"Effective Strategies For Students To Become More Successful Math Word Problem Solvers"

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EFFECTIVE STRATEGIES FOR STUDENTS TO BECOME
MORE SUCCESSFUL MATH WORD PROBLEM SOLVERS

by
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A capstone submitted in partial fulfillment of the
requirements for the degree of Master of Arts in Education.

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CHAPTER ONE

Introduction

Opening

It seems almost everyone has some part of school they dread. Perhaps it is playing basketball in gym, giving a speech to the class in English, or painting a portrait in art. Some of these activities are dreaded by many students and some by only a few. One such activity people may recall years after school is attempting to solve math word problems. This paper will explain why math word problems are taught in school and highlight some reasons students have difficulty solving math word problems. I will also explore strategies that have been used in an attempt to help students become more successful word problem solvers.

I intend to find out which strategies work best for students in helping them get a deeper understanding of word problems and becoming better and more confident word problem solvers. Since I teach middle and high school math, I think that drawing a diagram/picture will not be the most beneficial strategy because diagrams may be more confusing to draw (Crespo & Kyriakides, 2007). I think that explicitly teaching students what to look for in a word problem (actual question, key words, relevant information) will be the best strategy for improving problem solving skills and confidence in math (Jitendra, DiPipi, & Perron-Jones, 2002; Pennant, 2015). Many of my students are aware of key words already, but they seem to be overwhelmed by the amount of information given and lack the confidence to attack the problem.

Research Question
My main research question is: What effect do different strategies have on middle and high school student comprehension and success in solving math word problems? I do not like seeing my students struggle with a word problem when I see them complete arithmetic problems just fine. The purpose of this study is to try out different strategies to see which ones work best for students, though some students may prefer to use different strategies than others. Once I have seen what strategies work and have a better idea of how to implement them to help students, I plan on sharing this with my coworkers so we can work together to enhance student success on word problems and increase standardized test scores as well as overall mathematics understanding. Related questions I have are: Are the difficulties in comprehension or computation? What effect do different strategies for word problems have on student confidence in math? What effect do these strategies have on retention?

In order to answer these questions I will need to first assess whether it is comprehending the question or computing the answer that is the difficulty students have. Reading comprehension could be another hindrance. If students cannot understand the question, how can they answer it? I am choosing to focus on students’ ability to solve word problems in math. This is important to me because I have noticed in my years of teaching that no matter the age or math ability, students struggle with word problems. Jitendra and colleagues (2015) found over three hundred journal articles on teaching math word problems in the last five decades. Zheng and colleagues (2012) completed a similar study that looked at any type of literature about interventions for solving math word problems and found over four hundred in the last three decades. The most common issue I see is an inability to set up the problem; students are unable to decipher the key words
that tell them what operations to use. Because of this, confidence goes down and frustration goes up. Teachers are trying to make math a more relatable subject, and the word problems are key because they provide context for when a student might use the skills they have learned outside of school.

Often times I am asked “When will I use this math?” and sometimes I struggle to find a good answer. Word problems are one of the most important ways to show students how math from the classroom can be applied to their lives (Fuch et al., 2006; Greer, 1997). In word problems the number sentences from the lesson are given context. However, students seem to get frustrated and try to get out of completing word problems, which leaves them wondering why they tried to learn the skills. If students are better taught how to tackle word problems, they may retain concepts better for the future (Alter, 2011).

I want students to become better at solving word problems in hopes they become more confident in their math abilities. If students can see how we apply math concepts outside of the classroom, they may start to realize just how much math they already do in their lives and start to understand that math is worth learning and practicing. We need to make math more real so students can see its value and remember more of it. There has been a huge push in STEM fields and all of them require math. If society is saying the more math you know the better job you can get, why wouldn’t we help students see those connections to math and expose them to possible future careers?

I feel like this is something that I can work on improving in my class. If I am able to help students read the questions carefully and look for the specific words that tell them
what they are supposed to be doing mathematically, I think I will see an increase in confidence and performance.

This research can be helpful for guardians as well. When I discover which strategies work best to increase student confidence and success I can share these with guardians for when they help with word at home. I can also share this information with colleagues in an effort to present unified word problem strategies. I think this is also good for students because using only a few strategies presented the same way throughout their education will ease some confusion. Even just using the same terms to discuss solving word problems could help.

**Personal Experience**

The opening credits of the show NUMB3RS (a show where a math professor solves crimes alongside his FBI agent brother) says “We all use math every day” (Falacci & Heuton, 2005). Whenever I have shown an episode in my class I make sure to point this out. The math we use every day is not written out as “Lucinda bought 13 pineapples and gave four away…” but as a problem to be solved. Sometimes the math problems we see day to day are equations to be computed, but often they are presented in story form and do not seem like a math problem at first glance. When students ask about using math outside of school I tell them there are many different answers. I have started asking students what they want to do in the future and tell them an explanation of when they will need to use math to complete their tasks. Often this earns the comment that they will not need to do that every day, so I ask them how they know when to leave for work or how much more they can drive before they run out of gas. These are the everyday algebra problems people face, but because they are so used to these types of problems they fail to
see that they are doing math. When it comes to solving math problems that we see every

day, it is not an issue. So why is it I see so many students shut down when they see a
word problem on paper?

While I was in school I was always involved in extracurriculars, especially ones
that involved math. In fifth and sixth grade I was put into Math Masters. I greatly enjoyed
the challenging problems presented and loved testing myself to see what I could do. I
vividly remember one Math Masters meet where we were completing the group portion
of the test. The smartest boy in our grade kept insisting he was right about a problem and
everyone on the team wanted to write his answer, but I knew I was right and just wrote
my answer down instead. We ended up winning the group portion because of it. For me
this was affirmation that math was easy, as long as you look carefully at the problem
presented. I think this is part of the reason that students shut down when they see word
problems – they are not sure which parts are most important or how to carefully read it.
Every time I have a student ask for help on a word problem, I ask if they have read it
first. Often they have not so I ask them to read it out loud. I then try to help the student
break the problem down, but at the next word problem we start all over again. I would
like to find a way to help students gain confidence in their word problem skills so they do
not feel a need to ask for help each time. I think this is important for them as students
because it seems that many questions on standardized tests are presented as word
problems. I believe that it will also increase their confidence in math because they will
begin to see all the real-world math they can accomplish by breaking the problem down.

I remember in second grade having to complete minute math sheets with addition
and subtraction. I always got all of them right and began to feel ashamed because other
students were picking on me for being smart. I hid my math skills from students and
never let them see my grades. It was not until my senior year in AP Calculus that other
students again learned how good I was at math. Throughout junior high and high school I
helped my friends with their math. I also got in trouble for getting my math assignment
done while the teacher was still teaching the new concept. I was frustrated by how easy it
all was. I was lucky enough to get the same math teacher for tenth, eleventh, and twelfth
grade. In twelfth grade I was in AP Calculus and it was the first time I was challenged in
school. At first it was frustrating, but I learned how to read a math book to understand
what it is telling me. I think this is what helped me grasp mathematical language the
most. I quickly became the top student and used all of my study hall time to help others. I
developed a love for calculus and decided I wanted to pursue math in college. Once in
college it was not until my work study that I realized I wanted to teach math. My work
study was in an elementary magnet school for recent immigrants. I soon found I loved
going to work more than class.

I was able to find a teaching job right after I finished my undergraduate studies. I
was to be the only math teacher for grades eight through twelve. This gave me some
anxiety because I had not taught any high school classes during my student teaching and
now I would be teaching five different classes a day. I also had nobody to talk with to
learn about the math curriculum used or how to teach it to these students. I quickly
learned that my students had their own anxieties about math. While they could often
quickly compute equations, they would stall on word problems. I tried to instill more
confidence and help them break down the problem, but it only worked for the problem
As I started writing this paper I found myself having a conversation with one of my students about his own difficulties with math word problems. I was driving him to a school activity and we were talking about classes so far this year. He is part of a group of students taking college exposure classes (not for credit) once a week in math and English. He told me that the previous week their math class was all about word problems and he had struggled with a few. I share this because this student is one of the fastest to catch on in math and has had the highest standardized math test scores in the school since he was in eighth grade (he is now in tenth grade). When students like this young man can breeze through computations but stumble when it comes to work problems, something needs to be done. That is why I am researching strategies to help students become more successful with math word problems.

**Conclusion**

This chapter stated my research question: “How can I improve student comprehension and success in solving math word problems?” Along with this I will be looking at computation versus comprehension, retention, and confidence. I am more interested in students’ ability to figure out what the problem is asking (comprehension) and seeing if they can find a strategy to solve the problem. Retention is another important factor because I want students to consistently be able to solve math word problems in the future and not just the day class focuses on word problems. I also want to better understand students’ feelings about word problems because confidence plays a critical role in success. For instance, I have never driven any vehicle in a race so I lack
confidence to maneuver quickly about turns, which lowers my chance of winning (success). The reason I chose to look into the difficulty of word problems is to help my students gain confidence and feel success in mathematics. Too often people feel math is something done in the classroom and I hope that a part of this research changes that idea for my students.

I also shared my story with confidence in mathematics and how I became a math teacher. Although math has always been easy for me, I tried to hide my skills for fear of rejection from other students. I later found math was something I enjoyed doing and early in college realized I had a passion for sharing knowledge with others so I turned to teaching. Now that I am a teacher, I see my students consistently struggling with word problems and I want to ease their confusion and increase their confidence.

In chapter two I will review studies on different strategies for teaching word problems. I will also look into studies on the amount of time spent teaching word problem strategies and analyze how word problems appear outside of the classroom (standardized tests and everyday life). Chapter three will cover my plan to gather data. This includes student surveys to understand more about their confidence levels and evaluations of their skills. Chapter four will discuss the results of my findings. I will talk in detail about students involved and what I have found from their surveys and tests. And finally, chapter five will discusses conclusions I have drawn and steps I will be taking moving forward.
CHAPTER TWO

Literature Review

Introduction

This chapter will discuss literature that explores the question *What effect do different strategies have on middle and high school student comprehension and success in solving math word problems?* Other questions that will be considered are: Are the difficulties in comprehension or computation? What effect do different strategies for word problems have on student confidence in math? What effect do these strategies have on retention? The chapter will start with an overview of the importance of word problems. First math word problems outside the classroom will be discussed - those on tests and in real-life situations. The section following will discuss various difficulties students have with math word problems. The final section will present studies of various strategies that intend to help students become better word problem solvers.

Although the United States has focused many studies on word problems in mathematics (Jitendra et al., 2015), the question is why is this seen as important? Some researchers point to the relevance of word problems to real-world math (Swanson & Beebe-Frankenberger, 2004) and the problem solving skills math word problems give students. Other researchers point to the common belief that word problems are more difficult for students to solve (Koedinger & Nathan, 2004). As a society we see the value of learning to solve word problems; there are entire books dedicated to the subject (Nolan, 2009; Wayne, 2002). Solving word problems can also alleviate some of the cries of “When am I ever going to use this math in real-life?” Some textbooks make a point of
including several word problems with each skill that show real-life application (Larson, Boswell, Kanold, & Stiff, 2004; Bellman, Bragg, Charles, Handlin, & Kennedy, 2004). These problems give insight into how math can be applied in various careers and events after high school. Not all students will use this real-life math – not everyone is going to be a carpenter or statistician – but it can help them understand how to solve the various word problems they will encounter.

**Word Problems in the Real World**

Math is all around us, but just how much? This section intends to look at how prevalent word problems are outside of the classroom: in real-life and on standardized tests. The Minnesota Comprehensive Assessment (MCA) test will be analyzed for number of word problems, as well as the American College Test (ACT). In order to understand if word problems are as important as some people feel, it is necessary to see where they are found currently and in what capacity. The question “why teach about word problems?” gives 4,770,000 results on Google ranging from opinion pieces and journal articles to books.

Some of the books written about solving story problems are *Killer Math Word Problems for Standardized Tests* and *How to Solve Math Word Problems on Standardized Tests* (Nolan, 2009; Wayne, 2002). These two texts discuss strategies for reading word problems thoroughly and making a plan to solve them quickly given time constraints on many standardized tests. *How to Solve Math Word Problems on Standardized Tests* walks students and parents through a step-by-step process for solving word problems that focuses on grammar and mechanics. This strategy is similar to locating keywords, as Wayne (2002) mentioned. Wayne (2002) argued that part of the
reason students become confused and frustrated with word problems in math is because of the specialized language of mathematics.

*Killer Math Word Problems for Standardized Tests* (Nolan, 2009) focused on the SAT, GRE, and GMAT. While these tests are not taken in high school (though students could take the SAT, the ACT is more common), it shows that even after high school word problems continue to confuse and frustrate students. When it comes to elementary and secondary students, statewide standardized tests are the time when understanding word problems is most important.

**Word Problems in Standardized Tests**

Much of what is done in schools has been based on standards and test scores. In Minnesota the statewide standard-based assessment is the Minnesota Comprehensive Assessment (MCA).¹ A look at the sample questions of the MCA can give insight into the importance of word problems in math. On the seventh grade sample test there are nine word problems out of twenty-six total, about 34.6 percent (Minnesota Department of Education, 2013). The eighth grade sample test is similar in number with ten word problems out of twenty-four, about 41.7 percent (Minnesota Department of Education, 2013). Students do not take the math MCA again until eleventh grade. At this point the sample test has fourteen word problems out of twenty-four, about 58.3 percent (Minnesota Department of Education, 2013). This suggests that as students get older word problems become more important. Eleventh grade students are also required to take the American College Test (ACT) for graduation. The ACT website also has a sample

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¹ For the purpose of this paper, a math word problem is defined as a story problem in which students have to come up with an equation and solve it for the particular situation.
test and thirty-three of the sixty problems are word problems, which is fifty-five percent (American College Test, 2016). By eleventh grade, students need to make the leap from twenty percent of practice being word problems (Larson, Boswell, Kanold, & Stiff, 2004) to nearly sixty percent of their major tests being word problems.

**Word Problems in the Classroom**

While the MCA and ACT suggest the importance of word problem skills, many traditional classes and lessons do not (Larson, Boswell, Kanold, & Stiff, 2004). Looking through McDougall Littell’s Algebra 2 (Larson, Boswell, Kanold, & Stiff, 2004) practice assignments shows an average of two to four word problems on a typical worksheet. This works out to between five and twenty percent of the questions. These questions only appear at the end of the practice and utilize the specific skill of the lesson. There is a discrepancy between what is standard with practice and what is tested. If students are supposed to be able to solve word problems so easily – and quickly since the ACT math portion is sixty questions in sixty minutes (American College Test, 2016) – why is there not more focus in the classroom?

A look at the Minnesota standards for math (2007) shows the importance of solving real-world problems.² For seventh grade math six of the standards focus on solving real-world problems (Minnesota Department of Education, 2007). This is nineteen of the thirty-four benchmarks. Benchmarks for word problems often used the word “represent,” suggesting the student will have to create an equation to solve the problem. In eighth grade three of the standards focus on real-world problem solving

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² For this study, standards with the phrase “real-world situations” were used as a basis for real-life problems.
(Minnesota Department of Education, 2007). This works out to nineteen of the thirty-five benchmarks. In high school thirty-eight of seventy-three benchmarks focus on real-world problems (Minnesota Department of Education, 2007). This seems odd since the number of word problems increases in the MCA tests. The benchmarks themselves focus on computation problems that are not applied to real-world situations. When it comes to the breakdown of the MCA in seventh grade, questions on real-world problems make up between twenty-four and thirty-two questions out of forty-two (Minnesota Department of Education, 2013). In eighth grade anywhere from sixteen to twenty-five of the forty-two questions involve real-world situations (Minnesota Department of Education, 2013). The MCA in eleventh grade has a total of forty-seven questions, between nineteen and thirty-seven of which focus on real-world problems (Minnesota Department of Education, 2013). This does not resemble the sample tests provided by the MCA makers. In those tests, just under half of the questions were real-world problems where students needed to set up equations. While these two areas do not coincide perfectly, it is still evident that real-world problems make up a significant portion of math. With the percent of questions on standardized tests focusing on word problems, what are the barriers students face in successfully answering such problems?

**Difficulties with Word Problems**

There are many possibilities why students may have difficulties in mathematics – learning disabilities, lack of confidence, race, gender, computation skills, and comprehension skills to name a few. These differences may cause gaps in math abilities, but there could be ways to compensate for them. This section will analyze the different reasons why students display varying abilities in mathematics. Some of the widely
discussed reasons for difficulties in math word problems are: changing registers, issues with semantics, processing, and teacher skills with word problems.

**Changing registers.** There are always word problems that seem easier to complete than others and this may have to do with the direction one has to think. Duval (2006) looked into the issues of comprehension based on a language aspect using the idea that mathematics may use different thinking processes. The problem arises when students need to shift between different semiotic representation systems, the explicit to the abstract or vice versa. Semiotic representations are defined as the different signs and symbols used to relate mathematical ideas. Duval claimed there are four distinct registers: 1) can be written as algorithms and use definitions/relations, 2) can be written as algorithms and involve shapes, 3) cannot be written as algorithms and involve shapes, and 4) cannot be written as algorithms and use definitions/relations (2006). An idea of a problem fitting into register 1 would be a computation, while a proof would fit into register 4. It is then easy to see that there is a vast difference in the amount of work and processing that goes on in various problems. One of the comprehension problems Duval (2006) saw was teachers thinking students can see the various parts occurring in geometry problems without explicit instruction. Students may not have taken into account the overlapping part of two shapes and how it could help them solve the problem. Another issue is changing registers (Duval, 2006). The direction of change in register can have an even greater effect on comprehension. In fact, Duval tested out register changes in different directions and found differences in correct answers ranged from thirty-three percent to sixty-five percent (2006). This means that students have a difficult time when it comes to changing their thinking, but the way problems are worded could also be key.
Semantics. Many have researched the issues students have the wording of math word problems (Abedi & Lord, 2001; Clement, 1982; DeCorte & Verschaffel, 1987). While there are specific math vocabulary students must know to complete a problem, there is also an element of understanding how the words go together. Clement (1982) decided to take a look at the word problem skills of college students in science-oriented fields. This is of interest for the current study because many studies involving word problems seem to use elementary students for participants (Alter, 2011; Fuchs et al., 2015; Jitendra, DiPipi, & Perron-Jones, 2002; Leh & Jitendra, 2013; Nesher & Katriel, 1977; Pennant, 2015; Xin, Jitendra, & Deatline-Buchman, 2005). DeCorte and Verschaffel (1987) focused on the strategies used by first graders based on the wording of the question. They bring up the major types of word problems: change, combine, compare. Clement (1982) asked students to solve six algebra problems, three of which were word problems. Only twenty-seven percent of students were able to solve the sixth problem, and Clement concluded this was due to a lack of understanding the wording, not the process (1982). Like Duval said, part of the problem lies in translating between representations (Duval, 2006). Moving from pictures to equations, tables to equations, or equations to sentences all present issues for students (Clement, 1982).

Clement said there are two types of errors to analyze: syntactic word order matching and semantic static comparison (1982). In static comparison the symbols take on more meaning, a definition instead of a variable. Word order matching is a problem that is seen in other studies as well. The word order matching problem occurs when students assume the order of the words matches the operations needed. De Corte and Verschaffel (1987) found that some students rely on the sequence the numbers are
presented in order to figure out the answer. While this works fine for addition problems, it could be problematic as students become older. When it came to subtraction problems, it was found that most often students would subtract the smaller number from the larger without regard for the question (De Corte & Verschaffel, 1987).

Koedinger and Nathan (2004) looked at the two phases of solving story problems: the comprehension phase and the solution phase. Researchers have noted difficulty in the comprehension phase when it comes to understanding the linguistics of the problem. The solution phase focuses on students’ strategies to solve the problems, the equations they use and how they proceed (Koedinger & Nathan, 2004). The cover stories used by Koedinger and Nathan (2004) involved situations students may find themselves in, such as buying donuts or a share of a basketball. One of the problems used was:

After buying donuts at Wholey Donuts, Laura multiplies the 7 donuts she bought by their price of $0.37 per donut. Then she adds the $0.22 charge for the box they came in and gets the total amount she paid. How much did she pay? (Koedinger & Nathan, 2004, p. 137).

This problem specifically stated which operations to use and when. Looking through an algebra one textbook where similar problems can be found, they most often do not explicitly state the operations (Bellman, Bragg, Charles, Handlin, & Kennedy, 2004).

Koedinger and Nathan (2004) focused their study on algebra one students. This is important to remember when looking at their results. Koedinger and Nathan (2004) found that these students had an easier time with word problems than algebraic equations, though this could be because of their lack of familiarity with variables and
how to solve for a variable. The results of this study could be contested because other studies have been completed with college students who are familiar with solving for variables. In the studies with college students, the difficulty was setting up word problems or finding a way to solve the word problems (Clement, 1982).

Hegarty, Mayer, and Monk (1995) continued to look into the idea of word order matching in a slightly different light. These authors started off their research with the idea of inconsistent and consistent word problems. A consistent word problem is when the vocabulary of the problem primes the correct operation, whereas an inconsistent problem primes the reader for the incorrect operation (Hegarty, Mayer, & Monk, 1995). An example of this is comparing the prices of two kinds of cereal. One could say that box A is $3.00 and box B is $.50 more (consistent), or that box A is $.50 less than box B (inconsistent because the wording sounds like subtraction). Hegarty, Mayer, and Monk focused their study on successful and unsuccessful problem solvers in college, thereby attempting to eliminate computation errors, reading errors, and errors from lack of familiarity with word problems (1995). Hegarty, Mayer, and Monk believed that unsuccessful problem solvers would focus on numbers and operational terms while successful problem solvers would focus on the variable names (1995). Their experiment showed that unsuccessful problem solvers did look at numbers and operational terms more frequently, but there was little difference in the amount of times either group looked at variable names. Hegarty, Mayer, and Monk also noted that successful problem solvers still looked at numbers and operational terms more than variable names (1995). In a second experiment, Hegarty, Mayer, and Monk tested out the idea that successful problem solvers focus less on wording and more on the meaning of the words. They
found that unsuccessful problem solvers made more semantic errors (recalling operational terms incorrectly), while successful word problem solvers made more literal errors (recalling the correct operation but wording it differently). This again showed that successful problem solvers had a better understanding of the meaning of the problem.

Abedi and Lord (2001) took the idea of wording a step further and tested modified wording of standardized test word problems to see if it increased success. The questions were modified so that wording was simpler but the mathematical content was the same, for instance a question that asks “What is the total number of beetles after five days?” would be changed to “How many beetles were there after five days?” (Abedi & Lord, 2001). The first part of this study was seeing which type of question the students preferred, and significantly more students picked the modified questions (almost twice as many) (Abedi & Lord, 2001). Overall students said that the modified questions were easier to understand. Based on the difficulties noted in the previously stated studies, it makes sense that students would prefer a question where they are better able to understand what they are supposed to be doing. After all, people tend to like clear instructions.

While this study focused more on the proficiency of English Language Learner (ELL) test scores, it also questioned the general population’s ability to succeed with modified word problems (Abedi & Lord, 2001). The second part of the study had students complete modified and unmodified word problems, changing those types between group A and B so that there was a basis to judge which type enabled students to be more successful. It was found that the modified word problems had a slightly higher success rate, enough to be statistically significant only (Abedi & Lord, 2001). This
continues the idea that the wording of math problems plays a large role in student success.

Pierce and Fontaine (2009) lamented the multitude of vocabulary used on math standardized tests, from words with a continuum of meaning to math specific words. Wayne (2002) shared this idea of math vocabulary when he said math has its own specialized language. Teachers should define words in language students can understand versus using the dictionary definition. Pierce and Fontaine (2009) listed several of the ambiguous words from the Massachusetts Comprehensive Assessment System for third graders: key, table, ruler, kind, area, and shade to name a few. This can confuse students because these words mean something different outside of math class.

Gerofsky (1996) was also interested in the language of word problems. She decided to look at math word problems as a literary genre and describe the features in order to help educators see word problems in a new way (Gerofsky, 1996). Nesher and Katriel (1977) shared Gerofsky’s view that word problems are similar to riddles when they studied the strategies of first graders in solving word problems. The reason behind this is that riddles are presented as a separate entity where one needs to use the information given to come up with an answer. Gerofsky (1996) broke down word problems into three components: a set-up/background story, information to solve the problem, and a question. She argued that while the set-up gives word problems their ‘story,’ it can confuse students and lead them to think about other factors not important for solving the problem. Nesher and Katriel (1977) discussed the different verb usage in word problems and how sometimes it is not clear if the two sets go together. An example they gave is “Dan found three stamps and bought three stamps” (1977). In this situation
questions can arise from Dan’s paying for stamps and in turn change how many stamps he has if he did not pay for all of them (Nesher & Katriel, 1977). When students have been asked to create their own word problems, they often create problems similar to those in their textbooks and not relevant to their lives (Gerofsky, 1996). While students understand what a word problem is, they are unable to apply the ideas to their own real-lives. This can be frustrating for a teacher because word problems are meant to embody real-life situations, but if students have no connection to the situations in the problem they fail to apply the mathematical ideas.

The actual words used in math word problems can cause difficulties for students. Students may struggle with the specificity of math vocabulary or the ordering of the words in connection with operations. If students are able to overcome their difficulties breaking down the vocabulary of math word problems, they may still encounter problems in processing how to put it all together.

**Processing.** As Abedi and Lord (2001) noted, students frequently look back to word problems to recall numbers, operations, and variables. Similar to this idea, others have researched the relationship between memory and success with word problems. Swanson and Beebe-Frankenberger (2004) focused their work on the differences between working memory and short-term memory in terms of word problems. For this study, working memory was defined as preserving information while processing (like getting directions to an address) and short-term memory was defined as holding a small amount of information and recalling it sequentially (like remembering a phone number for a brief time). They found that better working memory (tested in various areas) played a large role in better problem solving because it enabled students to recall information and
process what the word problem was asking. Students with less working memory will therefore struggle to understand what a problem is asking right away. This could lead to errors in creating an equation for the question.

Not only are students at risk for processing errors in setting up an equation for a word problem, they could make errors by assuming the first answer they get is right. Students sometimes give unreasonable answers to questions, such as needing 4.5 busses to transport the grade to the museum. Students are quick to write down their answer without checking to see if it makes sense. Hegarty, Mayer, and Monk (1997) suggested that successful word problem solvers reflect on their answers. Along with this, Greer (1997) contended that there is frequently a lack of reflection while computing answers for word problems, giving an answer that makes no sense for the problem. One such word problem involved needing rope to tie two poles together but not having a long enough piece (Greer, 1997). The problem students frequently (almost all students in fact) have here is not accounting for the amount of rope needed to tie the pieces together (Greer, 1997). Greer felt that students needed to learn to look beyond the numbers of a word problem and look more closely at what the problem is asking. In this way students would become better critical thinkers because they will take reality into account. However, this has caused problems for students because they look too deeply into the problem (Gerofsky, 1996) and include unneeded information.

Students may have problems with the wording of a question or move on too quickly to analyze their answer, making them less successful with word problems. While much research focuses on the difficulties students have with word problems, they are not
the only people in the classroom. Perhaps part of the reason word problems are difficult lies with the teachers.

**Teaching skills.** Nasrin, Mumtaz, and Abaidullah (2015) studied teaching methods for math problems in Pakistan for high school students. This is important for the current study because it involves the same age group as will be used later. Nasrin, Mumtaz, and Abaidullah (2015) found that the education system focused more on working through exercises than understanding mathematical concepts. Because of this there is little work done on applying math to real-world situations. Based on the textbook analysis previously discussed (Larson, Boswell, Kanold, & Stiff, 2004), the same is true in United States schools. Nasrin, Mumtaz, and Abaidullah found that many teachers reported a lack of training on how to teach problem solving (2015). Nathan and Koedinger (2000) also looked at the attitudes of math teachers and math education researchers. They found that most thought story problems would be more difficult than equations. Ideas about difficulty with word problems permeate many fields: personal, mathematical, and scientific (Koedinger & Nathan, 2004).

In order to learn more about teaching problem solving, Nasrin, Mumtaz, and Abaidullah (2015) distributed surveys and conducted interviews with experienced and inexperienced teachers with and without majors in math. These teachers received training in problem solving and were asked to reflect on how it helped them conduct lessons on problem solving (Nasrin, Mumtaz, & Abaidullah, 2015). This is also important for the current study because the current study asks a teacher to try out different strategies for solving word problems.
It was found that while the teachers valued the training and importance of problem solving, they felt they still had difficulties helping students with differing abilities (Nasrin, Mumtaz, & Abaidullah, 2015). A look through leveled lessons in an American textbook showed fewer word problems for students below grade level than those at or above grade level (Larson, Boswell, Kanold, & Stiff, 2004). However, the teachers surveyed felt that problem solving was important for daily life math and that activities in problem solving help to keep all students engaged. This is in agreement with both Greer (1997) and Fuchs et al. (2006). It is important to note that experienced teachers and less experienced teachers differed significantly in opinion on incorporating problem solving into planning and curriculum (Nasrin, Mumtaz, & Abaidullah, 2015). It is not evident from this text whether it was the experienced teachers or the less experienced teachers that felt it was difficult to incorporate problem solving into planning. Nasrin, Mumtaz, and Abaidullah (2015) also found that teachers with a background in math felt it was more difficult to conduct problem solving activities with a large class. One of the teachers interviewed said that teachers avoid problem solving because they do not themselves understand different approaches to problem solving (Nasrin, Mumtaz, & Abaidullah, 2015). If this is the case, the current study could shed light on the topic through analysis of various strategies further in this chapter. In the end, whether or not teachers like using problem solving it will not happen regularly until the curriculum, textbooks, and assessments reflect the importance of problem solving and constraints on time and resources are removed (Nasrin, Mumtaz, & Abaidullah, 2015). Although this study was completed in Pakistan, it seems to parrot the feelings of teachers in the United States.
Another study focused on helping teachers become more comfortable problem solvers themselves – since Nasrin, Mumtaz, and Abaidullah (2015) noted that part of the problem was not knowing different problem solving approaches. Sakshaug and Wohlhunther (2010) decided to look at teaching problem solving to students through a graduate course for teachers. In this study, teacher graduate students completed their own word problems. Sakshaug and Wohlhunther (2010) found that the teachers struggled on word problems individually, but were able to come up with correct answers most of the time when working in a group. The authors also interviewed teachers as they implemented the same word problems in their own classroom. It was found that teachers were not able to consistently present the different word problems or give students time to work on their own ideas for solving (Sakshaug & Wohlhunther, 2010). Based on what both Sakshaug and Wohlhunther (2010) and Nasrin, Mumtaz, and Abaidullah (2015) found teachers may need more help teaching word problems to students.

**Instructional Strategies for Word Problems**

The National Council of Teachers of Mathematics (NCTM) released *Principles and Standards for School Mathematics* in 2000. It outlined the different areas of math students should work on, with a focus on problem solving skills (NCTM, 2000). Buschman used this preface to say that while teachers can teach students the myriad different problem solving strategies, students should be able to problem solve in a way that makes sense to them (2004). There is value to teaching students how to solve problems in their own way because it can enable them to become more confident problem solvers in the future, it may not be the best way to correctly solve problems on standardized tests.
Furner, Yahya, and Duffy (2005) made a list of strategies to help students become better at mathematics, many of which apply to word problems. Use manipulatives, encourage students to create a drawing, use real-life situations, have students create their own word problems, encourage students to follow the problem solving process, and rewrite word problems in simpler terms were some of their ideas (Furner, Yahya, & Duffy, 2005). All of these ideas have been researched and are discussed in this paper. The previous sections of this chapter outlined the need to learn how to solve math word problems and various difficulties students and teachers have when attempting to work on word problems. At this point it is time to focus on what teachers can do to help students become more successful word problem solvers.

While Furner, Yahya, and Duffy list different strategies to solve word problems, others have analyzed what strategies are researched most often. Zheng et al. (2012) completed an analysis of studies from 1986 – 2009 to synthesize literature on word problem solving intervention studies for children with math disabilities. Although 425 studies were found that discussed mathematics or problem solving, only fifteen group/single-subject studies met the criteria of the authors. The studies that met the criteria were published between 1990 and 2005 and conducted in the United States (Zheng et al., 2012). Jitendra and colleagues (2015) set out to determine the quality of the studies on strategy instruction in math problems, specifically for students with learning disabilities or at risk for math difficulties. The researchers conducted a meta-analysis study by looking through databases at studies published in peer-reviewed journals from 1960 to 2011 (2015). Using keywords like mathematics, story problems, at risk, etc. the group located 322 abstracts.
Of the group design studies, seventy-eight percent focused on conceptual understanding of word problem solving (Zheng et al., 2012). More than seventy percent of the interventions used the following instructional components: sequencing, task reduction, advanced organizers, questioning, elaboration, strategy cues, and skill modeling (Zheng et al., 2012). These are similar to the strategies presented by Furner, Yahya, and Duffy (2005). Of the single-subject studies that Zheng and colleagues found, all focused on solving problems with multiple arithmetic operations, but none focused on both computation and problem-solving skills (Zheng et al., 2012). For the present study computation will not be in question, but computation errors will be noted.

When it comes to word problems there are various strategies that claim to increase student success – hence the many sources found by Zheng et al. (2012). Among these are keywords, drawing a picture, and a combination of both (Swanson et al, 2013). Some of these strategies are meant to help students with math difficulties, but some are meant to help all students. Although there are multiple strategies that claim to support student understanding of math word problems, there is a question of how carefully researched these strategies are in terms of quality (Jitendra et al., 2015). The following paragraphs will analyze the more popular strategies for success, limitations, and thoroughness of research available.

**Problem solving steps.** When it comes to getting things done, some people like to follow steps. There are steps to baking cookies, steps to changing a tire, steps to applying to college, and steps to writing a paper. Perhaps students could also learn steps to solving math word problems. Pennant (2015) wrote a short article on teaching problem solving to young learners in which she outlines steps for students to follow. The process
Pennant suggested uses four steps. The first was called “getting started” and involved representing the question with a diagram, model, or action. The next step was to work on the problem, which meant the student should use logic and look for a pattern while trying out different solutions (Pennant, 2015). After this Pennant said that students should try to generalize or prove their findings, and finally communicate those findings. While these steps make sense to an adult, it seems students would stop after step two. As Greer (1997) noted, students do not often take time to think about their answers, thus missing the last stage of the problem solving process. Alter (2011) tested out similar steps with three students with emotional and behavioral disorders at a public elementary school in a lower socioeconomic status neighborhood.

Alter (2011) wanted to pilot a model for teacher training that changes the manner of instruction, focusing on conceptual understanding versus ability to come up with an algorithm. Each worksheet used to test effects of the intervention contained five problems that included finding the correct operation, locating key information, recognizing the pattern to predict what number comes next, and performing arithmetic correctly (Alter, 2011). This test of strategy intervention effects will be similar to the present study, though the present study is not concerned with correct computation. The problems were set up so students could draw a picture, guess and check, or make a table. All students in the study at least doubled their percent of word problems correct, with an average of fifty percent correct (Alter, 2011). Alter noted that although students’ percentage correct increased, it did not reach mastery level (2011). Another possible concern is the small size of the group studied. One of the concepts learned from the study is that student
strategies are important to student thinking and teachers cannot do the thinking for students (Alter, 2011). This is in agreement with Buschman (2004).

The Florida Department of Education (FDE) (2010) created an article on strategies for problem solving through twelfth grade. This is important to the present study because many other studies focus only on elementary problem solving as noted earlier. The FDE set up the article like the problem-solving process that Pennant (2015) explained: understand the problem, design a plan, find a solution, and check your solution. Within the first two steps are various ways that students can accomplish the goal of said step (FDE, 2010). Many of these strategies seem to be meant for classroom purposes and not individual testing situations, such as share with a pattern, discuss with a partner, or cooperative learning groups. While it is good to get students comfortable with word problems in a group, strategies that students can quietly and quickly complete in testing situations are of more interest in the present study. Of the strategies the FDE listed only a few appear to be made for silent work: paraphrasing (finding key words and reasking the question), visualization (having students draw a visual of the problem), guess and check, look for a pattern, use a formula, and work backwards (FDE, 2010). Guess and check is not an ideal strategy in a testing situation because it can waste valuable time. Using a formula seems like an appropriate strategy, but students may get confused on which formula to use or where different quantities belong in the formula. Because of this, paraphrasing, visualization, looking for a pattern, and working backwards seem to be better strategies for students to apply in the individual testing situation. These also appear to be popular strategy choices as evidenced in the following paragraphs.
**Schema-based instruction and conceptual modeling.** The analysis Jitendra and colleagues (2015) conducted found that explicit strategy instruction priming, when implemented with fidelity, was likely to lead to significant improvement in problem solving skills. Three strategies from high quality studies were: schema based instruction, schema-broadening instruction, and conceptually based model of problem solving. These three strategies are discussed in the same order in this section. Most people are familiar with drawing a model to help solve a word problem so it makes sense that that is an included strategy. Schema based instruction asks students to find the underlying problem structure, make a visual, and then the teacher gives explicit instruction on solving the problem (Jitendra et al., 2015). Schema-broadening instruction works on taught problem types that introduce unexpected features (Jitendra et al., 2015).

Jitendra studied schema-based instruction with other colleagues at earlier dates. An examination of students’ pretest performance in both groups indicated a lack of conceptual understanding: Students typically grabbed all the numbers in the problems and indiscriminately applied an operation to get the answer, regardless of the nature of the problem (Xin, Jitendra, & Deatline-Buchman, 2005). Jitendra, DiPipi, and Perron-Jones (2002) studied the effects of schema-based instruction on middle school students with learning disabilities. Students with learning disabilities tend to be taught rote memorization and computational skills instead of learning how to become problem solvers, thus achieving significantly lower scores on tests (Jitendra, DiPipi, & Perron-Jones, 2002). Xin, Jitendra, and Deatline-Buchman (2005) conducted a study on schema-based instruction versus general strategy instruction for students in middle school with learning problems. The schema-based instruction was similar to the general strategy
instruction, but it included identifying the type of problem before drawing a picture and transforming the problem into a math sentence before solving (Xin, Jitendra, & Deatline-Buchman, 2005). In 2002, Jitendra, DiPipi, and Perron-Jones focused on the use of schema-based instruction for multiplication and division word problems. It also had students complete a Likert scale on the usefulness of the strategy and open-ended questions about students’ feeling towards word problems. The current study intends to do the same. Xin, Jitendra, and Deatline-Buchman (2005) found that students in both groups improved from the pretest and were able to maintain improved scores even after the study was completed. Students in the schema-based instruction group made much higher gains in the posttest and were able to continue to make gains (Xin, Jitendra, & Deatline-Buchman, 2005). Of the four students in the Jitendra, DiPipi, and Perron-Jones (2002) study, all of them went from less than fifty percent correct to one hundred percent correct after schema-based instruction. Three of the four were also able to maintain that growth when tested after instruction had ended. The authors cautioned that this small study may not apply to larger numbers as well. These particular studies of schema-based instruction led schema-based instruction to be included in the experiment portion of the present study.

Schema-broadening is defined as understanding the schema used when changes in cover story, vocabulary, and question occur, as well as including extra information or combining problems (Fuchs et al., 2006). Fuchs et al. (2006) focused their study on schema-broadening instruction with third graders. Frequently discussed schemas are: change, group, and compare (Fuchs et al., 2006; Xin, Jitendra, & Deatline-Buchman, 2005; Jitendra, DiPipi, & Perron-Jones, 2002). Fuchs et al. completed an experiment where one group was given specific instruction on schema-broadening problem solving
(2006), one got the schema-broadening instruction with real-life problems, and one group functioned as a control with teacher led instructions on other problem solving ideas. Fuchs et al. found that both groups receiving schema-broadening instruction improved more than the control group of students (2006). When it came to real-life questions, the students in the group with schema-broadening instruction focusing on real-life problems surpassed the other groups, but the schema-broadening group outscored the others on standard schema-broadening questions (Fuchs et al., 2006).

Xin et al. (2011) studied the effects of a conceptual model-based problem solving (COMPS) approach in helping students better understand algebraic word problems, specifically multiplication and division problems. One group received COMPS instruction while the other received general heuristic instruction (GHI). The COMPS group learned a specific model to help them find the unknown in a word problem laid out in factor-factor-product form. This is similar to the part-whole strategy used by Swanson et al. (2013). The GHI group learned steps for problem solving, much like those presented by Pennant (Xin et al., 2011). The authors found that students in the COMPS group significantly improved their scores over the GHI group (Xin et al., 2011). One of the reasons this is likely is that the students in the COMPS group were better able to model the problem (Xin et al., 2011). This makes sense because they were given a specific format to use to solve algebraic word problems whereas the GHI group had more room to change their format for each problem.

**Diagrams.** Diagrams are generally accepted as the standard for solving word problems (Uesaka & Manalo, 2007). Yet students have various problems when it comes to creating diagrams, most often lack of spontaneity, incorrect construction, and incorrect
inferences (Uesaka & Manalo, 2007). There is much research on the functions of diagrams and success students have when using diagrams to solve word problems, but Uesaka and Manalo focused on how to encourage students to create diagrams more often. Uesaka and Manalo suggested that diagrams be used not only for problem solving, but for tools of communication (2007). In this study an experimental group of students were encouraged to make a diagram and told they would have to explain their thinking to another student – the control group was told to solve the problem. The researchers found that students in the experimental group were more likely to create a diagram and choose a more appropriate diagram than those in the control group (2007). Uesaka and Manalo thought that explicit teaching of diagram use could help students understand the importance of diagrams in solving word problems. Although this article claims to show teaching methods for using diagrams, it merely says that the teacher needs to make a comment that students should create a diagram when they are about to solve a word problem. This also only applies to helping students create a diagram, but their evidence shows that students were still unable to continually produce correct diagrams or answers.

Crespo and Kyriakides (2007) discussed the concept of drawing to help students solve math problems. They start by saying that drawing is accessible to all students no matter their abilities. However, children may rely too much on drawing and draw a picture when that is not the best strategy to solve the problem (Crespo & Kyriakides, 2007). Because drawing a picture is emphasized most in elementary, Crespo and Kyriakides had students in grades one through four complete several story problems (2007). The authors found that many younger students were not able to correctly draw the problem, or got the wrong answer after correctly drawing it. Crespo and Kyriakides also
discussed the level of detail some students put into their drawings, including spots and tails for cows, while others had almost indecipherable drawings (2007). An issue with drawing a picture is that it can take away from the math problem and become the focus, like the students drawing detailed cows instead of a quick sketch to help them understand the problem. Crespo and Kyriakides found that across all four grades, more students got the correct answer with a less detailed drawing (2007). They also caution teachers when using picture drawing as a problem solving strategy because not all students will know how to draw the picture (up to forty-seven percent in one of their cases) (2007).

Jitendra (2002) made a case for graphic representations over diagrams. Graphic representations use shapes to help students find the proper placement for variables. A graphic representation focuses on the beginning, change, and end sets instead of the semantics of the word problem (Jitendra, 2002). The types of problems Jitendra uses are change, combine, and compare – the same as DeCorte and Verschaffel (1987). The problem may start with Luke having twelve Pokémon but he hatches three more. In this situation, the student uses graphic representation to locate the beginning and change set. “More” signals addition so the student can find the end. Jitendra claimed this strategy is especially helpful for students at-risk for math difficulties because they need to focus less on the words, but they will need to identify the operation eventually to find the end set. Jitendra made statements about how to set up the graphic representation for a problem based on whether the total is known or unknown (2002). This seems like it could still be confusing for students and has them rely on semantics. It also only works for addition or subtraction problems, leaving many problems unsolvable and possibly not translating to problems later in algebra.
**Animations.** Scheiter, Gerjets, and Schuh (2010) explored a different strategy to solve word problems: animations. For their study animations are considered frames that are altered to show change. Scheiter, Gerjets, and Schuh use the following description to focus their research:

>a conceptual understanding of a problem includes the construction of four interrelated representations, namely, ‘a text-base as a propositional representation of the textual input, a situational model as an elaborated qualitative representation of what the text is about, a mathematical problem model as the abstract gist of the situation, and an equation.’ (2010, p. 490)

Scheiter, Gerjets, and Schuh also referenced several other authors that have found it does not help to memorize step by step solutions when to comes to problem solving (2010). Previous research has also shown that worked-out examples are more effective than having students solve problems on their own.

In this paper Scheiter, Gerjets, and Schuh (2010) wanted to see if hybrid animations could increase student success with algebra based word problems. They defined hybrid animations as animations that start realistic but morph into more abstract problems and show the steps to the solution. For this study they had thirty-two high school students take part in a project day with new media. A pretest was given to get a baseline understanding of students’ problem solving skills (Scheiter, Gerjets, & Schuh, 2010). Students were asked to read nine worked-out examples from three contexts. Some students were given the problems as text only while others received them in the form of hybrid animations. Scheiter, Gerjets, and Schuh found that students who read the hybrid animations performed significantly better on the posttest. When it came to problems that
were similar or unrelated to the worked-out examples, students who had the animations got twenty-four to twenty-seven percent more correct, with a smaller standard deviation (Scheiter, Gerjets, & Schuh, 2010). While this shows that hybrid animations can help students become more successful with math word problems, Scheiter, Gerjets, and Schuh pointed out that it is unclear whether it was morphing from realistic to abstract or explicit mapping that helped students (2010). While this study gives another strategy for solving problems, it is uncertain if the animations themselves are responsible for increased success.

In terms of the present study, animations will not be used as a means to create more successful word problem solvers because they need to be made by the researcher in order to accomplish the stated task and nothing else. There are various math help websites that offer animations that could be used in some ways however.

**Computer instruction.** Besides hybrid animations of problems, computers can take the place of teachers and instruct students in strategies to solve word problems. In this study, Leh and Jitendra (2013) looked at the effectiveness of computer-mediated instruction in solving word problems, particularly for students with math difficulties. They found no statistical difference in the teacher-mediated instruction versus the computer-mediated instruction (Leh & Jitendra, 2013). It is worth noting that students in teacher-mediated instruction liked doing the word problems but became bored with instruction, while those in the computer-mediated instruction reported disliking the difficulty of the word problems but enjoyed the instruction (Leh & Jitendra, 2013). Based on the computer-mediated instruction and teacher-mediated instruction that Leh and
Jitendra implemented, there was no difference on student posttest scores, thus implying that quality of instruction is more important than environment (2013).

Lalingkar, Ramanathan, and Ramani (2015) tested computer assistance in solving word problems also. They developed a machine-readable program for surface area and volume. The program not only walked students through word problems, but took note of their errors and misconceptions (Lalingkar, Ramanathan, & Ramani, 2015). The authors found this program could be helpful to teachers for analyze student success with word problems. The program may help weaker students become better problem solvers and improve their beliefs on their mathematical abilities.

Comparing strategies. The current study is not concerned with teaching students on strategy, but rather on analyzing the effects of different strategies on student success with word problems. For that reason it is important to review Swanson and colleagues’ study comparing multiple strategies. Swanson et al. (2013) studied 120 elementary students with and without math difficulties in one of four categories: general-heuristic, visual-schematic, general-heuristic + visual-schematic, or control. The focus of this study was not on calculation, but word problem deficits (Swanson et al., 2013), as in the current study.

Each treatment group was taught twenty scripted lesson over the course of eight weeks with each thirty minute lesson administered three times a week in small groups (Swanson et al., 2013). Each lesson started with a warm-up and then went into direct instruction where a total of seven rules were presented throughout the treatment (Swanson et al., 2013). The lessons continued with guided practice and independent practice.
The general-heuristic strategy directed students to underline the question, circle the numbers, box the keywords, and cross out any extra information (Swanson et al., 2013). The visual-schematic strategy asked students to use two types of diagrams: parts making a whole and comparing quantities (Swanson et al., 2013). This is repeated in studies by DeCorté and Verschaffel (1987) as well as Jitendra (2002). It is important to note that all three times this strategy was used with elementary students and may not work as well on algebra problems. The general-heuristic + visual-schematic combined these two strategies. Students were given points based on correctly using the strategy and correctly solving the problem (Swanson et al., 2013).

This study found that students with math difficulties had the most growth in the visual-schematic group (Swanson et al., 2013). Students without math difficulties had the most growth in the general-heuristic group (Swanson et al., 2013). Focusing on text seemed to be more helpful for lower readers, although some children may have focused on the text so much that they did not engage in actual problem solving (Swanson et al., 2013). Overall, visual-schematic and general-heuristic + visual-schematic strategies saw the most success for both students with math difficulties and without. Although the visual-schematic strategy saw the most success for students, it was not effective during high-stakes silent reading problem solving tests (Swanson et al., 2013). There was improvement on norm-referenced tests (Swanson et al., 2013). Part of the reason the general-heuristic strategy could have been less successful for students with math difficulties is because of its high demand on executive working memory skills (Swanson et al., 2013). Recall that Swanson and Beebe-Frankenberger (2004) found better working
memory to lead to higher success with word problems because students can better process the question.

**Real-life basis.** McNeil, Uttal, Jarvin, and Sternberg (2009) – widely assumed that students perform better on real-life problems than traditional exercises. The authors examined the effects of using highly realistic concrete objects when students are working on word problems. Their first experiment showed students without the highly realistic concrete objects scored better on the test (McNeil, Uttal, Jarvin, & Sternberg, 2009). The second experiment tested to see if it was the objects that hindered test scores or the quality of the objects. They found again that students with highly realistic concrete objects scored worse than students with no objects or with bland objects (McNeil, Uttal, Jarvin, & Sternberg, 2009). There was little difference in scores for students with no objects and students with bland objects. However, students with highly realistic concrete objects made fewer conceptual errors than students in the other groups (McNeil, Uttal, Jarvin, & Sternberg, 2009).

Koedinger, Alibali, and Nathan (2008) also studied the effects of grounded and abstract representations. This study is based in part off of Koedinger and Nathan’s previous study (2004) where they found students had an easier time solving word problems than solving equations. This idea is different from many other studies that show students have a difficult time with word problems (Jitendra et al., 2015). Other researchers have found students have a difficult time figuring out which way to set up an equation with algebra word problems (Clement, 1982). Koedinger, Alibali, and Nathan suggest that for beginning algebra students there are more problems with solving equations versus solving word problems (2008). The authors worked with undergraduate
students to test their hypothesis that for simple algebra problems grounded representations would be more successful, but more complex problems are easier to solve in abstract form (2008). Koedinger, Alibali, and Nathan showed examples where students solved equations and story problems using the same equations (2008). For problems where students had to use an unknown once, their hypothesis held true. However, for problems where students had to use an unknown twice (such as a problem that gives the discount priced and the original price is unknown), students were unable to come up with correct word problem equations (Koedinger, Alibali, & Nathan, 2008). These second type of problems are considered by the authors to be more complex, but they are standard for high school algebra (Larson, Boswell, Kanold, & Stiff, 2004).

**Summary and Conclusion**

It is clear that a combination of using diagrams and underlining key words is effective for students with math difficulties (Swanson et al., 2013). One issue is that much of this research was conducted with lower elementary students (Crespo & Kyriakides, 2007; Jitendra, 2002) where drawing a diagram can be much easier. There may be times in algebra where drawing a diagram is not realistic or makes things more confusing. However, without instruction on how to use strategies to solve word problems, students do not show as much growth as students with or without math disabilities using any strategy.

There are many aspects that play into the difficulty students have with math word problems. The language of word problems seems to be the most reviewed issue with word problems. This also gives teachers difficulty because they are not trained specifically to teach word problems. Since there are clear difficulties with word problems
many strategies have been created to supposedly alleviate issues. The last section discussed the problem solving process, diagrams, and schema-based instruction as strategies to help students become more successful problems solvers. These are the strategies that will be used in the present study.

The next chapter will explain the methods of the study and participants. In order to answer the research question, this will include Attitude surveys, interviews, teacher-made tests, and standardized test scores. While there is a need to see which strategies help students become more successful, it is also important to understand student feelings about strategies and their own growth with solving word problems.
CHAPTER THREE

Methodology

Introduction

This study is designed to learn the effects different strategies have on student success with math word problems. Koedinger and Nathan (2004) noted that word problems are often seen as a difficult part of math for students. For this reason, I intend to teach my students several strategies to employ when attempting to solve word problems. I have seen students shut down when they approach a word problem and I want to help them become more confident.

This chapter will focus on the design of a lesson plan outline that engages students in different strategies to solve word problems. This lesson plan outline is focused on the question *What effect do different instructional strategies have on middle and high school student comprehension and success in solving math word problems?* So far I have shared my personal experience with mathematics and attempted to show the importance of understanding word problems. Chapter two was a literature review that outlined the use of word problems in and outside of the classroom (on standardized tests and in real-life) as well as various reasons why word problems may be difficult for students. From there chapter two discussed various strategies researchers have used in an attempt to help students become more successful math word problem solvers. Chapter three lays out the process being used to develop a curricular approach to engage students in using different word problem strategies. Along with my main research question, I am interested in the following questions as well: Are the difficulties in comprehension or computation? What
effect do different strategies for word problems have on student confidence in math? What effect do these strategies have on retention? In order to attempt to answer these questions I have identified participants and procedures, outlined a plan to teach students different problem solving strategies, and identified data to collect.

**Setting and Participants**

Students taking part in this unit are in Algebra 2 at a reservation school in Minnesota. This class of 12 is 100% Native American. All of these students receive free or reduced lunch. The class has four females and eight males. Three of the students have identified learning disabilities. The class period is one hour.

**Procedures**

I investigated different problem solving strategies that claim to help students become more successful and boost their confidence. In order to do this, I need to give explicit instruction in different strategies and talk with students to understand their feelings on word problems. Through my research it seems that some strategies are more researched than others (Crespo & Kyriakides, 2007; FDE, 2010; Jitendra, 2002; Jitendra, DiPiPi, & Perron-Jones, 2002; Jitendra, et al., 2015; Pennant, 2015; Xin, Jitendra, & Deatline-Buchman, 2005; Xin, et al., 2011; Zheng, et al., 2012). For this reason, I have focused on the problem solving process, schema-based instruction, and use of diagrams. The problem solving process teaches students steps to guide them through solving a word problem. For schema-broadening instruction, students are asked to think about a similar problem and use the solving of the similar problem to assist in solving the current problem. Diagrams are a visual that the student creates in order to better understand what the problem is asking and the approach needed to solve the problem.
**Baseline.** In order to measure the effects of the different strategies taught, I will need to know students’ skills with math word problems prior to intervention. I also want to learn about students’ feelings towards solving word problems before the intervention. In the unit plan, I have made time for a pre-test and post-test where students will solve word problems. A pre-and post-attitude survey for students to formally share their feelings towards word problems and the strategies they employ have been created.

**Intervention.** For this eleven day unit, students will learn how to use different strategies for word problems: problem solving process, schema-broadening instruction, and diagrams. Each strategy gets the same amount of time (three days). The strategy will rotate every day in order to keeps things fresh in students’ minds. The strategy will be the focus of class for one class period (sixty minutes). Students will receive explicit whole group instruction on using each strategy and will complete several problems as a class that uses the strategy. Whole group instruction will be followed by small group work solving problems using the given strategy. Students will then work individually on problems using the strategy of the lesson.

**Post-intervention.** After students have learned these three strategies for solving math word problems, I need to know their new skills and feelings regarding word problems. Students will complete a word problem post-test the week after the intervention to check on retention of skills. After the word problem test, students will also complete an attitude survey regarding feelings towards word problems and strategies learned. Strategies should be applied in daily practice with word problems related to each lesson to ensure continued retention.
Data Collection

Attitude surveys. Students will complete an attitude survey to get an idea of starting feelings and strategies used (see Appendix A). It includes statements about student confidence in math computation and student confidence in math word problems, as well as statements to see if students already employ the strategies to be taught. Students will complete another attitude survey at the end of the intervention and some complete a short interview with me for more details on their feelings.

Teacher made tests. I will give a pretest that is grade/subject appropriate using questions from the textbook (see Appendix B). For this pretest, I will assign points based on correctly identifying a strategy to solve the problem and setting up the problem correctly. I will also look at the correctness of the answer based on chosen strategy, including correct computation for my study but not for student grades. For example, a student may correctly identify a problem as a two-step equation with multiplication and addition and properly place all given numbers, but fail to subtract correctly. This student will be given full points.

The week after the intervention has been completed, students will take a final test where they use whichever strategy they prefer. I will analyze these tests based on correctness of strategy and correct computation again. I will assign points for correctness of answer and correctness of strategy for each test. I will then have to find a mean and standard deviation for each test.

Unit Plan

This unit plan is designed for a high school algebra course. The reason behind using high school algebra is that it can incorporate essential algebra ideas as well as
advanced geometry concepts. In this way, future researchers may have more ideas for applying the strategies to their own classrooms.

**Minnesota math standards.** In order to help students’ better understand how the chosen word problem strategies can be applied, problems have been chosen that align to high school math standards for Minnesota. The following are the standards addressed in the practice problems in the unit (Minnesota Department of Education, 2007).

9.2.2.1 Represent and solve problems in various contexts using linear and quadratic functions.

9.2.2.5 Recognize and solve problems that can be modeled using finite geometric sequences and series, such as home mortgage and other compound interest examples. Know how to use spreadsheets and calculators to explore geometric sequences and series in various contexts.

9.2.4.2 Represent relationships in various contexts using equations involving exponential functions; solve these equations graphically or numerically. Know how to use calculators, graphing utilities or other technology to solve these equations.

9.2.4.3 Recognize that to solve certain equations, number systems need to be extended from whole numbers to integers, from integers to rational numbers, from rational numbers to real numbers, and from real numbers to complex numbers. In particular, non-real complex numbers are needed to solve some quadratic equations with real coefficients.
9.2.4.4 Represent relationships in various contexts using systems of linear inequalities; solve them graphically. Indicate which parts of the boundary are included in and excluded from the solution set using solid and dotted lines.

9.2.4.8 Assess the reasonableness of a solution in its given context and compare the solution to appropriate graphical or numerical estimates; interpret a solution in the original context.

9.3.1.5 Make reasonable estimates and judgments about the accuracy of values resulting from calculations involving measurements.

9.3.4.7 Use algebra to solve geometric problems unrelated to coordinate geometry, such as solving for an unknown length in a figure involving similar triangles, or using the Pythagorean Theorem to obtain a quadratic equation for a length in a geometric figure.

9.4.3.1 Select and apply counting procedures, such as the multiplication and addition principles and tree diagrams, to determine the size of a sample space (the number of possible outcomes) and to calculate probabilities.

9.4.3.8 Apply probability concepts to real-world situations to make informed decisions.

Unit goals. This section outlines the goals for the unit. Each day students will work towards these goals through a variety of activities and problems. There are also clues the teacher can use to assess student progress toward the goals.

- Warm-ups:
  - Students talk through how they would solve a word problem
- Students use and explain a strategy on how to solve a word problem

- Instructional tasks:
  - To introduce formal strategies for solving word problems
  - To develop an understanding of different problem solving strategies
  - To recognize if an answer is reasonable for the problem

- Small group and/or independent practice and homework:
  - To translate problem solving strategies to new problems
  - To build fluency in using problem solving strategies

Assessment:

- What to look for:
  - Can the student follow the steps of a strategy to reach an answer?
  - Can the student explain their thinking as they process the steps for solving a word problem?
  - Is the student able to apply a strategy to a new word problem?
  - How does the student reflect in comparing one strategy to another?

- Indication of need for additional support:
  - Limited ability to follow steps of a strategy to solve word problems
  - Limited ability to explain thinking through steps of a word problem using a strategy
  - Limited capacity to apply a strategy to a new word problem
- Limited capacity to reflect and compare/contrast the usefulness of different strategies to solve word problems

**Unit Description**

**Pre-assessment.** This unit starts with a pre-assessment. It includes both a pre-test on current word problem solving strategies and skills, as well as a student attitude survey on feelings towards solving word problems.

**Rotation 1.** The first three days of the unit are spent introducing each of the three chosen strategies. Class starts with displaying the new strategy for students and reading through the strategy together. Students use the new strategy to work together (with teacher assistance as necessary) to solve a word problem. In pairs, students discuss how the strategy helps them solve a problem and the confusions they still have. As a group, students solve another problem using the new strategy and reflect on its use. Next, students work independently to solve a word problem using the day’s strategy. When they are done, students work in pairs to discuss the benefits and confusions of the strategy. During this time, the teacher listens for limited capacity to use the strategy and decides if more practice together is necessary. The class may regroup to solve two more problems together to help students that are struggling. Class ends with students receiving an assignment of word problems.

**Rotation 2.** The following three days review the chosen strategies and work more with one each day. Class starts with a warm-up problem using the previous day’s strategy. The whole group then reviews the strategy and works together to solve two word problems using this strategy. In pairs, students discuss pros and cons of the strategy
and how other strategies may apply. Students finish the class period with a homework assignment of word problems.

**Rotation 3.** The following three days review the chosen strategies and work more with one each day. Class starts with a warm-up problem using the previous day’s strategy. The whole group then reviews the strategy and works together to solve two word problems using this strategy. In pairs, students discuss pros and cons of the strategy and how other strategies may apply. Students finish the class period with a homework assignment of word problems.

**Post-assessment.** On the last day of the unit, students will complete a post-assessment that consists of a post-test solving word problems using the taught strategies and a student attitude survey on the strategies.

**Lesson Outline**

<table>
<thead>
<tr>
<th>Day 1</th>
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<tbody>
<tr>
<td><strong>Warm-up:</strong> students show how to solve a word problem</td>
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</tbody>
</table>
| Instructional tasks: *independent* – complete attitude survey on solving word problems, pretest of word problem skills  
*public sharing* – share feelings on solving word problems and steps/ideas students use to work on word problems |
| Homework: none |

<table>
<thead>
<tr>
<th>Day 2</th>
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<tbody>
<tr>
<td>Standards addressed – 9.2.2.1, 9.2.2.5, 9.3.1.5, 9.3.4.7, 9.4.3.1, 9.4.3.8</td>
</tr>
<tr>
<td><strong>Warm-up:</strong> students share ideas for steps to approach solving a word problem</td>
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</tbody>
</table>
| Instructional tasks:  
*whole group* – introduce problem solving process, work together to solve word problems using problem solving process  
*independent* – use new strategy to solve a word problem  
*small group* – think-pair-share on how using the problem solving process helped/confused students while solving word problem  
*whole group* – use comments from think-pair-share to complete a few more problems |
<p>| Homework: word problems |</p>
<table>
<thead>
<tr>
<th>Day 3</th>
<th>Standards addressed – 9.2.2.1, 9.2.4.2, 9.3.1.5, 9.3.4.7, 9.4.3.1, 9.4.3.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-up: students show how to solve a word problem using their ideas from previous day</td>
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<tr>
<td>Instructional tasks:</td>
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<tr>
<td>whole group – introduce schema-broadening instruction, work together to solve word problems using schema-based instruction</td>
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<tr>
<td>independent – use new strategy to solve a word problem</td>
<td></td>
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<tr>
<td>small group – think-pair-share on how using schema-broadening instruction helped/confused students while solving word problem</td>
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<tr>
<td>whole group – use comments from think-pair-share to complete a few more problems</td>
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<tr>
<td>Homework: word problems</td>
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<tr>
<th>Day 4</th>
<th>Standards addressed – 9.2.2.1, 9.2.4.2, 9.2.4.4, 9.4.3.1, 9.4.3.8</th>
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<tbody>
<tr>
<td>Warm-up: students show how to solve a word problem using their ideas from previous day</td>
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<tr>
<td>Instructional tasks:</td>
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<tr>
<td>whole group – introduce using diagrams, work together to solve word problems using diagrams</td>
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<tr>
<td>independent – use new strategy to solve a word problem</td>
<td></td>
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<tr>
<td>small group – think-pair-share on how using diagrams helped/confused students while solving word problem</td>
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<tr>
<td>whole group – use comments from think-pair-share to complete a few more problems</td>
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<tr>
<td>Homework: word problems</td>
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<tr>
<th>Day 5</th>
<th>Standards addressed – 9.2.4.4, 9.3.1.1, 9.3.1.5, 9.3.4.7</th>
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<tbody>
<tr>
<td>Warm-up: review problem solving process, independently solve a word problem using the problem solving process</td>
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<tr>
<td>Instructional tasks:</td>
<td></td>
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<tr>
<td>whole group – solve several problems using problem solving process, listen for confusion on steps or limited ability to complete steps</td>
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<tr>
<td>Homework: word problems</td>
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<tr>
<th>Day 6</th>
<th>Standards addressed – 9.2.2.1, 9.2.2.5, 9.2.4.1, 9.2.4.4</th>
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<tbody>
<tr>
<td>Warm-up: review schema-broadening instruction, independently solve a word problem using schema-broadening instruction</td>
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<tr>
<td>Instructional tasks:</td>
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<tr>
<td>whole group – solve several problems using schema-broadening instruction, listen for confusion on steps or limited ability to explain process</td>
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<tr>
<td>Homework: word problems</td>
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<tr>
<td>Day 7</td>
<td>Standards addressed – 9.2.2.1, 9.2.4.4</td>
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<tr>
<td></td>
<td>Instructional tasks:</td>
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<td></td>
<td>Homework: word problems</td>
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<tr>
<th>Day 8</th>
<th>Standards addressed – 9.2.2.1, 9.2.2.5, 9.2.4.1, 9.2.4.4</th>
<th>Warm-up: review problem solving process, independently solve a word problem using the problem solving process</th>
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<tbody>
<tr>
<td></td>
<td>Instructional tasks:</td>
<td>whole group – solve several problems using problem solving process, listen for confusion on steps or limited ability to complete steps</td>
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<td></td>
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<th>Day 9</th>
<th>Standards addressed – 9.2.2.1, 9.2.4.3, 9.2.4.4, 9.2.4.8, 9.4.3.1, 9.4.3.8</th>
<th>Warm-up: review schema-broadening instruction, independently solve a word problem using schema-based instruction</th>
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<tbody>
<tr>
<td></td>
<td>Instructional tasks:</td>
<td>whole group – solve several problems using schema-broadening instruction, listen for confusion on steps or limited ability to explain process</td>
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<td>Homework: word problems</td>
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<tr>
<th>Day 10</th>
<th>Standards addressed – 9.2.2.5, 9.2.4.2, 9.2.4.8, 9.3.1.5, 9.3.4.7, 9.4.3.1, 9.4.3.8</th>
<th>Warm-up: review using diagrams, independently solve a word problem using diagrams</th>
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<tbody>
<tr>
<td></td>
<td>Instructional tasks:</td>
<td>whole group – solve several problems using diagrams, listen for confusion on steps or limited ability to explain process</td>
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<tr>
<td></td>
<td>Homework: word problems</td>
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<tr>
<th>Day 11</th>
<th>Warm-up: none</th>
<th>Instructional tasks:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Independent - post-test on word problems and attitude survey</td>
<td>Public sharing - feelings on word problems now and strategy preferences</td>
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<tr>
<td></td>
<td>Homework: none</td>
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Summary

This chapter describes the unit plan for teaching the problem solving process, schema-broadening instruction, and using diagrams to solve word problems. To analyze effectiveness of this unit, a pre-test on word problems precedes lessons. Student attitudes will also be collected prior to lessons to gauge change. Since the focus of this study is not solely on student test scores but on attitudes as well, students will be asked to formally explain their feelings towards math word problems at the beginning and end of the study. Students also reflect on the strategies in think-pair-share activities. Each strategy is presented for three days, rotating strategies daily for continued comprehension. A post-test and final attitude survey complete the unit, though strategies will be utilized in daily problem solving practice. Chapter four discusses in depth the daily lesson plans for this unit.
CHAPTER 4

Lesson Plans

Introduction

This chapter will focus on the daily of a lesson plans of the unit outline from the previous chapter. Each lesson aims to engage students in different strategies to solve word problems. This lesson plan is focused on the question What effect do different instructional strategies have on middle and high school student comprehension and success in solving math word problems? In chapter one, I shared the story of a student that excels in math computation, but sometimes struggles with understanding word problems. This student's struggles are similar to what I see daily in the classroom, and that is why I want to explore strategies to help students become more successful when solving word problems. Chapter two was a literature review that outlined the use of word problems in and outside of the classroom (on standardized tests and in real-life) as well as various reasons why word problems may be difficult for students. From there, chapter two discussed various strategies researchers have used in an attempt to help students become more successful math word problem solvers. Chapter three developed a unit plan to enable students to engage more deeply with strategies to solve word problems. Along with my main research question, I am interested in the following questions as well: Are the difficulties in comprehension or computation? What effect do different strategies for word problems have on student confidence in math? What effect do these strategies have on retention? These questions may be answered in the detailed lessons of chapter four.
The lessons in chapter four outline a structure meant to allow students to practice different strategies and reflect on helpfulness of said strategies.

While teaching the lessons, remind students that these strategies are not the only way to solve word problems and they should not feel limited to these strategies. The idea of this unit is to teach students three different approaches to solving word problems in hopes they become more confident and success. Students should know that they may not have all the same steps for solving the problems, and that is okay. For schema-broadening problem solving and using diagrams, it is likely students will come up with very different ideas to solve the problem. Students should have time to discuss these ideas in a think-pair-share activity on the first day of instruction. This may help them see there are many ways to find an answer even though we are focusing on a specific strategy.

**Day 1**

The lesson will start with students completing a word problem that is displayed on the board. Students will be asked to do their best and show all their work. An example of a word problem for this grade level would be: “You are on a boat in the Mississippi River. The boat’s speed is 20 miles per hour. You want to travel the entire 2,320 miles of the Mississippi River. How long will it take you, in days?” Allow students five minutes to read through and work on the problem. After the five minutes is up inform students that a unit on solving word problems will now begin. The reason for them solving this word problem was to help them think more about their feelings towards word problems. At this point, the teacher should hand out the initial attitude survey (see Appendix A) for students to complete individually. Once all students are done with the survey, have students get into small groups to talk about their feelings towards solving word problems.
Listen for students to mention confusion on wording or steps to solve problems. Also listen for students to mention not knowing how to approach a word problem or being unable to figure out the relevant information. After several minutes of discussion, ask students to return to their seats for an individual word problem pretest. Students will take a pretest (see Appendix B) to see what strategies they already employ to solve word problems and will not be graded on correctness of answers but on the work they do to get to an answer. When all students are done with the pretest and tests are collected students will be asked to share ideas they used to solve the word problems – hopefully students will mention things similar to the chosen strategies so they have something to build on.

Day 2 – Begin Rotation 1

For the problem solving process, I will use the steps described by Pennant (2015): get started, work on the problem, generalize, and communicate. Prior to teaching students the steps, I will create a poster that will be displayed in my room. As a warm-up, I will ask students to share ideas as a whole group to approach solving a word problem. Listen for students to mention steps and important words in the problem. While students mention ideas, I will record them on the SmartBoard. After students appear to have mentioned all their ideas on steps to solving word problems, I will display the poster at the front of the room and let students know that this will be our reference when solving word problems using the problem solving process. The class will read through the steps and pick out points where it aligns with the steps they mentioned. Using the presented steps and students’ current understanding of how to use these steps to work through a word problem together. As an example problem, I could use: “The men’s U.S. Open tennis tournament is held annually in Flushing Meadow in New York City. In the first
round of the tournament, 64 matches are played. In each successive round, the number of matches played decreases by one half. Find the total number of matches played in the men’s U.S. Open tennis tournament.”

Let students know that showing all their work will be critical for getting full points and fully understanding problem solving. For that reason, I will write our discussion on the SmartBoard and students should record it in their notebooks as well. This will allow all of us to look back at previously solved problems if we get confused.

The first step in problem solving process says to get started. Part of getting started for this problem may involve discussing how tournaments work and what a tennis match is. Students may have an understanding of tournaments from sports or quiz bowl involvement. Listen for students to say that each round of a tournament has only the winners of the previous round. Once this is mentioned, I will make note of there being 64 matches and that each round has only half the matches of the previous round. The tournament would end with a final match (1). Ask students what they would do next using the problem solving process. Listen for students to begin to list a pattern for number of matches in each round of the tournament. Let students know this means we have found a pattern and am ready to work on the problem – step 2 of the problem solving process. Ask students what they think needs to be done in this step. Listen for students to say they need to find half of 64. Students should then be able to continue the pattern quickly and find that 64 divided by 2 is 32. The next round would have half of 32 for matches, which is 16. Following this pattern I get 8, 4, 2, and 1. Before students move on, remind them they are using the steps of the problem solving process to help them complete the problem. Looking at those steps, the class has reached step 3 - generalize
the problem. Ask students to look back at the problem for an idea of what to do next. Listen for students to say the question asked for the total number of matches. Students should then be able to say they need to add up all the matches, including the first round. I would then write the equation $64 + 32 + 16 + 8 + 4 + 2 + 1 = 127$. The final step in the problem solving process is to communicate. Ask students what it is we need to communicate to solve this problem. Listen for students to say the problem needs a label and what the label should be. I would then write “There are 127 total matches in the U.S. Open tennis tournament.” Have students get into pairs to discuss how this process is similar/different from what they would normally do, how this process helped them solve the problem better, and the points where they are still experiencing confusion. Regroup and ask students to share their ideas. I will write ideas on the SmartBoard so we can check our progress as we continue to practice the problem solving process.

For the next problem, the teacher should try to let students lead the problem solving process as much as possible. It is important to remind students to look at the poster steps if they get confused so they have a plan to follow. “You are helping to create a new community garden and have 480 feet of fencing to enclose it. You want the length of the garden to be 30 feet greater than the width. Find the length of width of the garden if you use all of the fencing.” While solving the problem, the teacher will need to write down all of their steps on the SmartBoard to ensure students know what it means for them to show all their work. Students also need to be reminded they are expected to copy it into their notebooks. The teacher should listen for students to use the specific steps from the problem solving process to order their thinking.
Listen for students to use the phrase “get started.” Ask students what get started means for this problem. Listen for students to identify you have 480 feet of fence and need to make the length 30 feet longer than the width. Ask students if there is more information that would help with the problem. Listen for students to mention that it is a rectangle. Ask students why the shape is important for the problem and if any other shapes are possible. Listen for students to say that opposite sides are equal and we need the length and the width to be the sides of the garden. Ask students what is next and listen for “work on the problem.” When students begin to give ideas for how to work the problem, it may be necessary to remind them this is an algebra class and there are algebra skills that may make this problem easier. Listen for students to say that one side would be $x$ and the other would be $x + 30$. They may also say that one side is $l$ and the other is $w$. If this is the case, ask students how $l$ and $w$ are related and create an equation like the one mentioned previously.

Since it has already been mentioned, students should recall that there are two of each side to make a rectangular garden. Ask students what to do with this information and ask for a volunteer to write an equation: $x + (x + 30) + x + (x + 30) = 480$. I would then say that this problem looks a little long and ask for ideas to make it more concise. Have a student rewrite the equation as: $4x + 60 = 480$. Ask students what the next step would be – while this should hint towards the generalize step of the process, students may jump to solving without realizing they have moved to generalization. When students say to subtract 60, clarify if it is just from one side or both. Subtract 60 from both sides and have students rewrite the new equation to say $4x = 420$. It is likely students will go right into dividing at this point since this is meant for an Algebra 2 class. Once students find
the number 105, ask if the problem is done. Students will likely start to label the answer, but the teacher may need to remind students to look at the final step of the problem solving process. For this problem, students need to remember that we are looking for $x$ and $x + 30$. Students should then come up with 105 feet as the width and 135 feet as the length. After this problem has been solved, return to the slide with student observations from the first problem. Ask students what their thoughts are now that they have completed a second problem.

I would next tell students that they will be working independently for a few minutes to solve a word problem using the problem solving process. The following word problem is one that could be put on the board for students to solve: “A spinner can land on either red, blue, or green. You spin twice. Find the number of possible outcomes.”

After students have a few minutes to work on the problem, have they form groups to think-pair-share on their steps to solve the problem and if they found the problem solving process helpful. Have students share with the group the pros and cons of the problem solving process so far. If students are still showing confusion or frustration with the problem solving process, complete two more problems together. In order to allow students to see a variety of different types of problems that can be solved using the problem solving process, here is another example to use: “Before unlimited minutes, you had to pay for every minute used on your phone and a monthly service fee. Suppose a company charges $.09 per minute and the service fee is $5. Your bill shows you owe $27.23 for one month. Find how many minutes you used on your phone.” After the problem is complete, assign students a handful of word problems for homework.
However these problems are assigned, make sure there is plenty of space for students to show all their work. Remind students they will be graded on showing their work.

**Day 3**

To start off the day, students will be asked to do an individual warm-up word problem using the problem solving process from the previous lesson. An example problem could be: “You have decided you need a bigger TV for playing video games and an ultra high definition TV is on sale for $2,100. You can make no interest monthly payments for one year if you make a down payment of $300 today. What will your monthly bills be if you pay off the entire TV in one year?”

Schema-broadening is defined as understanding the schema used when changes in cover story, vocabulary, and question occur, as well as including extra information or combining problems (Fuchs et al., 2006). Prior to presenting schema-broadening problem solving, I will create a poster (see Appendix D) that asks students to read through the problem and think if there is a similar problem that they know how to solve. It will then ask students to solve the similar problem and apply that plan to the current problem. For the first problem, I think it would be beneficial to use a problem similar to one from the previous day so students have a common similar problem to compare. I would inform students that we will work together to use schema-broadening problem solving for the first problem. I will record all ideas and steps for the problem on the SmartBoard and remind students they will need to do the same in their notebooks.

A good idea for a question to use would be: “A triangle has a perimeter of 50 units. If two of its sides are equal and the third side is 5 more than the equal sides, what is the length of the third side?” After reading the problem, ask students if it reminds them of
a problem they have already seen. Listen for students to say that it reminds them of the
garden problem from the previous day. Have students refer to their notes when they
solved the garden problem to come up with an idea for the current problem. Listen for
students to mention the steps they used to get an equation for the garden perimeter. Ask
students how this can be applied to the triangle problem. Listen for students to say two
sides are equal and ask to write $x + x$. Listen for students to say that the third side would
be $x + 5$. Ask students what should be done with this information. Listen for students to
form an equation with the perimeter total: $x + x + (x + 5) = 50$. Listen for students to
simplify and begin to use the order of operations to solve the problem. If students think
they are done when they have $x = 15$, reread the problem. Ask what the 15 means and
what needs to be done to answer the problem. Listen for students to say 15 is the length
of the two equal sides and the third side must be 20 since it is 5 units longer.

When the problem is finished, have students get into pairs and discussion schema-
broadening problem solving. This discussion should cover how/if students have used
schema-broadening on their own before, how schema-broadening helped students
understand the problem better, and where students are still experiencing confusion. Have
the class regroup and share their ideas. Make sure to write all of these ideas on the
SmartBoard so students can refer to them later in class.

For the next problem, I would ask students to walk me through how to solve the
problem and I will write down all their thinking. An example could be: “You make a plan
to save $20 a week from work in order to buy a new phone that is $700. About how many
months will it take you to save enough money for the phone?” Listen for students to say
this is a division problem and let them know that sometimes problems are straightforward
and easy to connect to other problems. It is important to point out the labels at the beginning of this problem because they are not the same and change the answer. Listen for students to estimate the number of weeks in a month. Make sure to write down those ideas so students see that schema-broadening problem solving involves working on two problems to find an answer. Return to student comments on schema-broadening instruction and revisit their ideas now that they have practiced more. At this point, students should also compare and contrast schema-broadening with the problem solving process.

Tell students they will have several minutes to work on the next problem independently. Put the following problem on the board: “Eight rooms in a house need to be painted. Each room can be painted white or yellow. Find the number of possible outcomes.” If students are struggling to get started, mention that it sounds like flipping a coin a few times and it may be helpful to make a list of the outcomes. It may be necessary to do this together if multiple students are struggling. After students have completed the problem, have them pair up to do another think-pair-share. This time the teacher should pay attention to the similar problems students used to find their answer and see if those problems helped them reach a reasonable answer.

If students are still experiencing some confusion on how to use a similar problem to solve the current problem, work through another problem as a group. As before, it may help to use a problem similar to the previous lesson so students have a common basis to start the problem. Here is an example: “For biology, your class is studying a certain bacteria that doubles every 4 hours. If you started with 2 cells of the bacteria, how many
will there be after 2 days?” Assign homework word problems and remind students they will need to show their work to get full points.

**Day 4**

Students will start class by completing an independent warm-up word problem using schema-broadening problem solving. The following problem can be put on the board for students to solve: “You are working on a project in woodshop. You have a wooden rod that is 72 inches long. You need to cut the rod so that one piece is 6 inches longer than the other piece. How long should each piece be?”

Prior to instruction on using diagrams to solve word problems I will create a poster (see Appendix E) that asks students to read through the problem and make a diagram that can help them solve the problem. The poster will say that this diagram could be as simple as boxes for numbers and variables or could involve simple drawings from the problem. The poster will remind students not to draw too detailed of a diagram because it can take away from their thinking in solving the problem.

Here is one example of a problem to use a diagram for: “A new pizza place has opened next to the school! They have a lunch special where you can buy a large pizza with cheese, one vegetable, and one meat for $9.00. You have a choice of 3 cheeses, 6 vegetables, and 5 meats. How many different variations of the pizza are possible?” When students begin giving ideas for diagrams, refer to the poster on level of detail. It may be helpful to suggest a single letter stand for each option. While students are listing ideas, be sure to write them on the SmartBoard and have students copy ideas into their notebooks. Students may be able to figure out the answer without completing the pattern; these students should explain their thinking for the class so everyone can record it. At this point
I would mention that different people might make different diagrams. Ask students if they have any ideas for different diagrams I could have used for this problem. Have students form pairs and discuss how they have used diagrams before, how diagrams help them understand problems better, and their confusions around using diagrams. Regroup and record ideas on the SmartBoard.

For the next problem, I will display this on the board: “The school is planning a field trip of biking and roller skating. Not including time for transportation, there will only be 5 hours to do these activities. Bicycles can be rented for $8 per hour and roller skates can be rented for $6 per hour. The total budget per person is $34. How many hours should students spend doing each activity?” Let students know that it is okay to solve a problem in a way that does not use formal algebra language because sometimes it is easier to think about it that way. Ask students for ideas to get started. If they are struggling, let them know it might be easier to think in terms of groups. Students will hopefully want to write groups of 8s and 6s to try to equal 34. This should lead to an answer of 2 hours of bicycling and 3 hours of roller skating fairly quickly. Using the answer students found, help them write a system of equations they could have used to solve the problem. Since they knew it had to add up to 5, you can $x + y = 5$. Using the diagram, you can also write $8x + 6y = 34$. While this is not the point of this lesson, it may come in handy for future problems when students are struggling with other strategies. Ask students to compare this diagram problem to the previous one and how they could have used one of the other chosen strategies to solve this problem. Return to the ideas students had about using diagrams and ask what more they can add/change.
Have students complete an independent word problem for a few minutes. “Domestic bees make their honeycomb by starting with a single hexagonal cell, then forming ring after ring of hexagonal cells around the initial cell. What is the total number of cells in a honeycomb after the 9th ring is formed?” Once students have finished the problem, have them get into pairs for a think-pair-share activity. Let students know they should talk about the pros and cons of using diagrams to solve word problems. When students begin to share as a group, listen for the types of diagrams used and their complexity, confusion about how to draw a diagram, and benefits of diagrams for certain problems. Ask students to compare and contrast the use of diagrams to the problem solving process and schema-broadening problem solving.

Based on student discussion from think-pair-share, it may be necessary to complete another problem together using diagrams. Here is an idea for a problem: “You pay $38.50 for a sweatshirt that is marked 30% off the regular price. What is the regular price of the sweatshirt? How much did you save by buying it on sale?” After this problem is complete, students should be given a handful of problems for a homework assignment. Students should be given enough space to draw several diagrams for each problem and should be reminded that the diagrams are what will be graded.

**Day 5 – Begin Rotation 2**

Before starting the independent warm-up problem, review the problem solving process poster as a whole group. After reading aloud each part, place a word problem on the board. “The student council decided to sell sweatshirts and t-shirts to raise money for field trips. Student council charges $35 per sweatshirt and $15 per t-shirt. After one week
of sales, student council now has $5,500. Find three possible combinations of sweatshirts and t-shirts sold.”

After students have had several minutes to work independently on the warm-up problem, work as a whole group to solve two problems in order to further review the problem solving process. While completing the problems, listen for students to say the specific steps of the problem solving process. Some possible problems to use are: “A candy factory needs a box that has a volume of 30 cubic inches. The width should be 2 inches less than the height and the length should be 5 inches greater than the height. What should the dimensions of the box be?” and “You are helping an elder plant a garden on the side of their house. To keep animals out, you will enclose the garden with wire mesh along its three open sides. You will also cover the garden with mulch. If you have 50 feet of wire mesh and enough mulch to cover 100 square feet, what should the garden’s dimensions be?” Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if schema-broadening or diagrams were useful to them for these two problems. Listen for students to make connections between strategies and the possibility of combining strategies.

Students should then have time to work on their homework assignment of word problems using the problem solving process. Remind students again that in order to get a good grade on the assignment they must show all their work.

**Day 6**

Before starting the independent warm-up problem, review the schema-broadening problem solving poster as a whole group. After reading aloud each part, place a word
problem on the board. “The school has decided to host a basketball game of guardians versus students to raise money for new basketball uniforms. Adults pay $4.00 to watch the game and students pay $2.50. At the end of the game the total from tickets is $500. Find three possible combinations of adults and students that attended the game.”

After students have had several minutes to work independently on the warm-up problem, work as a whole group to solve two problems in order to further review schema-broadening problem solving. While completing the problems, listen for students to give similar problems that fit the current problem and the process used to solve the similar problem. Some possible problems to use are: “The half-life of Hydra’s blood is 71 days. How long would it take for 10 oz of it to be reduced to 2 oz?” and “Sophie is 27 and Marina is 11. How many years ago was Sophie three times as old as Marina?” Students may not know what the Hydra is and want to know more. Take time to show students a picture and explain the story of Hercules and the Hydra (cut off one head and two regrow) so students do not get distracted by their curiosity. Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if the problem solving process or diagrams were useful to them for these two problems. Listen for students to make connections between strategies and possibility of combining strategies.

Students should then have time to work on their homework assignment of word problems using the problem solving process. Remind students again that in order to get a good grade on the assignment they must show all their work.
Day 7

Before starting the independent warm-up problem, review the using diagrams poster as a whole group. After reading aloud each part, place a word problem on the board: “A caterer is planning a party for 64 people. The customer has $150 to spend. A $39 pan of pasta feeds 14 people and a $12 sandwich tray feeds 6 people. How many pans of pasta and how many sandwich trays should the caterer make?”

After students have had several minutes to work independently on the warm-up problem, work as a whole group to solve two problems in order to further review using diagrams. While completing the problems, listen for students to explain their chosen diagrams. Some possible problems to use are: “The Chunnel connects the United Kingdom and France by a railway tunnel under the English Channel. The British started tunneling 2.5 months before the French and averaged 0.63 kilometer per month. The French averaged 0.47 kilometer per month. When the two sides met, they had tunneled 37.9 kilometers. How many kilometers of tunnel did each country build?” and “The top of the Leaning Tower of Pisa is about 55.9 meters above the ground. As of 1997, its top was leaning about 5.2 meters off-center. Approximate the slope of the tower.” Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if the problem solving process or schema-broadening were useful to them for these two problems. Listen for students to make connections between strategies and possibility of combining strategies.
Students should then have time to work on their homework assignment of word problems using the problem solving process. Remind students again that in order to get a good grade on the assignment they must show all their work.

**Day 8 – Begin Rotation 3**

Before starting the independent warm-up problem, review the problem solving process poster as a whole group. After reading aloud each part, place a word problem on the board. Here is an example: “The half-life of a foul smelling substance is 4 years. If you have 8 ounces of this strange substance today, how much of it will you have after 20 years?” The teacher may need to explain what a half-life is and relate it to the tennis tournament problem students have in their notebooks. Since students have worked with the problem solving process in two previous lessons, they should need minimal review. As a whole group, use the problem solving process to solve two word problems together. Some examples may be: “You maintain a music-oriented website that allows subscribing customers to download audio and video clips of their favorite bands. When the subscription price is $16 per year, you get 30,000 subscribers. For each $1 increase in price you expect to lose 1000 subscribers. How much should you charge to maximize your annual revenue? What is your maximum revenue?” and “A theater has 20 seats in the first row, and each row after the first has one more seat than the row before it. How many seats are there if the theater has 16 rows?” Listen for students to say specific steps for the problem solving process. Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if schema-broadening or diagrams were useful to
them for these two problems. Listen for students to make connections between strategies and possibility of combining strategies.

Students should then have time to work on their homework assignment of word problems using the problem solving process. Remind students again that in order to get a good grade on the assignment they must show all their work.

Day 9

Before starting the independent warm-up problem, review the schema-broadening problem solving poster as a whole group. After reading aloud each part, place a word problem on the board. An example: “Castel and Gabriella are selling pies for a school fundraiser. Customers can buy apple pies and lemon meringue pies. Castel sold 6 apple pies and 4 lemon meringue pies for a total of $80. Gabriella sold 6 apple pies and 5 lemon meringue pies for a total of $94. What is the cost each of one apple pie and one lemon meringue pie?” As a whole group, work out two problems together using schema-broadening problem solving. Two examples could be: “You need to restock the iced tea at work today. There are 8 different types of iced tea your store offers. How many ways can the different types of iced tea be ordered in the cooler?” and “Your family is planning a 7 day trip to Florida. You estimate that it will cost $275 per day in Tampa and $400 per day in Orlando. Your total budget for the 7 days is $2,300. How many days should you spend in each location?” Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if the problem solving process or diagrams were useful to them for these two problems. Listen for students to make connections between strategies and possibility of combining strategies.
Students should then have time to work on their homework assignment of word problems using schema-broadening problem solving. Remind students again that in order to get a good grade on the assignment they must show all their work.

**Day 10**

Before starting the independent warm-up problem, review the using diagrams poster as a whole group. After reading aloud each part, place a word problem on the board. Here is an example: “The population of mice living in a certain restaurant in Paris triples every 7 months. If there are currently 98 mice living in the restaurant, how many will there be 2 years from now?” As a whole group, solve two problems together using diagrams. Some ideas are: “A standard Minnesota license plate has 3 numbers followed by 3 letters. How many different license plates are possible if numbers and letters can be repeated?” and “You have 240 feet of wooden fencing to form two adjacent rectangular dog runs. You want each dog run to have an area of 1,000 square feet. Find possible dimensions for the dog runs.” Once the two problems are solved, students should get into pairs to talk about how/if the problem solving process makes problems easier to solve, where their confusions lie, and if the problem solving process or schema-broadening were useful to them for these two problems. Listen for students to make connections between strategies and possibility of combining strategies.

Students should then have time to work on their homework assignment of word problems using the problem solving process. Remind students again that in order to get a good grade on the assignment they must show all their work.
Day 11

Inform students it is now the last day of this specific unit, though the skills will be helpful for a long time to come. In order to properly assess students’ use of strategies and increase in success with solving word problems, they will complete a posttest (see Appendix B). Students will be graded on correctness of answers and correct application of strategies used. When a student finishes the posttest, they should be given a final attitude survey (see Appendix A) on their feelings towards word problems now that they have studied word problems more closely. When all students are done with their posttest and survey, they should form small groups to further discuss about their feelings towards word problems now and strategies they prefer. Listen for students to make comments about increased confidence, less fear of word problems, and better understanding of how to approach a word problem.

Summary

Chapter four was a detailed unit plan for finding effective word problem strategies to help students become more successful word problem solvers. The unit consisted of three word problem strategies: the problem solving process, schema-broadening problem solving, and using diagrams. The lessons were designed for an hour long Algebra 2 class. The unit started with a pre-assessment of word problem solving skills and feelings towards word problems. A rotation of the strategies followed for the next nine days – three days on each strategy, changing strategies each day. The rotation was meant to keep students thinking about all three strategies and reflecting on usefulness of each. The final day of the unit was a post-assessment of new word problem solving skills and changed
feelings towards word problems. The ideas and strategies from this unit should continue to be used in the classroom frequently for word problems.
CHAPTER 5

Reflection

Introduction

This study is focused on the question *What effect do different instructional strategies have on middle and high school student comprehension and success in solving math word problems?* In chapter one, I shared the story of a student that excels in math computation, but sometimes struggles with understanding word problems. This student's struggles are similar to what I see daily in the classroom, and that is why I want to explore strategies to help students become more successful when solving word problems. The first chapter of this capstone lays out my reasons for pursuing education and my personal story related to mathematics. I also covered why math word problems have become important to me and why I chose to look more closely at them. Chapter two was a literature review surrounding student understanding of math word problems and the uses of word problems in school – in the classroom versus standardized tests. In this chapter, I explored various strategies that researchers have used in an attempt to figure out which ones may work best for my students. One of the missing parts of the research was how to help high school students with word problems. Along with my main research question, I am interested in the following questions as well: Are the difficulties in comprehension or computation? What effect do different strategies for word problems have on student confidence in math? What effect do these strategies have on retention?

In chapter three, I laid out a unit plan for teaching students three strategies for solving word problems that I found in my research. I identified standards that could be
covered by word problems in an Algebra 2 course. The three chosen strategies are taught in rotation over the course of nine class periods, each repeated three times. Chapter four then detailed the lessons for the unit to enable myself and others to test out which strategies work best for students. In the current chapter, I discuss the writing process and what steps are next.

Reflection

The writing process for this capstone was thought provoking. When I started to look for research others had completed, it was difficult for me to figure out what exactly I was looking for - identifying the key words that would help me find what I knew I would need, or even figuring out which search engines would work best for my purposes. After a little time, I discovered how to search for the information I needed and soon I had a handful of articles on teaching word problem solving strategies. Once I read these articles and began to write about and analyze what I found, I wanted to look for more information. Before I knew what was happening, I had over fifty articles and counting. If I found an article that brought up good points for me to cover, I would look at its references to see where the authors found their information. I realized I was spreading things too wide and no longer focusing on what it was I wanted to learn. I reigned things in and read as much as I could about different strategies to help students become successful word problem solvers.

Considering my focus on high school students, I was looking for which strategies could be applied to higher level mathematics and not just elementary math. This was difficult at first because many strategies I found had been tested on students in grades one through three. By adding “algebra” to my search for problem solving strategies, I found
research that had been conducted with middle school/junior high age students. I soon found three strategies that I wanted to try in my classroom. Unfortunately, I was not able to conduct research in my own classroom to see which strategies would become most beneficial to my students. For this reason, I started to plan out a unit I could teach in the fall.

Writing the unit plan helped me figure out more of where I am getting confused on the strategies and think of ways to make these three strategies accessible to all my students. In my classroom, I have students with learning disabilities, students with emotional/behavioral disorders, and students that are gifted in mathematics. For this reason, I needed to think about ways to reinforce strategies for students that need more help at the same time as allowing students that have a grasp on the strategy a chance to excel. From my personal experience as a student and my time as a teacher, having students work in mixed ability groups allows everyone a chance to shine. This way, students that have more understanding at the beginning can help out students that struggle at first. I built in think-pair-share time for each strategy so students could discuss with each other their thinking, and so I could have a chance to hear things in a different light. There is continued reflection through the unit both for my benefit and for students. Since part of my goal with the unit was to learn which strategies best helped students become more successful, I needed students to be actively thinking about the strategies and their usefulness.

Creating the unit plan also opened my eyes to just how much a teacher can accomplish. I think it is easy to get lost in the day to day and not realize how much really goes into a lesson. I have not created a lesson plan since before I student taught, which
made part of this difficult for me. It was difficult because I am not used to writing down all that I would like to do in a lesson and see just how much I want to get done. Looking at a single lesson in this way seems a bit daunting. I also had some difficulty with writing down what I wanted to do without the lesson becoming scripted. As most teachers know, comments are made in class that can open in the window for learning in a way different from the original plan. Often these moments help students better understand because they have become involved in the lesson by asking a question or making a connection.

One of my questions going into this research was whether the problem lies in comprehension or computation. I found strategies that should enable students to increase their comprehension so I can better answer this question. The answer to this question will lie mostly in the work students show on their assignments. Through these assignments I will be able to analyze errors in understanding and errors in computation.

I also want to know about student confidence using the chosen strategies. The student post-attitude survey should help start to answer this question. In order to fully understand the confidence of students, it may be necessary to complete one-on-one interviews with some students. Through these interviews, students can answer questions in detail about which strategies make them feel most confident and help them better understand word problems.

Next Steps

In the fall, I plan to start the year with this unit. I think that starting with a strong focus on word problem solving strategies could have a large impact on the entire year. The idea behind starting with word problem solving strategies is that it will make the rest of the year run a little more smoothly. The textbooks I have chosen for my classes
incorporate word problems into every lesson (part of the reason I chose those textbooks). By learning strategies for word problems at the beginning of the year, the class can continue to practice those strategies in the classroom frequently.

Like many schools, my school does fall, winter, and spring standardized testing. I think that spending time in the classroom to specifically focus on word problems could help increase scores and student confidence on these tests. For high school students, the available practice problems for standardized tests are often word problems. It is also how math will likely be presented to students in their lives outside of the classroom. While my unit plan focuses on an Algebra 2 class, I plan to implement similar plans for all of my classes.

After several months of practicing word problem strategies, I plan to analyze standardized test data to see if I can find a correlation among increase of scores and better word problem solving skills. If I am able to find a correlation, I will share my unit with my colleagues. I think that presenting a united front on solving word problems not only makes student scores increase, but shows students that their teachers are committed to trying new ideas for their continued success.

My hope is that other teachers (or guardians) could use this unit plan to help students that are currently struggling with word problems. As mentioned in chapter one, I have seen word problems challenge students of all abilities and cause students to shut down. However, I am aware that the way I would present a lesson to the classroom I currently have is not the way all people would present to various classrooms. For that reason I think that anyone looking to use this unit plan keep in mind their specific situation and change things accordingly.
Summary

The final chapter of this capstone project reflected on the writing process. The process allowed me to think more deeply about lesson planning and the details that seem small to me but matter to students. It was challenging for me to write down all that I would do in a lesson because I have not done this in some time. I built in reflection time for both myself and students in order to make positive changes to the unit. I intend to use this lesson with all my classes to enable all my students to become more successful. It is also important to me that I share this unit with my colleagues. While this unit has been created for a specific class, I hope that others are able to make a plan to implement it on their own.
REFERENCES


APPENDICES

Appendix A

Word Problem Attitude Scale – Pre Intervention

Please circle the word that best describes how you feel about each statement.

1. I feel like I am good at math computations.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree

2. I feel like I am good at math word problems.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree

3. I understand what a word problem is asking me to do.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree

4. I draw a picture to help me understand math word problems.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree

5. I identify key words to help me understand math word problems.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree

6. I use a similar problem to help me understand math word problems.
   
   Strongly disagree  Disagree  Neutral  Agree  Strongly agree
**Word Problem Attitude Scale – Post Intervention**

Please circle the word that best describes how you feel about each statement.

1. I feel like I am better at word problems than before we learned about different strategies to solve word problems.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

2. I feel like I understand what word problems are asking me to do.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

3. I feel comfortable using the problem solving process to solve word problems.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

4. I feel comfortable using the schema-based strategy to solve word problems.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree

5. I feel comfortable using diagrams to solve word problems.
   - Strongly disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly agree
Appendix B

Sample Teacher Made Test

1. A real estate agent received a 6% commission on the selling price of a house. If his commission was $8,880, what was the selling price of the house?

2. An electric motor makes 3,000 revolutions per minutes. How many degrees does it rotate in one second?

3. The area of a rectangular field is equal to 300 square meters. Its perimeter is equal to 70 meters. Find the length and width of this rectangle.
4. In a shop, the cost of 4 shirts, 4 pairs of trousers and 2 hats is $560. The cost of 9 shirts, 9 pairs of trousers and 6 hats is $1,290. What is the total cost of 1 shirt, 1 pair of trousers and 1 hat?

5. Four children have small toys. The first child has 1/10 of the toys, the second child has 12 more toys than the first, the third child has one more toy of what the first child has and the fourth child has double the third child. How many toys are there?
Appendix C

The Problem Solving Process Poster

**THE PROBLEM SOLVING PROCESS**

**HOW IT WORKS:**

**Step 1**
Get started
Read the problem. What information do you have? What do you need to find out?

**Step 2**
Work on the problem
Now that you know the information, find a pattern that can help you solve the problem.

**Step 3**
Generalize
Use your pattern to create an mathematical equation. Solve the equation.

**Step 4**
Communicate
Recheck the problem for labels. Make sure you have found what the question is looking for and write out your answer.
Appendix D

Schema-Broadening Problem Solving Poster

Read the problem carefully. Does this problem sound like one you have solved before?

Once you find a similar problem, recall how you solved that problem.

Use the same process to solve the new problem. Don't forget labels!
Appendix E

Using Diagrams Poster

A diagram does not have to be a detailed picture.

A diagram might be letters or shapes. It is meant to help you visualize the problem.

People may draw different diagrams and that is okay.