problems students can relate to. Kids get bored quickly when practicing the same skill over and over. Students also like the feeling of being a detective on the search for the correct method to solve the problem (New Zealand Ministry of Education, 2010). Furthermore, people enjoy getting a solution to something they have struggled with and worked on for a period of time (New Zealand Ministry of Education, 2010). The feeling of success after obtaining the correct solution creates positive attitudes towards math and increased self-confidence (New Zealand Ministry of Education, 2010). Increased self-confidence means students will be more willing to tackle challenging problems. A positive attitude towards math is important for elementary and middle school children as they still have several years of math education ahead of them (New Zealand Ministry of Education, 2010).

Finally, good problem solving skills are interdisciplinary. Students who are good problem solvers in math class are going to be good problem solvers in science or history (New Zealand Ministry of Education, 2010). Therefore, good problem solving skills will help student become successful in all areas of school. According to the New Zealand Ministry of Education (2010), "Approaching mathematics through a problem solving perspective puts the subject much more on par with other subjects." If students see math as being connected to other subjects and not disjoint, they will be more likely to apply skills, like problem solving, learned in math class to other areas (New Zealand Ministry of Education, 2010).

Reasons math classrooms lack problem solving. Despite the many benefits of problem solving, teachers are often reluctant to incorporate problem solving into their teaching. For one, it is difficult to teach problem solving. There is no set method or plan of how to problem solve and how to teach those skills (Buschman, 2004). Each problem involves different strategies and different knowledge bases. Additionally, to teach these skills, good problems need to be available. Problems typically used for problem solving activities are not readily available in textbooks (Buschman, 2004). This means teachers would need to create the problems for their curriculum, which can be a time consuming process. Teaching problem solving also uses lots of class time. If teachers are truly going to allow their students to problem solve, they need time to work though the problem, make mistakes, and evaluate their work (Buschman, 2004). With the educational demands of today, most teachers cannot fit all grade level standards into their school year. When would there be time for problem solving? Teachers give priority to

standards as standards are what is measured and tested, not problem solving skills (Buschman, 2004).

Strategies Chosen for Research

After conducting the research for this literature review, three problem solving strategies have been chosen to be implemented into the researcher's classroom. The first strategy is the graphic organizer. This strategy has been chosen because it helps students classify information and see any missing information needed to solve the problem (Zollman, 2009). The organizer also helps students persevere through a problem because they know they are not finished until all spaces in the organizer are filled in (Zollman, 2009). The second strategy is cooperative learning. Cooperative learning was chosen because it forces students to explain, justify, and discuss the problem and the strategy used to solve it (Lynch, Lynch, & Bolyard, 2013). This causes students to learn from one another instead of watching a teacher solve a problem. Finally, students will complete a written reflection on their assignment. Written reflections are helpful in the problem solving process because reflecting on a problem results in more connections between concepts and an improvement in metacognitive abilities, crucial aspects of the problem solving process (Bicer, Capraro, & Capraro, 2013). These three strategies will hopefully combine together to improve students' problem solving skills.

Summary of Chapter Two

This chapter reviewed the literature on mathematical problem solving, the benefits, and different strategies to improve mathematical problem solving in the classroom. The

chapter gave a detailed definition of problem solving and included a brief history on mathematics education in the United States. The history of problem solving is helpful as it explains the initial understandings of how to problem solve and why problem solving has become a crucial part of the mathematics curriculum. The third section was about the differences in good and poor problem solvers. It is important to identify the skills poor problem solvers are lacking so teachers can target these skills when developing lessons. Strategies can be developed and put to practice to improve upon those skills. The last section was on various strategies and studies that have been done to improve students' problem solving skills.

Preview of chapter three. Chapter three takes the information from the literature review to make a plan for research. The chapter begins by looking at the research setting and subjects. It then explains the rational for conducting a study on problem solving in the mathematics classroom and explains how the researcher intends to improve students' problem solving skills throughout the study. The research design for this study is the concurrent mixed methods approach. The researcher will collect quantitative and qualitative data. Approval to conduct this research and collect data was given to the researcher. This process has been described in the following chapter.

CHAPTER THREE

Methods

Introduction

My literature review provided valid research on various methods to improve problem solving in the mathematics classroom and the effectiveness of those methods. It also explains why problem solving is invaluable in the math classroom and the history behind why it has become a crucial part of math curriculums. In the following section, I describe my action research methods on implementing a problem solving strategy to my students and how I will determine the effectiveness of the strategy. These methods were chosen based on the information in the literature review. The action research is designed to answer the following question: How can cooperative learning, graphic organizers, and writing improve eighth grade advanced geometry students' problem solving skills?

Overview

The following chapter explains the methods used for completing this action research. The first section describes the research setting and the subjects. The following section explains the rationale and relevance of the research plan. The section goes into detail on the importance of improving students' problem solving skills as well as the rationale for the problem solving strategies being used to improve these skills. The third section depicts the research design and methods. This research is using a concurrent mixed methods approach and will collect quantitative and qualitative data. Approval has been

granted to conduct this research and the process for approval is outlined in this chapter. Finally, the last section provides a summary of the chapter and a preview of chapter four.

Research Setting and Subjects

The following action plan took place in a northern suburban middle school for students in an eighth grade advanced geometry class. The school is comprised of students from several small towns which come together to form a close community and has around 800 students in grades six through eight. Within the district, 94.5% percent of students are white, 2.1% are Asian, 1.5% are Hispanic, 1.2% are African American, and 0.7% are American Indian. All students in my geometry classes were offered the opportunity to participate in the research portion of the study and parent permission was obtained before conducting any research. Of the 52 students whose parents consented, there are 2 students of color and 50 Caucasian students. There were no special education students in this population.

Rationale and Relevance of the Research Plan

Based on the research in chapter two, there is a definite need for students to become successful problem solvers. Problem solving helps students develop their cognitive abilities in the area of mathematics. When students need to problem solve to find a solution, they are forced to make connections between concepts and deepen the understanding of those concepts (Cai & Lester, 2010). Students can also improve their creativity through mathematical problem solving. When students are given a problem without a set algorithm to find the solution, they need to expand their thinking and

explore different methods to come to a solution (New Zealand Ministry of Education, 2010). Additionally, good problem solving skills are necessary for students to be successful in high school and college math courses and future careers. Goldthorp (2013) states, "Those students who learn problem solving as well as interpersonal skills and critical-thinking skills will be the most successful." (p. 70). As teachers, it is our job to teach these skills and prepare our students to be successful in the future. Therefore, we need to find ways to help our students improve their problem solving skills.

The math educational community has recognized the importance of problem solving in the classroom for several decades. This has resulted in the development of the National Council of Mathematics Teachers process-based standards for problem solving. These standards call for students to build new knowledge through problem solving, solve problems that arise in various contexts, apply a variety of strategies to problems and reflect on the process of problem solving (NCTM, 2000). Despite these standards, many math teachers do not teach problem solving skills. Many teachers find problem solving difficult to teach because the teachers feel they lack the necessary knowledge, cannot find good problems to use, or they claim they do not have time (Buschman, 2004).

Problem solving strategies used. There are many strategies available to improve a student's problem solving skills. This study used cooperative learning, graphic organizers, and writing to improve advanced eighth graders problem solving skills. These three strategies were chosen for this study for the following reasons. First, cooperative learning is a useful strategy in teaching problem solving because group work

promotes discussion, explanation, and justification (Lynch, Lynch, & Bolyard, 2013). Additionally, students can see good problem solving techniques modeled by their peers. Secondly, the graphic organizer is a worthy tool for improving problem solving because it helps students classify information and see any missing information needed to solve the problem (Zollman, 2009). With the use of the graphic organizer, student thinking does not need to be linear. Students can write down important information in any order. The graphic organizer helps students persevere on a problem because they know they are not done until all parts of the organizer are completed (Zollman, 2009). Lastly, writing can also improve problem solving. When students write about a problem, they are forced to reflect on their learning. This results in more connections between concepts and improved metacognition (Bicer, Capraro, & Capraro, 2013). The purpose of this action research plan is to determine the effectiveness of combining the best parts of each strategy into one problem solving method.

Research Design and Methods

The research plan used a concurrent mixed methods approach. A concurrent mixed methods approach uses qualitative and quantitative data that is collected at the same time. The data collected is then incorporated together to interpret results and draw conclusions. The use of a mixed methods approach is stronger than the use of solely qualitative or quantitative approaches (Creswell, 2009). This research method was chosen because it creates a triangulation in the data collected, meaning not all data comes from one source. By incorporating triangulation, I used the best qualitative method and the best

quantitative method to collect data. This helped me more fully understand my topic and data than compared to using only one method (Mills, 2014).

Quantitative Data. During the 2014-2015 school year, I developed problem solving assignments for each chapter in the geometry textbook. These assignments incorporate several of the newly learned skills from the chapter and previously learned algebra skills. Each assignment consists of three or four multi-step, higher order thinking problems which may include word problems. Students completed these assignments at the end of each chapter in groups of three or four to fulfill the cooperative learning aspect of this study. One class period will be used to complete the assignment.

The students completed the assignment using the four-corners-and-a-diamond graphic organizer as a guide to help them solve the problems. Students individually reflected on one of the problems from the assignment and wrote a paragraph about their solution, the method they used to find the solution, and why the solution is valid. The teacher selected which problem from the assignment the students wrote about. Each student wrote the reflection individually and not in their group so the teacher could determine each students' knowledge of the problem and the process they used to find the solution.

For this action research, the data collection period included two units of study. Throughout these units, students solved challenge assignments a minimum of two times (See appendix A). Data was collected after each problem solving assignment was completed. Each student completed a Likert-scale survey at the conclusion of the assignment. The survey (See appendix B) asked students to respond to a series of

statements on a one to five scale with one being strongly disagree and five being strongly agree. These statements have students assess their own problem solving skills, the effectiveness of cooperative learning, graphic organizer, and writing as problem solving strategies and the difficulty of the problems. Each student's assignment which included the graphic organizer and written paragraph reflection was also assessed on a rubric (See appendix C). The rubric for the graphic organizer and written response assessed students on completeness of answer, ability to form a plan, and the ability to explain the problem solving process to get to an answer.

The use of student surveys and rubrics provided numeric values for the students' problem solving abilities and the effectiveness of each strategy. This helped the researcher look for patterns in the data and allowed the researcher to run statistical measures on the data. The researcher looked at the mean of the scores from the survey and rubrics and determined if there was a trend in the data over time. The survey results were broken down and analyzed by statement as some statements pertain directly to each problem solving strategy. Referring to the survey in appendix B, the results from statements six and seven were analyzed to determine the effectiveness of cooperative learning to improve problem solving. The data analyzed for the use of graphic organizers comes from statements two and three in the survey (See appendix B) and the data used to analyze the use of writing as a problem solving strategy comes from statement eight in the survey and the rubric scores.

The student survey was not anonymous so the researcher could compare survey results with assignment scores. This allowed the researcher to have data to support or counter the students' responses to the survey. For example, the researcher looked for students whose challenge assignment scores on the rubric were improving with extended use of the problem solving strategies but whose survey scores continue to be low.

Qualitative Data. Data was also collected through student interviews. Students were interviewed at the end of the study. Students were pulled from their study halls and were asked questions about their problem solving abilities and the problem solving tools used in class. The interview questions were not given to students ahead of time. The students chosen for these interviews were students who have study hall at the same time as the researcher's free hour. Interviews were conducted in the researcher's classroom. These interviews provided valuable insight on a student's perspective of problem solving and the usefulness of the strategies used throughout the study. See appendix D for interview questions. Students were able to explain why or why not the graphic organizer is helpful, the advantages or disadvantages of the writing process, and if they have used these skills in other classes. The researcher looked for patterns in the interview data and cross referenced any findings with the numerical data from the surveys and grading rubrics. Additionally, the teacher kept an observation journal. The teacher recorded events that occurred on the problem solving assignment days or any other observations related to problem solving.

Approval to Conduct Research

I received approval from my school principal and the Hamline School of Education to conduct my research. The requirements of Hamline's Human Subject Research review have been met. Parents or guardians signed consent letters for minor children to participate in the research, take surveys, be interviewed, or both and to have results portrayed in this capstone. They were assured all results will be anonymous and confidential.

Summary of Chapter Three

Chapter three takes a closer look at the action portion of this research. The chapter begins with a description of the school where the study takes place and the participants in the study. The chapter then discusses the rational for the study, why graphic organizers, cooperative learning, and written reflection were the chosen strategies and how the research will be conducted. The research is a mixed methods study and will collect both quantitative and qualitative data. The chapter explains the data collection process and how the data will be analyzed. Finally, the chapter gives an explanation of the approval process to conduct research.

Preview of chapter four. Chapter four will look at the results and findings from the study and their relationship with the literature review. The first section of the chapter reintroduces the action research plan. The following section covers the results of the action research. The results are broken down into each problem solving strategy and then

combined to look at the data from all three strategies as a whole unit or strategy. The final section concludes the chapter and provides a preview of chapter five.

CHAPTER 4

Results

Introduction

This study looked to answer the question how can cooperative learning, graphic organizers, and writing improve eighth grade advanced geometry students' problem solving skills? This was a mixed methods study. Students were given two challenge assignments (See appendix A) and were required to solve the problems on the challenge assignments through cooperative learning and by using graphic organizers. They were then asked to write about their problem solving process. The teacher demonstrated to the students how to effectively use the graphic organizer to solve problems. Problems on the challenge assignments incorporated current geometry topics being studied in class and algebra concepts learned the previous year. Students completed two challenge assignments for the study.

After each assignment, students were asked to fill out a survey about the problem solving process (See appendix B). Students' graphic organizers and writings were also graded according to a problem solving rubric (See appendix C). After the assignments, three students were interviewed about their problem solving skills, the use of graphic organizers, cooperative learning, and writing about their problem solving process (See appendix D). The researcher also kept an observation journal throughout the study. The data from the student surveys and rubrics provided quantitative data while the student interviews and teacher observations provided qualitative data. Data collected from student surveys and rubrics are located in appendix E.

Overview

The following sections take a closer look at each problem solving strategy used in the study and the overall effect of the strategies on students' problem solving skills. The data from each strategy was broken down and analyzed separately by the questions on the student survey and the rubric scores. The data was also combined to look at the overall effect of the three strategies on the problem solving process. The last section in this chapter concludes the results from the study and provides a preview for chapter five.

Results

The following sections will look at the data collected from the student surveys, assignment rubric scores, student interviews, and teacher observations. The data is broken down into each problem solving strategy to determine the effectiveness of each strategy individually. Finally, the data will be looked at as a whole to determine the effectiveness of using the three problem solving strategies together.

Data about the graphic organizer. The graphic organizer was chosen as a problem solving strategy for several reasons. The first was because the organizer aids students in ordering information and determining missing information needed to solve the problem (Zollman, 2009). This also helps students persevere on a problem because they can visually see the problem is not completed until all boxes of the organizer are filled in (Zollman, 2009). Additionally, the organizer was chosen because it allows students to solve problems in a non-linear manner. Students do not need to fill out the boxes in the order they appear on the graphic organizer.

Upon looking at the data, students clearly did not like using the graphic organizer to solve problems. When responding to the student survey, the statement "The graphic organizer helped me solve the problems" had an average score of 2.69 on the first assignment and 2.77 on the second assignment. A score of 1 on the survey indicated the student strongly disagreed with the statement and a score of 5 indicated the student strongly agreed. These numbers suggest students felt slightly better about using the graphic organizer the second time they used it, but still did not like using it. This correlates directly with what was observed in class. During the second assignment, several students asked if they had to use the graphic organizer to solve the problems. Student interviews also procured the same results. One girl stated she did not like using the organizer because it took more time and felt there was not enough information to fill out the organizer for all types of problems.

Some observations disagree with the benefits found in the research for using the graphic organizer to solve problems. Zollman (2009) expresses a benefit of the graphic organizer is that it allows students to think about the problem in a non-linear manner as students can fill in the boxes in any order. However, as I observed my students work on their assignment and fill out the organizer, the majority were still following the problem and filling out the organizer in a linear manner. Since my students only used the graphic organizer on two assignments, they may have needed more practice with the organizer to feel confident working on the problems in a non-linear manner. Kids are taught to work through problems linearly from a very young age. They may need extra practice to feel comfortable breaking those habits.

Despite students' dislike of the graphic organizer, it did have some benefits in obtaining a correct solution on the challenge assignments. First, students felt they could adequately fill out each portion of the graphic organizer. On the student survey, the average score between both assignments for the statement, "I was able to fill in all boxes of the graphic organizer" was 4.15. By filling out every box in the organizer, students had all the information they needed to solve the problem along with a strategy for obtaining an answer. Additionally, there were six students who stated they either disagreed or neither agreed nor disagreed with the statement of filling out all boxes on the organizer from the student survey. These six students scored lower overall on the rubric score for their challenge assignment. Of the six, only one of them scored a three out of three for the correct answer and only two of them were able to write the correct number sentences needed to solve the problem. Furthermore, these six students scored lower on the explanation portion of the assignment. Their descriptions of how they came about their answer and how they knew their answer was correct were incomplete and lacking important details. They had trouble describing the strategy used to solve the problem.

Student interviews and classroom observations also indicated the graphic organizer was useful in the problem solving process. One student stated, "It [the graphic organizer] helped me break down the problem and see what information I had to solve the problem. It made the thinking process easier." Another student stated, "With the graphic organizer, I was able to work slowly and carefully and I could easily solve the problems." When students had time to work on these assignments in class, students often called me over when they got stuck on the problem. My first response in helping the students was

to have them take a closer look at their graphic organizer. Often times, they had not filled out the organizer. I would then prompt them to fill in as much information as they could on the organizer. In most cases, as they began filling in the organizer, a lightbulb would switch on in their head and they would have an idea of how to solve the problem. This shows the graphic organizer is an effective tool in helping students to develop a strategy to solve problems.

This data shows using a graphic organizer is a useful problem solving strategy. Students did not like using the organizer because it took them longer to solve the problem when using it, but the data confirms Zollman's research (2009) that the graphic organizer helps organize and clarify information needed to solve the problem. It also helped students create more complete answers and they did a better job of explaining their solution when they completely and adequately filled out the graphic organizer.

Data about the written reflection. The written reflection portion of the problem solving process was chosen for several reasons. First, writing about a problem forces the student to reflect on their thinking and learning. This results in more connections between concepts and improved metacognition (Bicer, Capraro, & Capraro, 2013). Students were asked to write about how they solved the problem and how they knew their answer was correct.

The student survey found writing about the problem was slightly helpful. Students were asked to agree or disagree on a one to five scale for the statement, "Writing about the problems and the strategy to solve the problem helped me better understand why my

strategy worked or didn't work." On the first challenge assignment, the average rank for the statement was 2.94; indicating students slightly disagreed with the statement. On the second assignment, the average rank for the statement was 3.15. Students found writing to be more helpful to them the second time they tried writing about a math problem. This indicates the writing process will become more helpful to students the more they practice thinking through the problems and math as they write about their process in solving mathematical problems.

The rubric scores yielded similar results. One the first assignment, students scored an average of 1.33 out of three on the writing portion of the assignment. On the second assignment, they scored an average of 1.78. While this still is not a great score, students did improve upon the ability to explain the strategy they used to solve the problem and the ability to explain how they know their answer is correct. When grading the assignments, students were much more thoughtful and articulate in their writing for the second assignment. Several students gave step by step explanations in the second writing assignment while very few did in the first assignment. Many students even cited the geometric theorems they used to solve the problem on the second assignment. Seeing this progression over just two assignments reinforces the research that writing improves connections between topics and improves metacognition in students (Bicer, Capraro, & Capraro, 2013). Students also stated in the interviews that the writing forced them to think deeper about the problem. Most students said they would not have done this kind of thinking if it were not for the writing portion of the assignment.

Some interesting trends emerged from teacher observations of students writing their reflection. Students did not want to justify their answer and many did not know how to respond to the writing prompt of how they knew their answer was correct. Many students tried asking me if their answer was correct and became frustrated when I would not tell them yes or no. Additionally, some students said they knew their answer was correct because another group had the same answer. This made me realize my students' metacognition skills needed to continue to be developed. Writing about these challenge problems is good way for them to improve upon these skills as it forces them to analyze their thinking and determine if their method to solve the problem was successful.

Data about cooperative learning. Using cooperative learning, or working in groups, as a problem solving strategy was chosen for many reasons. Cooperative learning is a useful strategy in teaching problem solving because group work promotes discussion, explanation, and justification (Lynch, Lynch, & Bolyard, 2013). When students have to discuss, explain and justify their procedure or answer to a problem, they actually learn the material better. Additionally, students can see good problem solving techniques modeled by their peers and hopefully work to emulate these techniques. Most students have seen their teachers work through a problem using various problem solving methods, but they have not seen classmates go through this process.

Cooperative learning was a strategy that was already being used in my classroom due to its many benefits. The students seem to agree with the research in the usefulness of cooperative learning because out of the three strategies used, it scored the highest on the

student surveys. The statement, "My group members helped me understand parts of the problems" scored an average of 4.13 out of five on the first assignment and a 4.42 on the second assignment meaning the majority of students agreed with this statement. Additionally, the majority of students agreed with the statement, "My group members worked together to form a strategy to solve the problems." On the first assignment, the average score was four out of five followed by 4.12 out of five on the second assignment. These numbers back the research that cooperative learning promotes discussion, explanation, and justification and students work together to find the best strategy to solve the problem. It also shows students are learning from one another since students agreed with the first statement which was, "My group members helped me understand parts of the problems."

Teacher observations and student interviews also support the benefits of cooperative learning. Students said they like working in groups because they have someone to help them when they get stuck on a problem. One student said, "I was able to partially solve the problems, but my partners were a big help." The kids also stated they like having someone with whom they can talk through the problem, determine which pieces of information are necessary to solve the problem and find the best strategy to solve the problem. This was evident by walking around the classroom during working time. Students worked well together and stayed on task throughout the hour. Kids were having good discussions about the problems, how to solve the problem, and why a certain method would not work. Struggling students who normally shut down when given

difficult tasks remained engaged with their group and continued to participate in the discussions.

Data about the overall process. The researcher chose to incorporate three problem solving strategies into this study instead of just one for two reasons. First, while each of these strategies can be effective on their own, there are valuable parts in all three strategies. Using them together, could have a greater impact on students' problem solving skills than using just one alone. Secondly, not all students learn the same way. Using three different strategies hits more learning styles than one strategy. The researcher believed more students would improve their problem solving skills if several methods were incorporated instead of only one.

Student survey data shows students did improve their overall problem solving skills over the two assignments. On the student survey for the first challenge assignment, students scored the statement, "I was able to solve all the problems on the assignment" at an average of 3.27 or slightly agreeing with the statement. On the second assignment, students gave the statement an average score of 4.08, indicating more students agreed with this statement than previously. Additionally, students' levels of confidence went up from the first assignment to the second assignment. When responding to the statement, "I am confident in my problem solving skills" students' average scores went from 3.80 to 4.38, an increase of 0.58. Many more students agreed or strongly agreed with the statement than in the first assignment. Each student's work and written reflection was also graded on a rubric (See appendix C) in the categories of number sentences, answer,

strategy, and written reflection. Students' scores from the rubric also improved from the first assignment to the second assignment. On the first assignment, the average score out of 12 was 7.72 or 64.31 percent. On the second assignment, the average score was 9.38 or 78.15 percent. These numbers indicating students were becoming better at solving the challenge assignments and problem solving skills were improving. Therefore, the three strategies used in this study worked together to improve students' problem solving skills.

Conclusion

In an effort to improve problem solving skills, students were asked to solve problems using a graphic organizer, cooperative learning, and written reflection on a challenge assignment at the end of each unit. The challenge assignment consisted of three to four problems which extended the material learned throughout the unit and incorporated algebra skills learned the previous year. Data was collected over two challenge assignments in a mixed methods approach and was collected through student surveys and interviews, grades for the challenge assignment based on a rubric, and teacher observations.

After analyzing the data, the three strategies proved to be beneficial in the problem solving process. Students stated the graphic organizer helped them organize their thinking and remain persistent in the problem solving process. Through cooperative learning, students were forced to explain and discuss the problems, promoting deeper thinking, and were able to see other students' methods for solving problems. The written reflection created opportunities for students to think deeper about the problem, the

strategy used to solve the problem, and how they know their answer is correct. This also allowed students to make connections between different mathematical concepts. Overall, these three strategies led to an improvement in students' problem solving skills. Over the course of using the strategies, students became more successful at solving the problems and more confident in their ability to solve problems.

Preview of chapter five. The next chapter will take a deeper look into the study. The chapter begins with the researcher discussing the most useful parts of the literature review and how it impacted the study. The researcher then looks at connections between the data from this research and the information found in the literature review. The chapter will also discuss the implications and limitations of the study. The researcher also describes future research to be done based off the results from this study. The last section of the chapter provides a conclusion to the study.

CHAPTER FIVE

Conclusion

Introduction

Throughout the research process, this capstone looked at answering the question, how can cooperative learning, graphic organizers, and writing improve eighth grade advanced geometry students' problem solving skills? The research done in the literature review and the data collected in this action research project have allowed the researcher to make the conclusion that these problem solving strategies help improve problem solving skills by helping students organize information, persevere on a problem, learn from one another, and develop metacognitive skills. These results have many implications on my own classroom and the mathematics department at my school and have urged me to continue using these strategies in my own classroom as well as try to extend them to my math colleagues.

Overview

This chapter has allowed the researcher to reflect on the capstone project as a whole. The first section takes a look back at the literature review. It starts by discussing the most useful parts of the literature review and then moves to connections between the data from the study and the literature review. The next section of the chapter looks at the implications of the study and how it will affect the researcher's classroom and school. Throughout this research, there were some limitations that may have had an impact on

the data. These implications and limitations have caused the researcher to look into further research on the topic of problem solving and writing in the math classroom. The final section of the chapter provides a conclusion to the capstone with a summary of what was learned throughout the process.

The Literature Review

The literature review took a look at the history of problem solving in mathematics curriculum, problem solving strategies and the differences between successful and unsuccessful problem solvers. There were several portions of the literature review that proved to be important for my research. After looking at my data, I have been able to make new connections and develop deeper understandings with the literature review.

Useful parts of the literature review. While the literature review was an important part of this capstone, there are a few sections that were more useful than others throughout the process. First, the section on problem solving strategies was the most useful. As a math teacher, I knew the importance of teaching problem solving and improving my students' problem solving skills, but I did not know how to achieve this goal. The research done on problem solving strategies gave me ideas I could easily put into practice in my own classroom to improve problem solving. I had seen some of these strategies before but others were new to me. For example, I had not seen the strategy of using a graphic organizer to solve a math problem. This section also examined the advantages and disadvantages of each problem solving strategy. This was helpful in determining which strategies to use in the study.

The section of the literature review on characteristics of successful and unsuccessful problem solvers was also important in my research. This section helped me understand why some students are better at problem solving than others. It also helped me determine which skills needed to be built upon for students to become successful problem solvers. This knowledge helped me determine which problem solving strategies should be used in the study. I looked for strategies which focused on the skills students needed to develop to become better problem solvers. This led me to use graphic organizers, cooperative learning, and written reflection for this capstone.

Connections to the literature review. After analyzing the data, I found several connections to the literature review. Kaur's research (1997) on skills needed for good problem solvers, states students need to have good metacognitive skills in order to be successful at problem solving. After observing students throughout the problem solving process and looking at my data on the written reflection, I can see the connection between these skills and good versus poor problem solvers. Part of metacognition skills refers to being able to assess one's thinking. My students who struggled on the assignments and with problem solving struggled with assessing their thinking process. In the written reflection, they could not explain their strategy for finding their answer or they explained it poorly and could not explain why their answer was correct. This helped me understand the importance of developing these skills in my students.

There were also connections between the literature review and my data on graphic organizers being used as a problem solving strategy. Zollman (2009) explains how the

graphic organizer encourages students to persevere on a problem because they know they are not done until all the boxes on the graphic organizer are filled in. I found this to be the case as well. When students were stuck on a problem and asked for help, my first response to them was to have them look at their organizer. I then asked if they could put any more information into their organizer. As they started to fill out their organizer, they often came across an idea for solving the problem. Before using the organizer, most students would have given up when they got stuck on the problem. The organizer helped them keep working through the problem.

Data and the literature review. Overall, the data from my capstone agrees with the findings from the literature review. Data about using the graphic organizer in the problem solving process showed the organizer did help students solve the problem. Students who were able to fill out all of the boxes on the organizer had more complete and correct answers than students who were not able to fill out all boxes. During student interviews, students explained how the graphic organizer slowed down their thinking process and made them think deeper and more thoroughly about the problem. These are the same results Zollman (2009) found in his research on using the graphic organizer. One difference between Zollman's (2009) research and my own is how students filled out the graphic organizer. Zollman (2009) claims students are more successful in solving problems with the graphic organizer because they do not have to think in a linear manner when filling out the organizer. I found all my students still filled out the graphic organizer and completed the problem in a linear manner. The organizer did not encourage students to think in a non-linear manner.

The data on using cooperative learning to improve problem solving matches the literature review as well. According to the research, students learn the material better in a cooperative learning setting because they are forced to discuss, explain, and justify their thinking (Lynch, Lynch, & Bolyard, 2013). Students also learn problem solving skills from each other when working in a group setting (Lynch, Lynch, & Bolyard, 2013). The data I collected throughout my research has the same findings. Student surveys showed students received help from their group members to solve the problems and students learned something about the problem from their group. The surveys also showed students worked together within their group to find a strategy for solving the problem. These results, along with classroom observations, show students were discussing and explaining the problem, how to solve it, and the mathematical concepts within the problem.

The data about the written reflection corresponds to the findings in the literature review. One of the main correlations I found between my data and the research is the benefits writing about mathematics have on metacognitive skills. Metacognitive skills refers to the ability to analyze ones thought process by determining if their strategy is working and why or why not. According to the research, when students write about their math knowledge, they are forced to organize their thoughts into new structures of ideas, thus developing their metacognitive abilities (Kuzle, 2013). After reading through the written reflections on the first assignment, it was clear my students had weak metacognitive skills. However, they improved on the second assignment by giving much more thoughtful answers and step by step instructions for how they solved the problem.

The writing process helped the students become more deliberate in their explanations of their strategy and how they knew their answer was correct. Thus, the writing process helped to build students metacognitive skills. Research also states writing about the problem solving process will help students make connections between various mathematical concepts (Bicer, Capraro, & Capraro, 2013). I was not able to make any conclusions on students making more connections due to the writing process based on my data.

Overall, the data collected throughout this capstone corresponds to the information found in the literature review. Graphic organizers helped students organize their thoughts, persevere through the problem, and create a strategy to solve the problem. The cooperative learning strategy helped students to discuss, explain, and justify their method for solving the problem and allowed students to see how others go about the problem solving process. The writing process allowed students to develop their metacognitive skills, a crucial problem solving skill, by forcing students to assess their own work and why their answer was correct. Together, these three strategies helped students become more successful problem solvers and they became more confident in their problem solving abilities.

Implications

After reviewing the results of the study, there are several implications that can be made. The study shed light onto the effectiveness of the problem solving strategies used on advanced eighth grade mathematics students. The study also helped me determine

areas of need in my own classroom and improvements that can be made to promote the learning of all students.

The problem solving strategies used in this study, the graphic organizer, cooperative learning, and written reflection, were effective at improving problem solving skills in eighth grade advanced mathematics students. The graphic organizer helped students organize information about the problem and helped them stay on track when solving the problem. Cooperative learning allowed the students to learn from each other and forced students to discuss and justify ways to solve the problem. The written reflection forced students to think deeper into how they solved the problem and why they knew their solution was correct. The results showed these three strategies combined had a positive impact on students' problem solving skills.

After looking at this data, these strategies will continue to be used in my classroom to improve my students' problem solving skills. These strategies and my results will also be shared with the mathematics department at my school in hopes students in grades six through eight can use these strategies to become more successful at problem solving. I think students will be more likely to use the graphic organizer on their own if they start using it at an earlier age and continue to use it in class for the next couple of years. Students will also become more comfortable using the graphic organizer and may become more successful at problem solving when they discover how the organizer can work best for them. Also, students need more practice at doing written reflection in math class and we need to start developing the metacognitive skills used in reflection at an

earlier age. Hopefully, my results will encourage my colleagues to begin using these strategies in their own classrooms. I believe we need to get more teachers working on these skills with students to produce stronger problem solvers so our students can be more successful in post-secondary education and future careers.

Limitations

There were several limitations in this study. The first limitation was time. Due to scheduling, there was only time to do two challenge assignments with my students using the problem solving strategies before the end of the school year. Changing one's problem solving abilities is not something that can be done quickly. I would have liked to have done more assignments with the students using these strategies to see the long term effects on their problem solving skills. I plan on continuing to use these problem solving strategies with my students next year to see if there is even more positive improvement in problem solving skills. Another limitation was the difficulty of the assignments. I try to make all challenge assignments the same difficulty level, but I cannot be certain. The second assignment may have been easier for students to complete, which may have caused the improvement in scores and students' attitudes about their problem solving skills.

Future Research

This study also provided some insights about my own classroom and teaching and has caused me to consider areas for future research. First, I would like to repeat this study starting at the beginning of the school year. I would like my students start using

these tools right away so they can become more comfortable using them and possibly like using them more than my students did during this study. I also think students need more time develop stronger problem solving skills than was given in this study. Problem solving skills are not something that can be changed over the course of a few weeks but takes time and practice to develop. I am interested to see the data after a year of working with these strategies.

Throughout the study, my students struggled with the written reflection. They had difficulty putting into words how they solved the problem and they wanted to say their answer was correct because another group verified it was the correct answer or "because they did all the math correctly." This has made me realize my students are not good at this type of thinking or expressing their thought process. I need to have my students do more written reflection throughout my curriculum to develop their metacognitive skills by assessing and explaining their own work. I am interested to see how incorporating more writing in the mathematics classroom improves student knowledge of mathematical concepts, connections between concepts, and problem solving skills.

Conclusion

Throughout the completion of this capstone, I learned a tremendous amount about problem solving in the mathematics classroom and problem solving strategies, specifically graphic organizers, cooperative learning, and written reflection. The literature review found each of these strategies to offer different benefits to developing a students' problem solving skills and the results of the study confirmed the information

found in the literature review. These findings have provided insight and implications for my own classroom and for the mathematics department at my school. The findings of the research will be presented to my mathematics department and my colleagues will be encouraged to implement these problem solving strategies into their own classrooms. I believe having our students learn these strategies earlier will make students more likely to use them on their own, develop their metacognitive skills, and become better problem solvers. The study also helped me realize the need to create more opportunities for written reflection into my curriculum. Some limitations within the study have urged me to continue the study next year with my students. I would like to see the effects of the strategies when they have been used for the entire school year instead of two assignments. A longer time period will also flush out any discrepancies caused by varying levels of difficulty in the assignments.

The purpose of the study was to determine if graphic organizers, cooperative learning, and written reflection could improve problem solving skills in advanced eighth grade mathematics students. Results of the study show these problem solving strategies improved students' problem solving skills and boosted student confidence in problem solving. Many students expressed the strategies made problem solving easier because it helped them organize important information and stay focused on the problem. The students were also more independent when working on the assignments and I no longer had to run around the room trying answer questions. These strategies and the knowledge gained throughout this capstone will continue to be used in my classroom as it greatly enriches the curriculum and the problem solving process.

APPENDIX A

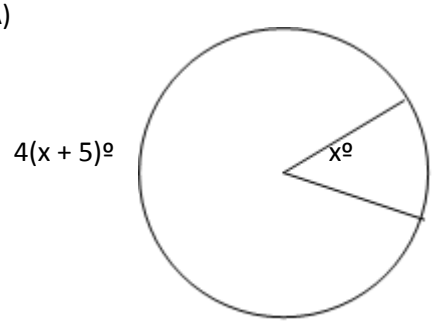
Challenge Assignments

Name: _____

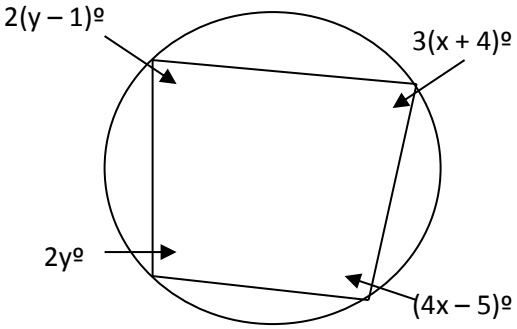
Chapter 10 Graded Assignment #1 Hour: _____

1. Solve for the missing variable(s) in the given diagrams:

A)

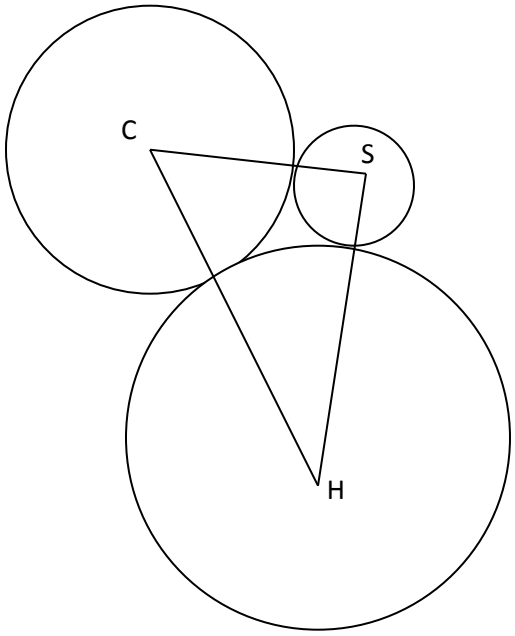


B)

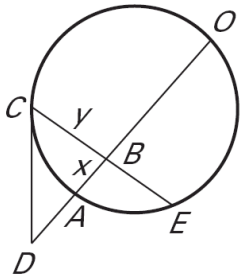


2. Find the length of the radii in each circle. (Hint: Start with one radius as x, one radius as y, etc…..)

CH = 20, HS = 16. and CS = 12



3. In the diagram below, *BE* = 7, *BO* = 14, *AD* = 6, and *CD* = 12. Find the values of *x* and *y*.



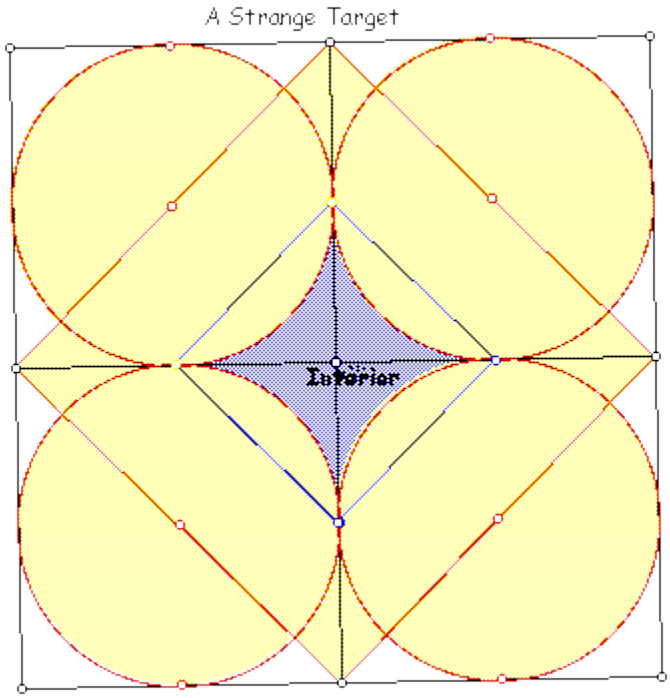
Name:_____

Chapter 11 Part 1 Challenge Assignment

1. A cow is tethered by a piece of rope 50m long. The rope is fastened to the edge of a barn measuring 60 m x 30 m. Over how much ground can the cow graze?

2. The track coach at Chisago Lakes wants to make 8 lanes each 1 meter wide on the running track.
    - The track has straight parallel sides and semicircular ends.
    - If the runners in a race lined up at the same spot and stayed in their own lanes throughout the race, they would not run the same distance.

To make the race even, by how much should each lane be staggered?



3. The dartboard above is 2ft x 2ft.

a) If you throw a dart randomly at this target, what would be the probability that you land in the interior purple region?

b) What is the probability of the dart randomly landing in the purple region given it must land within the yellow region?

APPENDIX B

Problem Solving Survey

Problem Solving Survey

Please state your level of agreement with the following:

	Strongly Agree	**Agree**	**Neither Agree or Disagree**	**Disagree**	**Strongly Disagree**
1. I was able to solve all problems on the assignment.	5	4	3	2	1
2. I was able to fill in all boxes of the graphic organizer.	5	4	3	2	1
3. The graphic organizer helped me solve the problems.	5	4	3	2	1
4. I was able to create a strategy for solving each problem.	5	4	3	2	1
5. I was able to use algebra skills to complete the assignment.	5	4	3	2	1
6. My group members helped me understand parts of the problems.	5	4	3	2	1
7. My group members worked together to form a strategy to solve the problems.	5	4	3	2	1
8. Writing about the problems and the strategy to solve the problem helped me better understand why my strategy worked or didn't work.	5	4	3	2	1
9. I am confident in my problem solving skills. Explain your rating:	5	4	3	2	1

APPENDIX C

Problem Solving Rubric for Graphic Organizer and Written Response

	3	2	1	0
Number Sentences	The math problem is written correctly including +,-, x, / and = sign and work is shown.	The math problem is mostly written correctly and/or work is shown.	The math problem is written incorrectly or no work is shown	The math problem is not written and there is no work.
Answer	The answer to the math problem is correct and labeled.	The answer is correct but not labeled.	The answer is wrong.	The answer is not present.
Strategy	The strategy used matches the problem correctly.	A strategy was used but does not match the problem.	The strategy is incoherent.	No strategy was used.
Explanation	The student explained their work. The explanation is fully correct, and matches the problem.	The student explained their work. The explanation is NOT fully correct, or does not match the problem.	The student gave a partial explanation of their work.	The student did not give an explanation.

APPENDIX D

Student Interview Questions

1. Do you feel you were successful in solving the challenge problems? Why or why not?
2. How was the graphic organizer helpful in achieving your solution?
3. What were some disadvantages of using the graphic organizer to help solve problems?
4. Have you learned anything from your group members about problem solving?
5. Was the writing process helpful in understanding the problem, your solution, or the method in how you arrived at your solution? Why or why not?
6. Have you used any of the problem solving strategies we use in math class in your other classes?

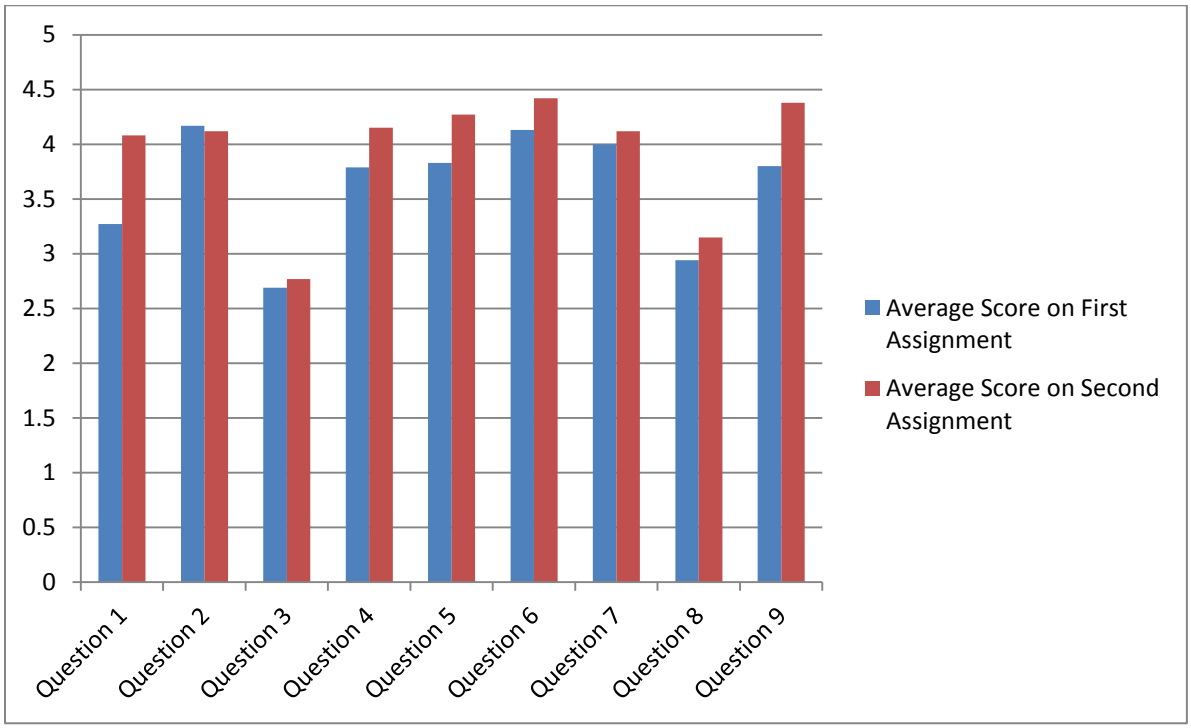
APPENDIX E

Data from Student Survey and Rubric Scores

Data from Student Surveys

Student Survey Question	Average Score on First Assignment	Average Score on Second Assignment
1. I was able to solve all problems on the assignment.	3.27	4.08
2. I was able to fill in all boxes of the graphic organizer.	4.17	4.12
3. The graphic organizer helped me solve the problems.	2.69	2.77
4. I was able to create a strategy for solving each problem.	3.79	4.15
5. I was able to use algebra skills to complete the assignment.	3.83	4.27
6. My group members helped me understand parts of the problems.	4.13	4.42
7. My group members worked together to form a strategy to solve the problems.	4.00	4.12
8. Writing about the problems and the strategy to solve the problem helped me better understand why my strategy worked or didn't work.	2.94	3.15
9. I am confident in my problem solving skills.	3.80	4.38

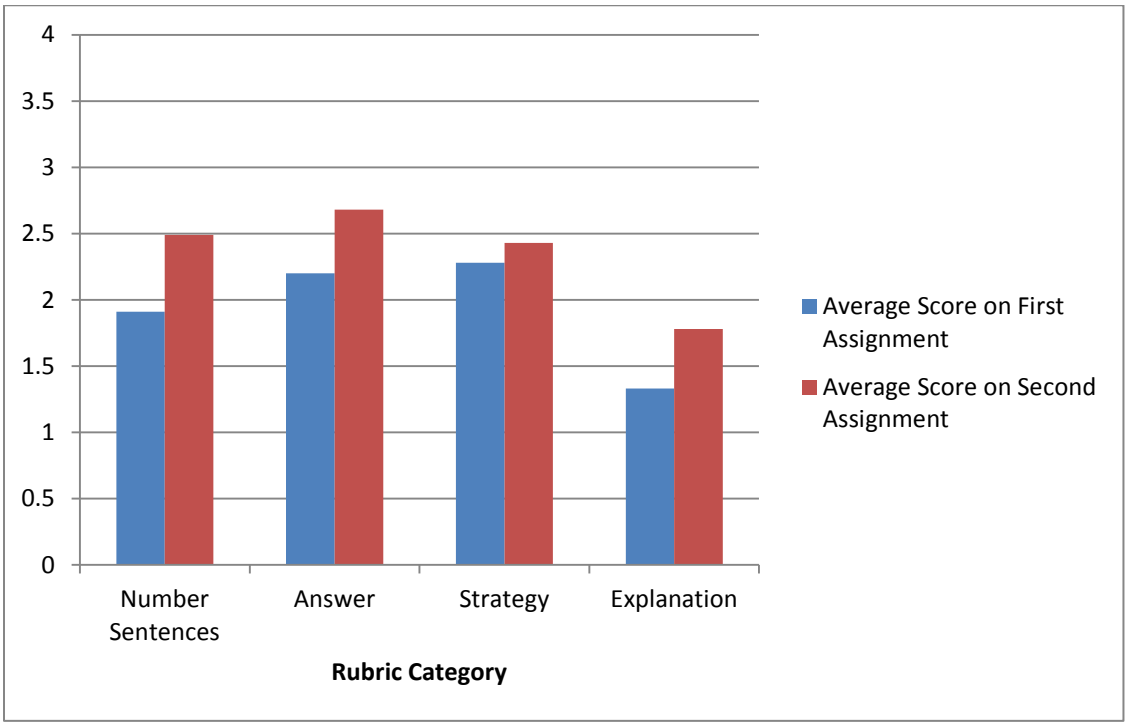
Bar Graph of Data from Student Surveys



Data from Rubric Scores

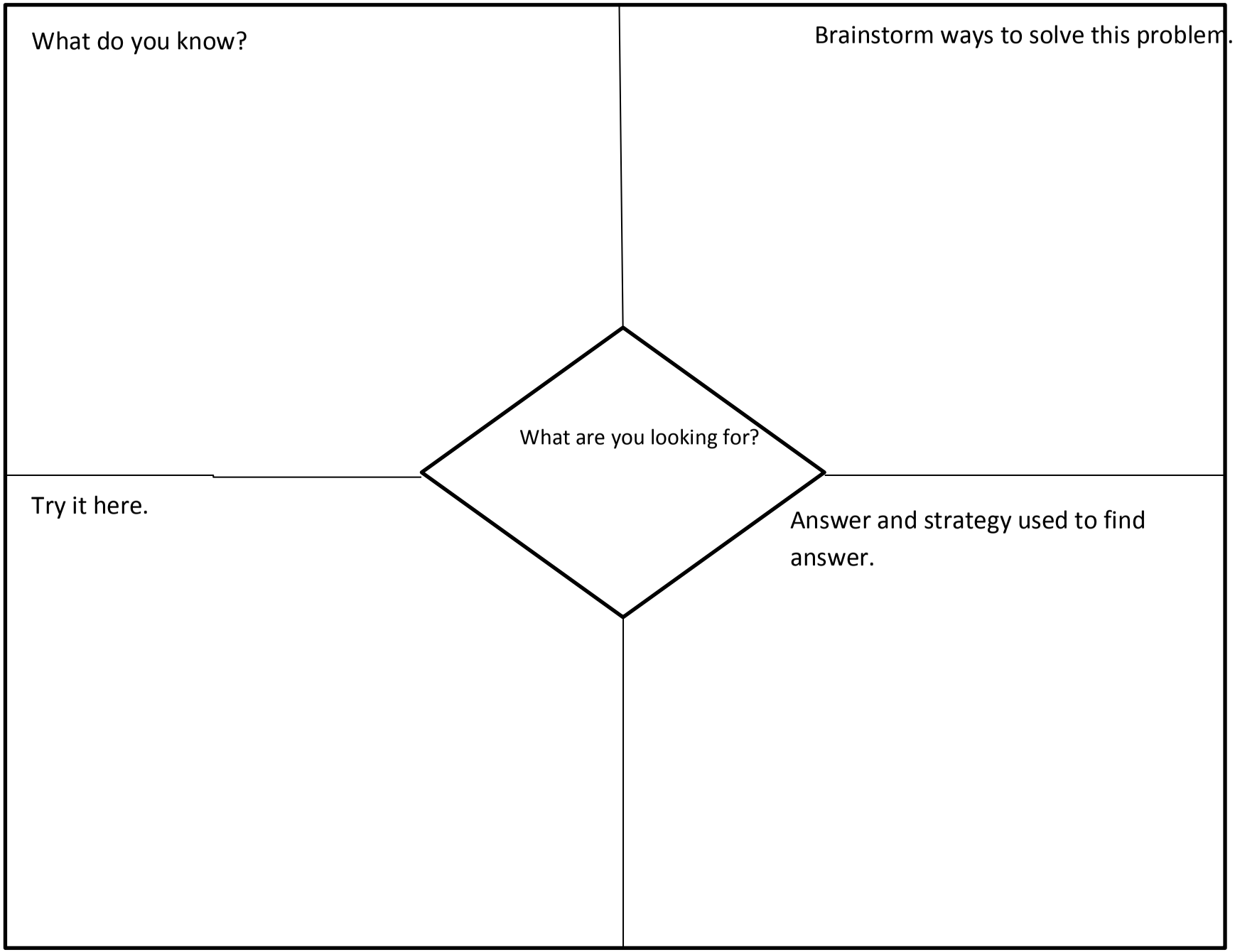
Rubric Category	Average Score on First Assignment	Average Score on Second Assignment
Number Sentences	1.91	2.49
Answer	2.20	2.68
Strategy	2.28	2.43
Explanation	1.33	1.78

Bar Graph of Rubric Scores



APPENDIX F

Graphic Organizer


What do you know?
Brainstorm ways to solve this problem.
What are you looking for?
Try it here.
Answer and strategy used to find answer.

APPENDIX G

Letter of Consent

Letter of Informed Consent to Parents/Guardians Requesting Permission for Minors to Take Part in Research

March 2, 2015

Dear Parent or Guardian,

I am your child's math teacher and a graduate student working on an advanced degree in education at Hamline University, St. Paul, Minnesota. As part of my graduate work, I plan to conduct research in my classroom from February 1st -April 30th, 2015. The purpose of this letter is to ask your permission for your child to take part in my research. This research is public scholarship the abstract and final product will be cataloged in Hamline's **Bush Library Digital Commons**, a searchable electronic repository and that it may be published or used in other ways.

I want to study how using cooperative learning, graphing organizers and reflective writing effects problem solving in my class. Problem solving is a large part of the mathematics curriculum and I am studying ways to improve problem solving skills. I plan to use cooperative learning, graphic organizers and reflective writing four times between February 1st and April 30th. Students will use a graphic organizer to solve problems from their challenge assignment. This assignment is given at the end of each chapter and pushes students thinking by combining concepts from the chapter, as well as previous geometry and algebra concepts. Upon completing the challenge assignment, students will be asked to write about one of the problems they solved. They will be asked to reflect on their method for solving the problem, how they assessed their work as they solved the problem, their thinking process and the reasonableness of their answer. The student's writing and graphic organizer will then be assessed on a rubric. These rubric scores will be analyzed at the end of the study. Students will also fill out a survey at the end of each assignment. The survey will ask questions about the strategies they used to solve the problems. Additionally, some students will be asked to be interviewed about their problem solving skills and the strategies we are using in class.

There is little to no risk for your child to participate. All results will be confidential and anonymous. I will not record information about individual students, such as their names, nor report identifying information or characteristics in the capstone. Participation is voluntary and you may decide at any time and without negative consequences that information about your child will not be included in the capstone.

I have received approval for my study from the School of Education at Hamline University and from the principal of Chisago Lakes Middle School, Jodi Otte. The capstone will be catalogued cataloged in Hamline's **Bush Library Digital Commons**, a searchable electronic repository. My results might also be included in an article for publication in a professional journal or in a report at a professional conference. In all cases, your child's identity and participation in this study will be confidential.

If you agree that your child may participate, keep this page. Fill out the duplicate agreement to participate on page two and return to me by mail or copy the form in an email to me no later than January 23rd, 2015. If you have any questions, please email or call me at school.

Sincerely,

Kara Odegaard
651-213-2474
kodegaard@isd2144.org

Informed Consent to Participate in Qualitative Interview

Keep this full page for your records.

I have received your letter about the study you plan to conduct in which you will be observing students' problem solving processes. I understand there is little to no risk involved for my child, that his/her confidentiality will be protected, and that I may withdraw or my child may withdraw from the project at any time.

_____ _____

Parent/Guardian Signature Date

Informed Consent to Participate in Qualitative Interview
Return this portion to Kara Odegaard

I have received your letter about the study you plan to conduct in which you will be observing students' problem solving processes. I understand there is little to no risk involved for my child, that his/her confidentiality will be protected, and that I may withdraw or my child may withdraw from the project at any time.

_____ _____

Parent/Guardian Signature Date

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