The Effects of GoSolve Word Problems Math Intervention on Applied Problem Solving Skills of Low Performing Fifth Grade Students

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THE EFFECTS OF "GO SOLVE WORD PROBLEMS" MATH INTERVENTION ON APPLIED PROBLEM-SOLVING SKILLS OF LOW PERFORMING FIFTH GRADE STUDENTS

A Dissertation Presented

by

JESSICA L. FEDE

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY

May 2010

School of Education

School Psychology Program
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THE EFFECTS OF *GO SOLVE WORD PROBLEMS* MATH INTERVENTION ON APPLIED PROBLEM-SOLVING SKILLS OF LOW PERFORMING FIFTH GRADE STUDENTS

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DEDICATION

I would like to dedicate this dissertation to my family and friends who have shown me an unlimited amount of support.
ACKNOWLEDGMENTS

I would not have been able to complete this research project without the help and support from some very talented individuals. I would like to start by thanking my committee members: John Hintze, Christopher Overtree, Margy Pierce and my dissertation chair Bill Matthews. I would like to thank Margy Pierce for presenting me with this research opportunity and supporting me through the data collection process and John Hintze for lending his expertise on the research design. Also, words cannot express my gratitude towards my dissertation chair Bill Matthews for his faith, patience, support, humor, and friendship throughout my graduate school career.

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I would also like to extend a thank you to Gary Stoner, my first year advisor, for helping me fall in love with the field of school psychology. Thank you to Cindy McGurl and Walter Leopold for providing me with opportunities to develop my skills and expand my knowledge in the field of school psychology. Also, I would like to thank Rebecca Gajda and Vivian Ferry for teaching me how to be an effective teacher in the classroom as well as John Palmer, my undergraduate advisor.

Thank you all so much.
This research investigation examined the effects of *GO Solve Word Problems* math intervention on problem-solving skills of struggling 5th grade students. In a randomized controlled study, 16 5th grade students were given a 12-week intervention of *GO Solve*, a computer-based program designed to teach schema-based instruction strategies (SBI’s) to solve math word problems and 16 control students continued with the standard school-based mathematics curriculum. A subset of items from the Massachusetts Comprehensive Assessment System (MCAS) as well as the Group Mathematics Assessment and Diagnostic Evaluation (GMADE) was used to measure student test performance. Examiner-made probes were given to both the treatment and control groups every other week to measure student progress. Results indicate that the mean difference scores of the experimental and control groups were statistically significant on a subtest of MCAS problems and a large effect size was reported. However, no statistically significant difference between the experimental and control groups was found on the Process and Application subtest of the GMADE. On examiner-made probes, there was a statistically significant difference between the experimental and control groups. Limitations of this study as well as implications for practice will be discussed.
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CHAPTER 1

STATEMENT OF THE PROBLEM

The passage of No Child Left Behind Act of 2001 has placed heavy emphasis on outcomes for all students and has forced school districts to adopt evidence-based teaching methods and interventions (U.S. Department of Education, 2005). However, most of the research conducted as a result of this legislation has focused on improving reading instruction outcomes (U.S. Department of Education, 2005). Over the last two decades, and more recently, with the National Reading Panel (2000) identifying the five major components of reading, a great deal of progress has been made in understanding reading difficulties. Disabilities and instruction in mathematics, however, have not been as closely studied (Fuchs & Fuchs, 2001).

**Summary of Research on Mathematics Instruction**

Fuchs, Compton, Fuchs, Paulsen, Bryant, and Hamlett (2005) found that compared to the areas of reading and reading instruction, less is known about effective mathematics instruction and interventions that can aid children struggling in mathematics. Even with the lack of research and attention given to the area of mathematics, two of the most commonly observed academic problems for children with learning disabilities involve difficulties acquiring basic skills in mathematics and reading (Robinson, Menchetti, & Torgesen, 2002). Furthermore, Fuchs and Fuchs (2001) indicate that prevention of mathematics difficulties in the United States is generally ineffective, not only for students with learning disabilities, but for non-disabled learners as well. Gersten, Baker, and Lloyd (2000) reported that one of reasons for the lackluster mathematics performance includes the scarcity of well designed intervention studies to validate effective teaching practices, now at their lowest level in 30
years. No doubt the lack of research on effective mathematics instruction, prevention and interventions contributes to the poor performance of U.S. students in mathematics.

In 2001, the report *Adding It Up* by the National Research Council (NRC) announced the findings of an 18-month project in which 16 experts in the field synthesized relevant research on mathematics learning from pre-kindergarten through Grade 8. The report concluded that research has consistently shown the weakness of U.S. students in mathematics (National Research Council, 2001). The National Assessment of Educational Progress (NAEP) (2005) survey of *The Nation’s Report Card* reported that 64% of 4th grade students failed to demonstrate a “proficient” level of required math skills (Perie, Grigg, & Dion, 2005). On the 2003 NAEP assessment, only 29% of 8th grade students scored at the proficient level in mathematics. Students who did reach proficiency struggled with mathematical knowledge, application to real-world situations, and mathematics analytic skills. Furthermore, NAEP (2003) found that although the trends for improvements in math have increased between the years 1990 to 2000, there are still a large number of students who have substantial trouble solving math problems. In addition, many studies indicate that even though U.S. students may not fare badly when asked to perform straightforward computational problems, they nonetheless have difficulty understanding basic mathematical concepts in word problems (National Research Council, 2001). For example, on the 2005 NAEP assessment, the following problem was given to 4th grade students: A club needs to sell 625 tickets. If it has already sold 184 tickets to adults and 80 tickets to children, how many more does it need to sell? Forty-four percent of 4th graders answered correctly, obtaining an answer of 361. However, 66% of students obtained an incorrect answer, answering 809. Clearly, many students in the United States struggle when solving word problems. According to NAEP reports dating back over 25 years, one of the greatest deficits
in U.S. students’ learning of mathematics is their ability to solve word problems (National Research Council, 2001).

**United States Compared to Other Countries**

The RAND Mathematics Study Panel (2003) was convened to inform the United States Department of Education’s Office of Educational Research on ways to improve the quality and usability of education research and development. One of the primary reasons for creating the panel was to better develop proficiency in mathematics in light of the current United States educational standards and the lackluster mathematics performance of United States students compared to the performance of students in other countries (RAND Mathematics Study Panel, 2003). In 2008, President Bush established the National Mathematics Advisory Panel via Executive Order 13398. The panel, which was supported by the United States Congress, indicated “international and domestic comparisons show that American students have not been succeeding in the mathematical part of their education at anything like a level expected of an international leader” (National Mathematics Advisory Panel, p. xii). Clearly, a need exists for substantial improvements in the mathematical achievements of U.S. students.

International comparisons of mathematics achievement demonstrate many of the same findings as the NAEP results. On several international mathematics assessments conducted since the 1970s, the overall performance of U.S. students has lagged behind the performance of students in other countries. Currently, the most comprehensive study is the *Third International Mathematics and Science Study* (TIMSS), which is the third comparison of mathematics and science achievement carried out since 1995 by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS is closely linked
to the curricula of the participating countries, providing an indication of the degree to which students have learned the concepts in mathematics and science to which they have been exposed in school. The most recent TIMSS report results indicate that United States’ 4th graders performed lower than their peers in eleven countries (Singapore, Hong Kong, Japan and Chinese Taipei, being the top four). Furthermore, United States’ 8th graders performed lower than students in nine countries (Singapore, Hong Kong, Chinese Taipei and Japan, being the top four). Results from the 2003 TIMSS also indicated that only 7% of U.S. 8th grade students scored at the advanced level, compared to about one-third of students from the highest performing countries (Singapore, Chinese Taipei, Korea, and Hong Kong). A report disseminated by the Programme for International Student Assessment (PISA) further illustrates how poorly American students are performing in the area of mathematics. The 2000 PISA report indicated that about two-thirds of the students in participating countries had average scores in mathematical problem-solving which were above those of U.S. students; in 2003, more U.S. students scored at or below the lowest level of proficiency in problem-solving than the international average (Kinder & Stein, 2006). In addition, unlike countries in which a national curriculum exists in mathematics (e.g. Japan and China), in the United States, the curriculum frameworks are developed by each state (Reed, 1999). Overall, reports have consistently underscored that American students have fallen behind students from other industrialized countries in mathematics (Beaton, Mullis, Martin, Gonzalez, Kelly & Smith, 1996; Geary, 1996; Kinder & Stein, 2006; Ysseldyke, Betts, Thill, & Hannigan, 2004).

Clearly, the disappointing mathematics achievement levels of middle school students in the United States have been well-documented, based on both national and international assessments. Too few U.S. students are “leaving elementary and middle school with adequate
mathematical knowledge, skill and confidence for anyone to be satisfied that all is well in school mathematics” (National Research Council, 2001, p. 407).

**The Demand for Adequate Math Skills**

The disparate performance of American students with respect to their international peers is alarming, given the growing demand for math proficiency and the need for math problem-solving skills in upper levels of employment. The National Research Council (2001) reported that the mathematical skills of students in the U.S. are falling short of what is needed in the workplace. United States’ students with weak mathematics skills will be adversely affected not only inside the classroom, but also outside the classroom and in the real world.

Today, it is essential for students to learn the necessary mathematics skills in order to attain success in society. According to the NRC’s (2001) report *Adding It Up*, “children today are growing up in a world permeated by mathematics. The technologies used in homes, schools, and the workplace are all built on mathematical knowledge” (p. 15). Yet, many students struggle to acquire basic mathematic skills. According to the NRC (2001),

Public concern about how well U.S. schoolchildren are learning mathematics is abundant and growing. The globalization of markets, the spread of information technologies, and the premium being paid for workforce skills all emphasize the mounting need for proficiency in mathematics. Media reports of inadequate teaching, poorly designed curricula, and low test scores fuel fears that young people are deficient in the mathematical skills demanded by society. (p. xiii)

The United States is currently experiencing a need for critical educational change. According to National Council of Teacher of Mathematics (NCTM) (2000), new knowledge, tools, and ways of performing and teaching mathematics are blossoming. The need to understand the demands for competency in mathematics as it applies to everyday life
continues to grow. Increased use of technology in American society indicates that the United States cannot afford to provide children with inadequate mathematics instruction and education (Glenn, 2000). Business leaders have claimed that the labor force in our information-oriented society needs more sophisticated mathematical skills, especially the ability to communicate with mathematical systems and to solve a variety of complex problems (Reed, 1999). Glenn (2000) estimates that approximately 85% of jobs can be classified as skilled, with jobs in the health and computer industries continuing to increase.

According to the National Mathematics Advisory Panel (2008):

> During most of the 20th century, the United States possessed peerless mathematical prowess -- not just as measured by the depth and number of the mathematical specialists who practiced here, but also by the scale and quality of its engineering, science, and financial leadership, and even by the extent of mathematical education in its broad population. But without substantial and sustained changes to its educational system, the United States will relinquish its leadership in the 21st century. (p. xi)

Even with job demands requiring greater emphasis on mathematical problem-solving and the need for individuals to possess mathematical skills, schools are not preparing students adequately. The learning and teaching of mathematics has not kept up with the changes in the labor force brought about by advances in technology (Reed, 1999). Although many individuals may have been taught calculation skills, oftentimes they remember rules that are not grounded in understanding (RAND Mathematics Study Panel, 2003).

According to the NCTM’s *Principles and Standards for School Mathematics* (2000), “those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures. A lack of mathematical competence keeps those doors closed” (p. 5). Furthermore, a report published by the U.S. Department of Labor (1991) emphasized the importance of thinking, reasoning, and problem-solving skills.
According to the NRC’s report *Adding It Up* (2001), “citizens who cannot reason mathematically are cut off from the whole realm of human endeavor” (p. 15). American children need to be leaving school with adequate mathematics skills in order to be competitive within the workforce, given that more jobs require mathematical skills. Phillips (2007) reports that 78% of adults cannot explain how to compute the interest paid on a loan and 71% cannot calculate miles per gallon on a trip. The RAND Mathematics Study Panel (2003) indicates, “the personal, occupational and educational demands placed on all Americans in the 21st century call for a level of a mathematical proficiency that in generations past was required of only a few” (p. 77).

**High-Stakes Mathematical Testing**

To ensure that students are meeting standards, states and districts have mandated and developed a variety of mathematical assessments. High-stakes testing has caused an increase in expectations for student performance and has generated a significant amount of controversy regarding how these tests are developed and administered. Reform efforts such as the accountability movement have aimed to improve mathematics instruction for all students. However, disagreement has centered on the specific competencies that should be measured (Miller & Mercer, 1997). During the first test given in the spring of 1999, Arizona, for example, had a 1 in 10 sophomore pass rate (National Research Council, 2001). In addition, many states such as Massachusetts and New York have lowered passing scores on exams; however, in order to graduate, students must pass these tests.

Despite the controversy, the trend of requiring testing for graduation has gained much momentum. Lerner (1993) indicated that over three-quarters of all school districts in the United States require high school students to pass a minimum competency test before
receiving a diploma. Minimum competency testing has been debated in Massachusetts with respect to the Massachusetts Comprehensive Assessment System (MCAS). Many have argued about the difficulty of the test, while others have focused on its content. For example, some educators have focused on the mathematics section of the MCAS and the way it aligns with the curriculum and standards taught in the classroom. A thorough examination of the MCAS reveals great emphasis is placed on a child’s ability to solve applied mathematical problems. Most problems are presented in a word problem format. Given the emphasis placed on applied mathematical problems on state tests such as the MCAS, students must acquire the necessary skills to solve complex mathematical problems. In addition, given the increased emphasis on the importance of mathematical problem-solving and the poor performance of students, many researchers have chosen to seek better instructional approaches and interventions for teaching these skills with greater efficacy and success (Babbitt & Miller, 1996).

Mathematics Instruction

Over the last ten years, a great deal of attention has been paid to curriculum reform in mathematics education, which is slowly starting to find its ways into American classrooms (Alper, Fendel, Frasser, & Resek, 1995). The strongest push for change has come from mathematics educators who have argued that current instruction has focused too much on efficient computation and not enough on problem-solving and mathematical understanding (Reed, 1999). The NCTM (2000) outlined critical content and process standards in the Principles and Standards for School Mathematics. These standards have created a roadmap for the creation and development of textbooks and assessments (O’Connell, 2007). Further, these standards have help to guide thinking of what should be taught in American
classrooms. The first five standards outline the content standards related to number and operations, algebra, geometry, measurement, and data analysis and probability (NCTM, 2000). The second set of standards outlines the process goals including problem-solving, reasoning and proof, communication, connections, and representations (NCTM, 2000). These standards must be taught to all children efficiently regardless of whether or not they have a disability. Jitendra and Xin (1997) emphasize the importance of providing quality instruction to students with disabilities and those at-risk for mathematical failure.

The NRC (2001) identified the following five components required for successful mathematical proficiency:

- **conceptual understanding**—comprehension of mathematical concepts, operation, and relations
- **procedural fluency**—skill in carrying out procedures flexibly, accurately, effectively, and appropriately
- **strategic competence**—ability to formulate, represent, and solve mathematical problems
- **adaptive reasoning**—capacity for logical thought, reflection, explain, and justification
- **productive disposition**—habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy.

The Council stressed that these five strands should be interwoven and interdependent by indicating:

One of the most serious and persistent problems facing school mathematics in the United States is the tendency to concentrate on one standard of proficiency to the exclusion of the rest. The integrated and balanced development of all five standards of mathematical proficiency should guide the teaching and learning of school mathematics. Instruction should not be based on extreme positions that students learn, on one hand, solely by internalizing what a teacher or book says or, on the other hand, solely by inventing mathematics on their own. (p. 11)

In response to these recommendations by the NCTM and the NRC, districts have begun to adopt curricula that follow and incorporate all of the standards. The six basic
principles that have guided curriculum reform and implementation are as follows: 1) equal opportunity for all students, 2) a comprehensive and coordinated curriculum across grades, 3) excellent teachers who have the content and pedagogical knowledge for assessing and instructing students, 4) active construction of knowledge by students who are empowered mathematically, 5) appropriate assessment that provides direction for instruction and supports learning, and 6) technology as an essential component of mathematics teaching and learning (NCTM, 1989, 2000). According to Montague and Jitendra (2006), teachers and districts have adjusted and modified curricula and instruction which represents a dramatic departure from traditional models. In addition, these new curricula, together with the principles disseminated by the NCTM (2000), emphasize the importance of problem-solving, conceptual understanding, and communication concerning mathematics.

**Increased Focus on Problem-solving**

NCTM (2000) has identified problem-solving as its number one priority. It has become quite clear that an individual’s ability to problem-solve in mathematics enhances his or her ability to function in the context of everyday situations and work settings (Bottge & Hasselbring, 1993). Results of the 2003 PISA study reveal that performance by United States’ 15 year-olds in math problem-solving when compared to other leading industrialized nations is alarming (National Center for Education Statistics, 2004). Specifically, in the area of problem-solving, United States’ students scored below the average scores of other industrialized countries and lower than 25 of the other 38 participating countries.

Lackluster mathematics performance may stem in part from the lack of a common understanding of what problem-solving entails. Babbitt and Miller (1996) indicate that understanding what is meant by mathematical problem-solving can be very complex and confusing to many. Depending on whom you ask, the answer to the question “What is
problem-solving?” can vary. Mercer and Miller (1992) examined ten books and numerous articles about problem-solving and identified thirty-seven different descriptors of mathematical problem-solving. Mayer and Hegarty (1996) defined problem-solving as “a process of moving from a given state to a goal state with no obvious way to progress from one state to the other state” (p. 31). Mathematical problem-solving encompasses the use of knowledge, skills, and strategies to solve novel problems (Xin & Jitendra, 2006). Chen and Liu (2007) indicate that most word problems consist of a “three component structure”: (a) a “set-up component,” consisting of the roles and places in the story problem, (b) an “information component,” which provides the data required to solve the problem, and (c) a “question component,” which is the main question students are asked to solve (p. 106). Yet, even without agreement about the definition, according to Jonassen (2003), problem-solving is perhaps the most important component of mathematics. As O’Connell (2007) states, “the ability to solve problems is the ultimate goal of mathematics” (p. 1). One of the primary goals in teaching mathematics is not to simply teach students to add, subtract, multiply and divide, but rather, to apply these various mathematics skills to solve word problems. When students are engaged in problem-solving tasks, they are able to develop an understanding of math content and use that content understanding to find solutions to problems.

In the United States, the structure of the math curriculum and the content of many math textbooks have reinforced a procedural approach to solving math word problems that undermines deep understanding. Traditional mathematics textbooks often do not provide the instruction that is recommended by the NCTM (Griffin & Jitendra, 2008). A study which examined five 3rd grade mathematics textbooks and assessed how they matched with the standards, Jitendra, Sczeniak, and Deatline-Buchman (2005) found that the textbooks inadequately addressed them. Specifically, opportunities for reasoning and making
connections were present in less than half the instances in these textbooks. Many problems in textbooks allow students to look at a few key words and numbers to apply the algorithm; they do not actually have to read and understand the problems. Sometimes the key word or direct translation approach may lead to success narrowly; however, this is not always applicable to all problems.

A great deal of mathematics instruction in the United States skips the steps of understanding and modeling the situation and moves directly towards a problem’s solution. Much instruction has primarily focused on key words which “subverts mathematical understanding” and oftentimes leads to wrong answers (Clement & Bernhard, 2005, p. 364). Mathematics curricula and textbooks have historically reinforced a procedural approach to tackling math word problems that undermines deep understanding. According to the NRC (2001), in comparison with the curricula of countries achieving well on international comparisons assessments, “U.S. elementary and middle school mathematics curriculum has been characterized as shallow, undemanding, and diffuse in content coverage” (p. 4). Stigler, Fuson, Ham, and Kim (1986) found that a textbook chapter usually presents a few mathematics problems for students to learn and then is typically followed by a set of similarly structured word problems that are related and are often in simple form. In addition, according to van Garderen (2006), traditional mathematics textbooks do not make explicit the relationship between numerical operations. Many textbooks organize problems in such a way that require students to solve word problems using all the same operation (Jitendra, Griffin, Haria, Leh, Adams, & Kaduvettoor, 2007). This does not allow students to have the opportunity to discriminate and learn about problems that require different strategies and solutions to solve.
According to Griffin and Jitendra (2008), most textbooks include general strategy instruction (GSI) that involves the use of heuristic and multiple strategies based on Polya’s seminal principles for problem-solving. Polya’s four-step problem-solving model includes: a) understanding the problem, b) devising a plan, c) carrying out a plan, and d) looking back and reflecting (Polya, 1957). However, GSI has recently come under scrutiny. Even though students are exposed to a variety of strategies and are encouraged to develop different ways of thinking about a problem, GSI does not train them to approach problem-solving in a systematic manner (Jitendra et al., 2007). Historically, a few experimental studies have explored specific instructional methods in the area of mathematics problem-solving (Kinder & Stein, 2006). Miller, Butler, and Lee (1998) synthesized the research on teaching mathematics problem-solving to students with learning disabilities and identified the following effective problem-solving interventions: cognitive and metacognitive strategy instruction, the use of manipulatives and drawing, use of schematic diagrams, and direct instruction involving fact families. According to Kinder and Stein (2006), many research reviews indicated that student performance improved through the use of peer tutoring, directed instruction, and systematic feedback. Fennema et al. (1996) found that the gain in students’ concepts and problem-solving performance appears to be directly related to changes in teachers’ instruction. In the classrooms, gains were reported. Although researchers were not able to directly connect the gains with specific changes, changes were seen across many dimensions which included: teachers providing more opportunity for students to reflect on concepts and engage in problem-solving, children being allowed to share their thinking, and teachers whose instruction was identified as being more cognitively guided to the problem-solving of children.
Research conducted by Miller, Butler, and Lee (1998) found that specific instructional procedures were of particular importance, including teacher demonstrations and student modeling. Specifically, research has shown that students need to have clear mental models and an understanding in order to make sense of the problems they encounter. For instance, research has shown a preference for video rather than text formats for constructing these mental models. According to the Cognition and Technology Group at Vanderbilt (1990), “It is dynamic, visual, and spatial, and students can more easily form rich mental models of the problem situation” (p. 2). More research is needed on evidence-based instructional practices in teaching mathematical word problems.

**Raising Word Problem Achievement**

The new mathematics curriculum standards have led both general and special educators to explore ways to help students with and without disabilities develop proficiency in problem-solving; however, gains in performance have been difficult to achieve for a variety of reasons (Cawley, Parmar, Yan, & Miller, 1998). According to Reed (1999), educators and cognitive scientists have criticized word problems as being too artificial in order to transfer to real-world situations. For example, Brown, Collins and Duguid (1989) stated the following in their influential article entitled “Situated Cognition and Culture of Learning”:

Math word problems, for instance, are generally encoded in a syntax and diction that is common only to other math problems...By participating in such ersatz activities, students are likely to misconceive entirely what practitioners actually do. As a result, students can easily be introduced to a formalistic, intimidating view of math that encourages a culture of math phobia rather than one of authentic math activity. (p. 34).

Word problems can pose difficulties for students because of the complexity of the problem-solving process (Jonassen 2003; Xin & Jitendra, 2006) and have always been
difficult for many students, but it is particularly so for students with learning disabilities. For instance, many students with disabilities have difficulties determining the correct operational process for solving the word problem as well as identifying and ignoring extraneous information (Lee & Hudson, 1981). In addition, according to Montague and Bos (1986), many children, especially children with disabilities, have difficulties completing all the steps to a word problem.

Research has shown that many students with learning difficulties also have difficulties with language. Learner (1993) indicates that children with language disorders may also have confusion with mathematics vocabulary, for instance, the terms “take away,” “minus,” “add,” and “borrowing.” In order for students to be able to complete word problems successfully, they need to understand the underlying language structure. Additionally, research has shown that some students oftentimes have no difficulty with the language they encounter, but are confused when the language in a word problem is not exactly like their own. Overall, many researchers have documented a number of reasons why it has been difficult raising math achievement of students with and without disabilities (Bottge, Heinrichs, Chan, & Mehta, 2003; Cawley et al., 1998).

Mathematics Disabilities

As the previous section outlined, today, children present with a wide range of academic needs which can impede the improvement of problem-solving skills. Research on mathematics disabilities and how they affect learning has lagged behind immensely compared to the area of reading disabilities (Fuchs & Fuchs, 2001; National Research Council, 2001). According to Bryant and Bryant (2008), when compared to the research base in reading difficulties, identification of mathematics disabilities is limited at best. The problem of mathematics underachievement appears to be particularly severe for students
with disabilities and those at risk for mathematics failure (Carnine, Jones, & Dixon, 1994). According to Brian, Bay, Lopez-Reyna, and Donahue (1991), at least a quarter of students with learning disabilities are identified for special education services because of significant discrepancies between aptitude and mathematics performance. According to the 21st Report to Congress (Glenn, 2000), students with disabilities have lower math skills than their general education peers. Jordan, Kaplan, Locuniak, and Ramineni (2007) reported that students with math disabilities usually fall at or below the 15th percentile on standardized math tests, despite having average or above average intelligence. Powell, Fuchs, Fuchs, Cirino, and Fletcher (2009) reveal that studies examining mathematics disabilities often have different procedures for identifying students. For instance, common criteria include performance 1, 1.5, or 2 deviations below the mean of a national normative framework, discrepancies of one or two deviations between achievement and IQ (Parmar, Cawley, & Frazita, 1996), or nationally norm-referenced percentile cutoff points, with cutoffs points including the 10th, 25th, 31st, 35th, or 45th percentiles (Mazzocco & Thompson, 2005). Therefore, students identified as having math difficulties in one study might fail to meet the inclusion criteria in another.

Another source of confusion stemmed from the labels used to characterize students who demonstrate challenges in learning and applying mathematics skills and concepts (Bryant & Bryant, 2008; Fuchs & Fuchs, 2005; Jitendra et al., 2005). One common way to identify students is with the label of mathematics learning disability (MLD). Research has shown a large percentage of students receiving learning disability services experience difficulties with mathematics calculation or mathematical reasoning, not attributable to other conditions (Bryant, Bryant & Hammill, 2000). For over 20 years, math disabilities have been recognized as a type of learning disability, as evidenced by the inclusion of mathematics in
the two most pertinent definitions of learning disabilities: the National Joint Committee on Learning Disabilities and the Individuals with Disabilities Act (Bryant et al., 2000).

Severe problems in mathematics are oftentimes referred to as dyscalculia, yet another term that is commonly used to describe students struggling in mathematics. According to Shalev, Manor, Kerem, Ayali, Badichi, Friedlander, and Gross-Tsur (2001), dyscalculia is a specific learning disability affecting the acquisition of arithmetic skills in an otherwise normal child. Other researchers have described dyscalculia in a somewhat different way. Landerl, Bevan, and Butterworth (2004) described dyscalculia as a condition in which a child is born with a condition that affects his or her ability to acquire the usual arithmetical skills.

As a more inclusive definition for students who struggle in mathematics, researchers have sometimes used the term mathematical difficulties to describe students who perform below certain benchmarks, regardless of etiology. This term allows researchers to include students whose math difficulties may stem from poor instruction or economic disadvantage, students who would be excluded under the terms described above (Mazzacco, 2007).

Barbaresi, Katusic, Colligan, Weaver, and Jacobson (2005) conducted a population-based prevalence study in the United States and have suggested that the cumulative incidence of math learning disability ranges from six to fourteen percent, depending on the way mathematics disabilities are defined. Lyon (1996) reports similar estimates, and that six percent of school-aged children are identified as having difficulties in mathematics that cannot be attributed to low intelligence. However, it is difficult to determine the prevalence of mathematical disabilities, since definitions differ and diverse learning difficulties overlap with mathematical deficits (Wadlington & Wadlington, 2008). According to Geary (2000), there are no universal criteria for diagnosing math difficulties and disabilities. With no
universal criteria and differing definitions, diagnosing mathematics disabilities can be very subjective.

Some controversy stems from the issue of whether or not a math learning disability (MLD) stems from a universal core deficit, or whether subtypes of students may show different profiles of strength and vulnerability in the wide range of skills related to mathematics. One potential candidate for the core deficit underlying MLD is number sense, the ability to quickly understand, approximate and manipulate numerical quantities (Dehaene, 1997). Wilson and Dehaene (2007) have argued convincingly that a core deficit in number sense is related to impairment in a region of the parietal cortex that specializes in approximate magnitude processing. Butterworth (2005) concurs, arguing that the human brain is hardwired for processing numbers. According to Butterworth, the difficulty some students have with mathematics can be traced to two main causes – genetics and inadequate instruction. He further explains that the reasons for inadequate performance in mathematics can be the result of genetics or, in a small number of instances, dyscalculia or dyslexia, which can impair mathematical ability. Clearly, more information is greatly needed about mathematics disabilities to inform the practices of early identification, intervention, or instructional modifications of children with persistent difficulty in mathematics (Garrett, Mazzocco, & Baker, 2006).

In contrast, efforts to identify subtypes of MLD have focused on the variability displayed by students in the range of skills important in mathematics, including memory, visual-spatial processing, language, phonological processing (or co-morbid reading disability and math disability). One of the most prominent models of the subtypes of MLD was developed by David Geary (2000), who identified the following potential subtypes of dyscalculia:
1. **Semantic memory**: difficulty retrieving arithmetic facts

2. **Procedural memory**: difficulty understanding and applying mathematical procedures

3. **Visuospatial memory**: difficulty understanding spatially represented numerical information such as misalignment of columns, place value errors, or geometry

This model highlights the role of memory in mathematics. In fact, research has demonstrated that many students who exhibit memory problems and who are slower in processing information lack the ability to retrieve arithmetic combinations that are often needed to solve mathematical problems commonly encountered in middle school (Bryant, Kim, Hartman & Bryant, 2006). Students who have memory difficulties can also have problems in recalling and executing the multiple steps that are needed to solve complex problems such as word problems (Bryant et al., 2006).

Another effort at identifying subtypes of students with MLD has focused on students with language difficulties (Wadlington & Wadlington, 2008). Many children with mathematical disabilities also struggle with language; therefore, language skills become very important to math achievement. The use of language is necessary for calculations and word problems (Miller & Mercer, 1997). When computing, language skills are needed to systematize the recall and use of many procedures, rules, and math facts. Math problem-solving is also complicated by students’ difficulty reading and understanding the language in word problems. Englert, Culatta, and Horn (1987) have found that irrelevant numerical and linguistic information in word problems are especially troublesome for many students with MLDs. Moreover, children with auditory comprehension problems may have difficulty learning new math concepts when they are presented orally. Similarly, children with
language retrieval deficits can exhibit problems explaining their thinking aloud (Wadlington & Wadlington, 2008).

The final line of research looking at subtypes of MLD considered the role of phonological processing as a common and underlying cause of both reading and math disabilities. Research has shown that some students perform poorly in mathematics yet perform relatively well in reading, whereas others perform poorly in mathematics and have concurrent reading difficulties. Hecht (2002) found that students may struggle both with reading and math due to weak phonological processing skills, whereas math difficulties that occur without concurrent reading difficulties may be due to poor number sense. Research has also shown that there are differences between students who have both math and reading disabilities (MDRD) and students with just math disabilities (MD-only). For example, Geary, Liu, Chen, Saults, and Hoard (1999) conducted a study in the fall and spring of 1st grade which assessed the performance of 25 students with MDRD and 15 students with MD-only on a global mathematics test. MDRD students scored below the 20th percentile on math and reading, whereas MD-only students scored below the 20th percentile in math but had average reading scores. In addition, on comprehension measures, MDRD students performed significantly below MD-only students and average-performing peers, and many MDRD students were unfamiliar with proper representations of numbers. Furthermore, Pellegrino and Goldman (1987) found that even when simple calculations are required to solve word problems, both MDRD and MD-only students struggled with problem-solving compared to average performing peers, but MD-only students generally outperform MDRD students. There is some evidence that “when IQ and reading are controlled, ‘true’ math deficits are specific to mathematical concepts and problem types” (Zentall & Ferkis, 1993, p. 6).
According to Bryant et al. (2008), much like current practices in early reading instruction, the achievement gap of students with disabilities compared to their typically achieving peers will remain problematic without preventive practice in the early grades. One of the contributing factors in mathematics instruction in special education, especially, has been focused on teaching rote memorization of facts and computational skills instead of developing important concepts and applying mathematics to real-world problem situations (Baroody & Hume, 1991). Jitendra, DiPipi and Perron-Jones (2002) indicate many researchers argue that “highly procedural instruction (meaningless drill and practice of computation facts) may sustain the characterization of students with learning disabilities as passive learners and fail to fill the gaps in their concepts” (p. 23). Therefore, it is not surprising that students with learning disabilities have difficulty with higher level mathematics skills, for example, solving word problems. However, Fuchs and Owen (2002) concluded that when elementary-aged students with mild disabilities are taught a strategy to solve math word problems, their performance on process and product was better than that of students who received conventional instruction. In addition, their study showed that an emphasis on transfer skills and peer mediation improved student performance. Overall, prior to 2000, research did not seem promising with respect to the remediation of children who are struggling and have a disability in mathematics. However, with the introduction of recent interventions, positive outcomes are much more promising.

**Differences in Problem-solving Skills**

Research on mathematical disabilities has contributed to our understanding of the development of problem-solving skills in school-aged children. Much of this work has focused on comparing the characteristics of good and poor problem-solvers. Research had shown that good math problem-solvers develop a representation of the problem they are
attempting to solve, and that students construct a mental model of the information and the relationships among the elements of the problems (Riley, Greeno, & Heller, 1983). Students are then able to take this information to select a solution strategy and apply the strategy to find the answer. Montague (2006) studied the difference between good between good and poor problem-solving skills.

Table 1.1

*Learning Differences Between Good and Poor Problem-solvers*

<table>
<thead>
<tr>
<th>Good Problem-solvers</th>
<th>Poor Problem-solvers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repertoire of strategies</td>
<td>Limited strategies</td>
</tr>
<tr>
<td>Metacognitive approach</td>
<td>Immature metacognitive abilities</td>
</tr>
<tr>
<td>Motivated</td>
<td>Low motivation</td>
</tr>
<tr>
<td>Memory capacity</td>
<td>Attention, memory, language problems</td>
</tr>
<tr>
<td>Developed language</td>
<td>Impulsive</td>
</tr>
<tr>
<td>Appropriately confident</td>
<td>Uncertain approach to problems</td>
</tr>
<tr>
<td>Attentional focus</td>
<td>Inability to detect and correct errors</td>
</tr>
<tr>
<td>Self-directed and self-regulating</td>
<td>Problem representation difficulties</td>
</tr>
<tr>
<td>Ability to generalize learning</td>
<td>Poor generalizers</td>
</tr>
</tbody>
</table>

Overall, Montague (2006) found that good problem-solvers used a variety of strategies to solve word problems and were described as self-directed. Poor problem-solvers had a limited number of strategies they could use when solving a word problem, were impulsive, and lacked motivation. In addition, Stigler et al. (1986) found that the better the student is at recognizing the problem situation and representing it, the better his or her ability to solve more complex math problems. Hegarty, Mayer, and Monk (1995) found that good
problem-solvers tend to look beneath the surface information at the underlying problem model.

**Effective Problem-solving Interventions and Research Themes**

As the previous discussion highlighted, there are considerable differences between good and poor problem-solvers, underscoring the need for effective interventions and teaching strategies targeting problem-solving. Although this line of research is still in its infancy, several promising components have emerged, which, when incorporated into classroom instruction, may prove beneficial for students who struggle with problem-solving. Therefore, each of the themes which have emerged from this body of research will be discussed further below.

One of the most commonly referenced approaches to teaching problem-solving involves the use of keywords. This also has been described as direct translation. Students are taught to look for particular cue words in their word problems. The typical strategy is to search for a keyword word such as “more” which can sometimes mean “to add”, and use this information to directly translate the problem into its computational form (Woodward, 2006). However, many researchers have criticized this approach, since the key words do not necessarily indicate the appropriate operation (Fuson, Carroll, & Landis, 1996; Nesher & Teubal, 1975; Verschaffel, Greer, & de Corte, 2000). Cognitive research during the 1990s demonstrated that this kind of instruction was not only limiting, but it was generally associated with poor problem-solvers (Woodard, 2006). In addition, research conducted by Hegarty, Mayer and Green (1992) found that students who search for keywords and who do not spend sufficient time representing the problem are more likely to make significantly more errors when problems are presented in an inconsistent format.
According to Sowder (1988), many well-meaning instructors teach the keyword strategy and are not aware of its shortcomings. Sowder (1988) acknowledges: “The spirit of teaching key-words -- getting students to think about the situation -- is all right, but students sometimes look only for the key words and ignore the whole context. It is, of course, also easy to write story problems with key words alone, that suggest incorrect operations for the problems” (pp. 230-231). Oftentimes, the keyword strategy approach causes children to arrive at the wrong answer.

Perhaps the classic example of this phenomenon is the “Captain’s Age Problem.” A group of French researchers presented a class of students with the following problem: “There are 26 sheep and 10 goats on a ship. How old is the captain?” Most students readily offered responses, even though the problem and their answers made no sense (Snyder, 2005). Many versions of this problem have been shown to students around the world, and their responses have been pretty much the same. Verschaffel et al. (2000) reported “traditional math education has taught students to approach word problems in a thoughtless and mechanical way” (p. 6). Overall, “problem-solving is more than just a goal of learning mathematics; it is also a critical process, woven across the entire mathematics curriculum through which students are able to explore and understand mathematics” (NCTM, 2000, p. 52).

A second theme found in the literature pertains to the instruction of general problem-solving strategies. Problem-solving strategies, according to O’Connell (2007), “are what we do in our heads as we make sense of and solve problems. They are our tools for simplifying problems and revealing the possible paths to solutions” (p. 28). Developing students’ problem-solving abilities can be a challenging task. Building problem-solving skills through the teaching of strategies requires attention to building both mathematical skills and the thinking process (O’Connell, 2007).
Babbitt and Miller (1996) list a variety of strategies that have been used to teach problem-solving skills. They indicate that the most crucial components of these strategies are: “reading the problems carefully, thinking about the problem via self-questioning or drawing, visualizing, underlying, or circling relevant information, determining the correct operation or solution strategy, writing the equation(s), and computing and checking the correct answer” (1996, p. 392).

Table 1.2

*Problem-solving Strategies*

continued on the next page

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Strategy Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babbitt (1993)</td>
<td>Read the problem</td>
</tr>
<tr>
<td></td>
<td>Underline the problem</td>
</tr>
<tr>
<td></td>
<td>Choose solution strategy and solve</td>
</tr>
<tr>
<td></td>
<td>Check, “Is the question answered?”</td>
</tr>
<tr>
<td></td>
<td>Check, “Does the answer make sense?”</td>
</tr>
<tr>
<td></td>
<td>Consider applications and extensions</td>
</tr>
<tr>
<td>Bennett (1981)</td>
<td>Read the problem</td>
</tr>
<tr>
<td>Pre-organize</td>
<td>Underline numbers</td>
</tr>
<tr>
<td></td>
<td>Reread the problem</td>
</tr>
<tr>
<td></td>
<td>Decide on the operation</td>
</tr>
<tr>
<td></td>
<td>Write the mathematical sentence</td>
</tr>
<tr>
<td></td>
<td>Read</td>
</tr>
<tr>
<td></td>
<td>Check operation</td>
</tr>
<tr>
<td></td>
<td>Check math statement</td>
</tr>
<tr>
<td></td>
<td>Check calculations</td>
</tr>
<tr>
<td></td>
<td>Write labels</td>
</tr>
<tr>
<td>Post-organize</td>
<td>Read</td>
</tr>
<tr>
<td></td>
<td>Check operation</td>
</tr>
<tr>
<td></td>
<td>Check math statement</td>
</tr>
<tr>
<td></td>
<td>Check calculations</td>
</tr>
<tr>
<td></td>
<td>Write labels</td>
</tr>
<tr>
<td>Case, Harris, and Graham (1992)</td>
<td>Read the problem out loud</td>
</tr>
<tr>
<td></td>
<td>Look for important words and circle them</td>
</tr>
<tr>
<td></td>
<td>Draw pictures to help tell what is happening</td>
</tr>
<tr>
<td>Deskripsi</td>
<td>Methode</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>Write down the math sentence</td>
<td>Write down the answer</td>
</tr>
<tr>
<td>Fleischner, Nuzum, and Marzolla (1987)</td>
<td>Read</td>
</tr>
<tr>
<td></td>
<td>Reread</td>
</tr>
<tr>
<td></td>
<td>Think</td>
</tr>
<tr>
<td></td>
<td>Solve</td>
</tr>
<tr>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>Kramer (1970)</td>
<td>Read the problem</td>
</tr>
<tr>
<td></td>
<td>Reread the problem</td>
</tr>
<tr>
<td></td>
<td>Use objects to show the problem</td>
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<tr>
<td></td>
<td>Write the problem</td>
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<tr>
<td></td>
<td>Work the problem</td>
</tr>
<tr>
<td></td>
<td>Check your answer</td>
</tr>
<tr>
<td></td>
<td>Show your answer</td>
</tr>
<tr>
<td>Miller and Mercer (1993)</td>
<td>Find what you’re solving for</td>
</tr>
<tr>
<td></td>
<td>Ask what are the parts of the problem</td>
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<tr>
<td></td>
<td>Set up the numbers</td>
</tr>
<tr>
<td></td>
<td>Tie down the sign</td>
</tr>
<tr>
<td>Then to compute the answer…</td>
<td>Discover the sign</td>
</tr>
<tr>
<td></td>
<td>Read the problem</td>
</tr>
<tr>
<td></td>
<td>Answer, or draw and check</td>
</tr>
<tr>
<td></td>
<td>Write the answer</td>
</tr>
<tr>
<td>Montague and Applegate (1993)</td>
<td>Read</td>
</tr>
<tr>
<td></td>
<td>Paraphrase</td>
</tr>
<tr>
<td></td>
<td>Visualize</td>
</tr>
<tr>
<td></td>
<td>Hypothesize</td>
</tr>
<tr>
<td></td>
<td>Estimate</td>
</tr>
<tr>
<td></td>
<td>Compute</td>
</tr>
<tr>
<td></td>
<td>Check</td>
</tr>
<tr>
<td>Polya (1957)</td>
<td>Understand the problem</td>
</tr>
<tr>
<td></td>
<td>Devise a plan</td>
</tr>
<tr>
<td></td>
<td>Carry out the plan</td>
</tr>
<tr>
<td></td>
<td>Look back to verify that the answer is reasonable</td>
</tr>
</tbody>
</table>
| Snyder (1988)          | **Read the problem**  
|                       | **I know statement**  
|                       | **Draw a picture**    
|                       | **Goal statement**    
|                       | **Equation development**  
|                       | **Solve the equation**  |
| Watanabe (1991)       | **Survey the question**  
|                       | **Identify key words and labels**  
|                       | **Graphically draw problem**  
|                       | **Note type of operation (s) needed**  
|                       | **Solve and check problem**  |

*Cited from Babbitt & Miller (1996)*

Other problem-solving strategies have involved introducing a graduated word-problem sequence (Miller & Mercer, 1993). This strategy has primarily been used in the younger grades and involves the progression from words to phrases to sentences, with the numbers still aligned. Then, a traditional word problem paragraph format is presented to the student and the first word problems are presented in the traditional paragraph format problems that do not contain any extraneous information. Once students have mastered these problems, problems with extraneous information are presented; then, students learn to make up their own word problems. According to Babbitt and Miller (1996), the entire graduated sequence is should be taught to students in twenty-one lessons.

Montague, Morgan, and Warger (2000) examined *Solve It!*, a research-based instructional program designed to help students having difficulty in mathematics to solve word problems. Specifically, *Solve It!* was designed to help students learn how to understand a mathematical problem, analyze information, develop logical plans to problem solve, and
evaluate solutions. The program was intended to help improve the problem-solving skills of middle and secondary students who have adequate reading and computational skills, but still have difficulty in solving math word problems. Strategies incorporated into the program were selected based on a review of the literature and a process-task analysis of problem-solving (Montague, 2006). Solve It! also provides teachers the opportunities to use proven instructional techniques in the classroom that help their students acquire and effectively utilize cognitive processes and self-regulation. A math problem-solving routine was developed and tested in a series of studies with middle and secondary students with learning disabilities (Montague, 1992). Results of the various studies conducted by Montague and colleagues have shown the effectiveness of the program with individual students and groups of between 8 and 12 students. After receiving the instruction, the students with learning disabilities were compared to average-achieving peers and performed well. Montague et al. (2000) concluded that the program was successful for students with mathematical LD and could, therefore, be used in inclusive general education and special education classrooms.

Prior to attempting to solve word problems, students must first memorize the cognitive processes and self-regulation strategies necessary for solving them (Montague, 2006). According to Smith (1998), verbal rehearsal is a mnemonic strategy that enables students to memorize. In addition, verbal rehearsal allows students to memorize and recall automatically the labels and definition of the problem-solving strategy. Montague (2006) developed an acronym to help students remember as they verbally rehearse while they are solving word problems. The acronym Montague (2006) developed was RPV-HECC, which stands for the following:

- **R** = Read for understanding
The goal of having students use acronyms is that they will be able to recite from memory the various strategies and processes needed to solve word problems effectively.

Process modeling is another common problem-solving strategy, also referred to as cognitive modeling. Process modeling is simply thinking aloud while showing an activity. When using process modeling, a child simply says everything he or she is thinking and doing while solving a word problem. According to Montague and Applegate (1993), process modeling enhances reading comprehension, computation, and problem-solving skills.

Another theme from the research teaches children to draw diagrams that represent the relationships among quantities in a given problem. Shigematsu and Sowder (1994) recommended students to “make a drawing” and further, Diezman and English (2001) indicated that drawing a diagram will make the relationships in a word problem become clear, thus providing a foundation to solve the problem correctly. Research by van Garderen (2006) showed that students with learning disabilities were less likely to include schematic information in their diagrams than typically-developing students. Moreover, when students were able to create schematic diagrams, they were more likely to produce a correct answer. Fuson and Willis (1989) worked with students of all ages, employing drawings to illustrate three addition and subtraction situations. They found that students who created correct drawings almost always selected a correct solution strategy. Labeling drawings also helps
students better identify the problem type and allow them to solve more difficult problems. Van Garderen’s research (2006) has also shown that with practice, students are able to become more proficient in generating correct diagrams.

Although diagrams have been cited to be powerful visualization strategies for representing word problems which help abstract concepts become more concrete, not all research has found this to be true. Van Garderen (2007) indicated that research examining the relationship between visualization -- both external (diagrams) and internal images (mental imagery) -- and mathematical problem-solving has been somewhat equivocal. Van Garderen’s research (2006) indicated that some studies have found a strong relationship, whereas others have found either a tentative or no relationship.

Overall, van Garderen (2006) reported that the use of diagrams supports the expectations set forth by the NCTM (2000) in that “students are expected to: a) use and create representations to organize, record, and communicate mathematical ideas, b) select, apply, and translate among mathematical representations, and c) use representation(s) to model and interpret physical, social, and mathematical phenomena” (p. 67). According to Dreyfus and Eisenberg (1996), the use of diagrams as a problem-solving strategy will only be effective for a student who has learned to use them in a flexible manner during the problem-solving process.

Another line of research on effective instruction in the area of problem-solving has focused on the utility of providing students with worked examples of word problems. A worked example involves the teacher modeling the problem-solving process prior to students engaging in the problem-solving process independently. Research by Cooper and Sweller (1987) has examined the role of worked examples in problem-solving and suggest that worked examples help students break the process into clear subgoals to aid them in
discovering the relationship to the problem situation as well as to the solution strategy. Furthermore, Cooper and Sweller (1987) found that providing students with worked examples increased their instructional efficiency in addition to improving their transfer for learning.

**Computer-Assisted Instruction**

Computer-assisted instruction (CAI) has been used to support general education and special education students, particularly in the area of reading. The NCTM (2000) calls for using technological tools that allow students to focus on “decision-making, reflection, reasoning, and problem-solving” (p. 24). However, little research has been conducted concerning the use of computers for teaching students mathematics skills, in particular, how to solve word problems. Recognition of the need to teach mathematics to students with learning disabilities has increased significantly over the last decade (Babbitt & Miller, 1996). Despite the amount of research conducted with respect to CAI in special education, few studies have produced conclusive findings on its efficacy with respect to math instruction for students with disabilities. Goldman and Pellegrino (1999) found that extended practice with computers increased automaticity in basic math tasks for children with learning disabilities. Also, Okolo (1992) found that simple drill and practice software programs and computer game formats were both effective in building acquisition and fluency skills.

Researchers have begun to look at the effects of the use of computers on more traditional instruction. According to Babbitt and Miller (1996), the results of these studies have been mixed. For instance, Trifiletti, Frith, and Armstrong (1984) compared the effects of SPARK-80 Computerized Mathematics System to traditional resource room instruction using Steck-Vaughn math workbooks. Trifiletti et al. (1984) found that the computerized program was more effective than the traditional resource room instruction. Also, Berthhold
and Sachs (1974) found that the use of computers with children with learning disabilities produced inferior gains when compared to traditional instruction. A study by Bahr and Rieth (1989) showed that the combination of directed teacher intervention and CAI is more effective than CAI alone. A study by Harskamp and Suhre (2007) explored the effectiveness of two interactive computer programs for high school students. Results indicated that both computer programs improved problem-solving ability more strongly than traditional mathematics instruction. Both weak and skilled students improved with the program. Research also found the programs aided students in improving the quality of their analysis during problem-solving. However, a study by Gleason, Carnine, and Boriero (1990) compared the effects of teacher-directed instruction versus computer-based instruction for students with learning disabilities. Students were taught multiplication and division word problems either by the computer or by a teacher. Researchers found that there was no significant difference between the students who received either the computer or the teacher-directed instruction. Furthermore, a report released by Dynarski et al. (2007) found that at one school, differences in student test scores were not statistically significant between classrooms that were randomly assigned to use mathematics software products and those that were randomly assigned not to use products.

Another potential benefit to CAIs involves the potential for individualizing certain aspects of instruction to the needs of an individual child. For example, CAI interventions often adjust the pacing of instruction and difficulty level to the performance of the student. Also, CAI programs provide the child with extensive opportunities to respond, as well as timely and specific feedback on the accuracy of those responses. CAI programs can also be designed to provide the teacher with assessment data that charts students’ growth on
particular skills. These aspects of instruction have been demonstrated to be particularly effective at improving student outcomes across the curriculum (Trifiletti et al., 1984).

Another theme in the research on effective instruction concerns the use and implementation of anchored instruction. The Cognition and Technology Group at Vanderbilt University (CTGV) (1990) examined the use of anchored instruction and found it to be an effective learning tool. Anchored instruction attempts to enhance learning by centering lessons around a concept, situation or idea that is of interest to students. The CTGV examined the way anchored instruction brings real-life problem-solving contexts into the classroom via computer videodiscs. Through this method, students are taught how to first identify important information and then to come up with their own strategies to find solutions. The CTGV (1990) published a series of video anchors called The Adventures of Jasper Woodbury developed by Goldman, Pellegrino, and Bransford (1994). The series allows students to navigate videodiscs to solve geometry and algebra problems and problems that focus on concepts such a distance and rates. The video anchor presents a realistic scenario to students and consists of multiple problems. The first series, designed for 5th and 6th grade students, involves a person named Jasper Woodbury. The program requires the students to follow Jasper Woodbury on an adventure during which they are required to solve complex mathematical problems. In the first adventure, Jasper sets out for Cedar Creek in a small motorboat to look at an old cruiser for possible purchase. The major goal is to get home before sunset before running out of gas. Throughout the program, students are expected to generate sub-problems that represent possible obstacles to his goal and to invent strategies for solving sub-problems. The goals of the program were to help students develop mathematical skills for formulating and solving word problems and to motivate students to become proficient in the basic skills of mathematics (Reed, 1999).
The CTGV (1990), along with the *GO Solve Word Problems* Position Statement by Snyder (2005), indicated that students need clear mental models in order to make sense of word problems. Furthermore, research by the CTGV concluded that students have a preference for video rather than text formats for building the mental models.

Bottge and Hasselbring (1993) compared the ability of two adolescent groups with learning disabilities to produce solutions to a contextualized problem after being taught problem-solving under the condition of standard word problems and anchored instruction on videodisc. Anchored instruction involved bringing real-life problem-solving via computer videodisc to the classroom and then teaching students to solve complex multiple step problems. The researchers found that both groups improved in their word problem-solving abilities, though students in the contextualized problem group who used anchored instruction performed significantly better in post-tests and transfer tasks.

The results on the benefits of using computer-assisted technology for teaching word problems are mixed. Roblyer (2004) advocates that many technology tools can help students achieve higher levels of understanding by giving them real-life experience relevant to their individual needs. However, research is limited in this area; specifically, more research on the development of effective and useful problem-solving technology for students who struggle with mathematics is needed (Babbitt & Miller, 1993). In fact, with the passage of *No Child Left Behind*, Congress demanded that the U.S. Department of Education conduct rigorous research studies on educational technology and its effectiveness on increasing student achievement (Campuzano, Dynarski, Agodini, & Rall, 2009).

**Problem Personalization**

Another valid research technique to enhance learning has been the personalization of word problems. Usually, word problems contain little or no connection to the individual
student. For example, they are not about people or places familiar to students. According to Brown et al., (1989), it is an obvious fact that word problems never really appear authentic and important to students. Lave (1993) indicated that word problems as a school activity have “no intuitive connections with everyday experiences” (p. 89). Mayer (1984) reported that personalization seems to increase the meaningfulness of the problem text with existing schemata. A study by Ku and Sullivan (2000) indicates personalized word problems are intrinsically more motivational for students because they allow them to draw and maintain their attention on the problem.

Research by Davis-Dorsey, Ross, and Morrison (1991) has shown that personalizing word problems leads to measurable improvements in student motivation and comprehension. Chen and Liu (2007) examined the effects of a personalized computer-assisted mathematic problem-solving program on the performance and attitude of Taiwanese 4th grade students. Results revealed that the personalized computer-assisted program on mathematics improved students’ performance and attitudes. Specifically, the achievement as well as the attitude of the students in the personalized group was significantly higher than those in the non-personalized group. Another study by Anand and Ross (1987) found that after receiving personalized lessons, 5th and 6th grade students scored significantly higher on word problems. They performed better than peers who did not receive personalized instruction solving standard problems.

Overall, according to Chen and Hung (2003), personalized learning that emphasizes and incorporates the application of personal preferences and interests into learning content helps students to learn. Personalized instruction can be an effective way to motivate students and to increase their potential in the study of mathematics (Chen & Liu, 2007).
Schema-based Learning: A Theoretical Explanation

As previously mentioned, most models for understanding and assessing students’ mathematical problem-solving abilities are generally derived from cognitive psychology (Briars & Larkin, 1984; Carpenter & Moser, 1984; Fennema, Carpenter, & Peterson, 1989; Reed, 1999). Primarily, these problem-solving models emphasize the importance of the problem’s semantic characteristics (Silver & Marshall, 1990). However, recent problem-solving research in special education and general education indicates an important move away from direct translation methods and towards strategy-based instruction, problem representation, and dialogue (Woodward, 2006). Research of this kind is vital because of the tendency on the part of so many students, particularly those with learning disabilities, to answer problems impulsively; therefore, it is necessary to explicitly teach students how to analyze the problem schema and how the various parts of the schema are related (Xin & Jitendra, 2006).

Schema-based learning has become a common technique for teaching children how to solve word problems (Jitendra et al., 2002). Schema-based instruction (SBI) teaches students how to establish and expand on domain knowledge in which schemas are the focus. A schema can be described as a general description of a group of problems that share a common underlying solution (Xin & Jitendra, 2006). Schemas are constructed at a relatively high level of generality and can provide a framework for interpreting specific events (Thorndyke, 1984). According to Fuchs et al. (2008), “methods based on schema theory inevitably involve a metacognitive approach because they explicitly teach students to group problems into types with similar underlying mathematical structures and teach students problem-solution rules for each problem type” (p. 157).
When students develop knowledge in a given domain, the knowledge structure eventually takes on the form of schema-mapping of relationships. Jitendra et al. (2002) reported that “schema as a knowledge structure serves the function of knowledge organization” (p. 24). According to Xin and Jitendra (2006), “the goal of schema-based problem-solving instruction is to help students establish and expand domain knowledge in which schemas are the central focus” (p. 53). Further, Marshall (1995) indicated schemata are the bases for understanding and serve as the appropriate mechanism for the problem-solver to “capture both the patterns of relationships as well as their linkages to operations” (p. 67). Jitendra et al. (2002) maintain: “A distinctive feature of schemata is that when one piece of information is retrieved from memory during the problem-solving, other connected pieces of information will be activated” (p. 67). Schemata pertaining to a wide range of problems involve five operations, including “change,” “group,” “compare,” “vary,” and “restate”. Oftentimes, these problem types are seen in word problems typically found in the elementary and middle grades (Van de Walle, 2004). For example, if the whole of the problem is not known, adding the parts is necessary to solve for the whole. On the other hand, if one of the parts is not known, subtracting the part(s) from the whole is needed to solve for the part not known. An important aspect of SBI is an emphasis on integrating all the various pieces of factual information that is known (Xin & Jitendra, 2006).

Jitendra and colleagues have supported schema-based word problem-solving instruction emphasizing conceptual understanding. According to Jitendra et al. (2002), “schema-based representational strategy, with its focus on schemata (i.e., problem pattern or structure) identification is known to benefit both students with learning disabilities and students at-risk for math failure” (p. 24). One of the main elements of a schema-based strategy that distinguishes it from other approaches is the use of schemata diagrams to map
important information and highlight semantic relationships in the problem and provide
greater emphasis on problem-solving heuristic procedures that lead to the correct answer.
describe a problem-solving model that emphasizes explicit schema understanding. The first
step, “Schema Knowledge/Problem Schema Identification”, focuses on the function of SBI,
which is to teach patterns or schema-metacognition. The second step, “Elaboration
Knowledge/Representation”, involves developing a schematic diagram or template that
relates to the representation of the problem identified in the first step. The third step,
“Strategic Knowledge/Planning”, involves setting up goals and sub-goals, selecting the
appropriate operation, and writing math sentence or equation. The final step is “Execution of
Knowledge/Solution”, which allows the students to carry out the plan. Overall, the goal of
schema-based problem-solving instruction is to help students establish and expand domain
knowledge in which the schemas are the central focus (Xin & Jitendra, 2006). SBI explicitly
analyzes the problem schema and the links pertaining to how different elements of the
schema are related. Using schema-based strategies allows students to approach the problem
in a way that focuses on the underlying problem-solving structure, thus leading to a
conceptual understanding and adequate word problem-solving skills (Xin & Jitendra, 2006).

Research has validated the effectiveness of using schematic graphic organizers to
master word problem-solving as well as suggesting successful instructional formats for
teaching this approach. Cooper and Sweller (1987) examined the role of worked examples in
schema-based problem-solving. Worked examples involve presenting students with a
thorough demonstration of working through specific examples. Rather than presenting the
solution path as a whole, worked examples break the process into clear sub-goals which
specifically highlight the relationship to the problem situation, schematic organizer, and the
solution strategy. Cooper and Sweller (1987) found that worked examples increased instructional efficiency and improved transfer of learning. SBI emphasizes integrating the various pieces of factual information essential for problem-solving, rather than focusing on isolating facts (Xin & Jitendra, 2006).

Deatline-Buchman, Jitendra, and Xin (2005) compared the effects of SBI to those of general strategy instruction, which required students to draw pictures on the mathematical problem-solving abilities of 22 middle school students. They found that the SBI group significantly outperformed the general study instruction group on immediate and delayed post-tests and transfer tests. Furthermore, Deatline-Buchman et al. (2005) concluded from that study that the effects of SBI enhanced conceptual understanding and helped to facilitate higher order thinking.

Jitendra and Hoff (1996) conducted a study of three elementary-aged students with learning disabilities who were provided instruction in a schema strategy to solve word problems. The schema strategy consisted of the development of both word problem translation and solution processes to facilitate performance on one-step addition and subtraction word problems involving change, group, and compare problems types. Results of the study revealed an increase in students’ scores on word problem-solving following the schema intervention. In addition, the maintenance of word problem-solving performance two to three weeks following the study was evident for all three students. Another study by Jitendra et al. (1998) examined the effects of a schema strategy and a traditional strategy on the acquisition, maintenance, and generalization of mathematical one-step word problem-solving. Thirty-five elementary students were randomly assigned to two treatment conditions (schema and traditional). Results indicated that the performance of both groups increased from pre-test to post-test. All students had maintained their use of word problem-solving
skills and generalized the strategy effects to novel problems. A study conducted by Xin, Jitendra, and Deatline-Buchman (2005) examined the differential effects of schema-based instruction (SBI) and general strategy instruction (GSI) on the mathematical word problem-solving performance of 22 middle school students who had learning difficulties or were at-risk. Results revealed that the SBI group significantly outperformed the GSI group on all tests -- immediate, delayed, and transfer tests. Overall, according to numerous studies by Jitendra and colleagues, schema-based strategies help students to solve word problems.

A challenge for instructors is to create learning conditions to help students learn rules in mathematics that will enable them to solve word problems in meaningful ways. However, this will require students to learn conceptual knowledge to support their use of procedural knowledge (Reed, 1999). The use of conceptual knowledge enables students to understand why a procedure works because each step can be related and connected to properties of objects that support that given procedure.

**Current Investigation**

As highlighted in the previous section, research on effective problem solving instruction has identified several promising approaches and techniques which allow students to become more successful problem solvers. Research has shown the use of schema strategies for teaching students in general education and special education to be quite helpful (Jitendra et al., 2002; Jitendra et al., 1998; Fuchs et al., 2004; Xin et al., 2005). Most of the schema-based research has primarily focused on using schema-based instruction in elementary school. Research is lacking on using schema strategies in middle school; therefore, this study focused on schema-based strategies used at the middle school level. Specifically, this study taught schema-based strategies to 5th grade students who had been identified as having poor problem-solving skills. The purpose of this study was to examine
the effectiveness of the *GO Solve Word Problems* intervention (Snyder, 2005) which is based on teaching students schema-based strategies. The program also incorporates many of the other effective techniques identified by the research, including GSI, worked examples, drawing diagrams, anchored instruction, CAI, and problem personalization. The present study attempted to extend the existing body of research by examining the effectiveness of this multi-componential intervention in promoting word problem-solving skills in middle school students.

Sixteen students in the experimental group received *GO Solve Word Problems* intervention and sixteen control students continued the standard school-based intervention for students struggling with math word problems. A subset of items from the state mathematic assessment test (MCAS), as well as the Group Mathematics and Diagnostic Evaluation (GMADE), was used to measure student performance. In addition, examiner-made probes were administered to examine student progress. This investigation posed the following hypotheses:

**Ho1:** There is no difference in math problem-solving skills as measured by a subtest of MCAS items taken from previous MCAS tests for students who received the *GO Solve Word Problems* compared to an equivalent group of students who received the standard mathematics curriculum.

**Ha:** Grade 5 students who received *GO Solve Word Problems* will show a statistically significant improvement in math problem-solving skills as measured by a subset of word problem items taken from previous MCAS tests compared to an equivalent group of students who received the standard mathematics curriculum.

**Ho2:** There is no difference in math problem-solving skills as measured by the Process and Application subtest of the GMADE for students who received the *GO Solve Word Problems*
as compared to an equivalent group of grade 5 students who received the standard mathematics curriculum.

**Ha**: Grade 5 students who received *GO Solve Word Problems* will show a statistically significant improvement in math problem-solving skills as measured by the Process and Application subtest of the GMADE compared to an equivalent group of students who received the standard mathematics curriculum.

**Ho3**: There is no difference in math problem-solving skills as measured by examiner-made probes for students who received the *GO Solve Word Problems* intervention as compared to an equivalent group of grade 5 students who received the standard mathematics curriculum.

**Ha**: Grade 5 students who received *GO Solve Word Problems* will show a statistically significant improvement in math problem-solving skills as measured by examiner-made probes compared to an equivalent group of students who received the standard mathematics curriculum.
CHAPTER 2

METHODS

This chapter presents a detailed description of the methods used in the current investigation. First, the participants, setting and criteria for inclusion in the study will be discussed. Next, the dependent measures of the study will be explained as well as social validity measures used. The independent variable, GO Solve Word Problems intervention, will be discussed in depth. Finally, the data analytic plan used in this study will be explained.

Participants and Setting

During the 2008-2009 school year, 32 5th grade students with low performing mathematics scores from one middle school in Western Massachusetts were selected. The population of middle school students was approximately 683; 337 were in the 5th grade and 346 were in the 6th grade (Massachusetts Department of Education, 2009). The median household income for the city was $49,390.

Three reasons supported the use of 5th grade students for this study: (1) even though GO Solve Word Problems is a 3rd through 6th grade intervention, 5th grade students would be likely to benefit from reviewing skills they may have not yet fully mastered as well as learn skills that are required for 5th grade mathematics, (2) the intervention allowed for the measurement of student performance on solving applied problems commonly seen in 5th grade, and (3) it also allowed children to learn strategies for solving applied problems which are commonly seen on the 5th grade state assessment (MCAS).

An a priori power analysis was conducted to evaluate whether the sample size was sufficient to detect a meaningful effect size of .25 in this study. Software G-power was used, given a sample size of 32 for a repeated measures ANOVA (2 repetitions) with alpha = .05,
effect size = .25 and power = .8 requires n = 34. Therefore, given the size of this sample, there was adequate power to detect a meaningful difference.

**Instructional Environments**

The middle school contained approximately 12 5th grade general education classrooms and two language-based inclusion classrooms. The school employed an inclusion model in which Special Educators would primarily enter the general education classroom to provide services to Special Education students.

The core mathematics program employed by the school was the Scott Foresman-Addison Wesley Mathematics Series by Randall Charles, Warren Crown, and Francis Fennell (2005). In addition to having all children receive approximately 45 mins of mathematics daily, all students (regardless of their general or special education status) received MCAS Math for two additional 45-min periods a week.

The MCAS math program began two years prior when the school was found to be making inadequate progress in the area of mathematics. One teacher at the school was employed to teach the MCAS math program. She was originally an elementary school teacher for over twenty years before taking on this position two years ago when the MCAS math program was created.

The MCAS math program did not use an additional mathematics program besides the core curriculum. The MCAS math teacher did not follow a specific scope and sequence. During the two 45 min. blocks, the MCAS math teacher covered the curriculum outlined by the regular classroom teacher. For example, sometimes she reviewed for a test, recapped previously taught concepts, practiced previous MCAS problems, or taught new concepts. Other times, the MCAS math teacher had students complete math worksheets that they would be reviewing at the end of class or had the students engage in various mathematics
activities. For the last three weeks of the school year, during the MCAS math block, students made different mathematics board games.

Criteria for Inclusion

All 5th grade students completed the Group Mathematics Assessment and Diagnostic Evaluation (GMADE) (Williams, 2004) during their MCAS math period. The MCAS math teacher reported that some students finished the GMADE in two sessions while some students took three or four sessions to complete. The entire GMADE was administered during December and January. Children were identified as struggling with word problems if they scored below the 30th percentile on the Process and Application Subtest of the GMADE. Students in special education were included, with the exception of students with severe developmental disabilities (e.g., mental retardation, autism) and severe emotional or behavioral disabilities. However, one child with Asperger’s Syndrome was included in the study.

To screen for reading difficulties, three 3rd grade Dynamic Indicators of Basic Early Literacy Skills (DIBELS) oral reading fluency probes (Good & Kaminski, 2002) were administered since GO Solve Word Problems is written at a 3rd grade readability level. The median score on the three probes was used in the inclusion process. Students who failed to read at the spring of 3rd grade level above the 25th percentile using DIBELS probes were excluded from the study. The primary reason for exclusion was that these students were likely to perform poorly on word problems and applied problems largely due to poor reading skills (Thurber, Shinn, & Smolkowski, 2002).

If students met the above criteria, a consent form inviting them to participate in a mathematics research study was sent home through their homeroom teacher. The assistant
principal followed up with parents whose children were identified as being eligible for the study and encouraged parents to have their children participate.

Thirty-five students met the criteria for inclusion and consented to be in the study. However, one student dropped out after becoming overwhelmed with the pre-testing, one student did not participate due to an extended illness, and a third student failed to meet the reading inclusion criterion. Approximately 337 5th grade students were screened using the aforementioned procedures. Thirty-two children in total participated in the study and were randomly assigned to the experimental or control group; 16 were in the experimental group and 16 were in the control group.

**Characteristics of Participants**

Participants included 10 and 11 year-old 5th graders. Twenty-four were female and eight were male. The experimental group (intervention) was comprised of 15 females and 1 male; the control group (no intervention) was comprised of 7 males and 9 females. Thirty-one were white and one was Asian. The participants’ Massachusetts Comprehensive Assessment System (MCAS) state assessment scores from the 4th grade were obtained. One out of the 32 participants scored in the “advanced” range, 6 scored in the “proficient” range, 18 students scored in the “needs improvement” range, and 2 scored in the “warning/failing” range. MCAS scores could not be obtained for 5 students.

All students in the study were reading at or above the 3rd grade reading level, as indicated by the administration of Dynamic Indicators of Early Basics Literacy Skills (DIBELS) 3rd grade probes. According to the 4th grade English Language Arts MCAS scores, no student was in the “advanced” range, 9 scored in the “proficient” range, 13 students scored in the “needs improvement” range, and 5 scored in the “warning/failing” range on the MCAS mathematics test. MCAS scores could not be obtained for 5 students.
At the end of the study, all participants were administered 5th grade DIBELS probes. In the experimental group, 14 students met the spring benchmark for 5th grade on the oral reading fluency probes, 1 participant was “at some risk” and 1 child was in the “at risk” range. In the control group, 13 students met the spring benchmark of Oral Reading Fluency for 5th grade, 2 students were at “some risk” and 1 student was “at risk.”

Seventeen out of the 32 students received their core mathematics program in their general education classroom; 12 received intensive mathematics, and 3 received mathematics instruction through their special education teacher. The Intensive Mathematics Program was considered general education mathematics; students who were not eligible for special education received “small” group mathematics instruction with approximately 15 other children. The Intensive Mathematics teacher followed the same scope and sequence as the general education classroom teachers. Six out of the 32 students had Individualized Education Plans (IEPs), 1 student was on a 504 plan and 5 students were on district accommodation plans. Two students were identified as English Language Learners. At least 5 students were on IEPs for mathematics.

**Research Design**

The basic format of this study was a one factor between (treatment versus control) and one factor within (pre/post) experimental design.

**Dependent Variables**

Five dependent variables were used in this research study: 1) a subtest of word problems taken from previous MCAS tests, 2) the Group Mathematics Assessment and Diagnostic Evaluation (GMADE) Process and Application subtest, 3) examiner-made probes, and two social validity measures: 4) a mathematics anxiety scale, and 5) a
questionnaire regarding the *GO Solve Word Problems* intervention. Each measure is described in detail below.

**Subtest of MCAS problems**

A subset of word problems items taken from previous MCAS tests were administered pre- and post-intervention to the experimental and control groups. Parallel forms of the test were developed using Item Response Theory (IRT) to create two tests of equal difficulty. Problems from the 2005, 2006, and 2007 5th grade MCAS were used to create parallel forms. Problems were selected from the MCAS which were similar to problems taught in the *GO Solve Word Problems* intervention program. An independent rater also identified problems similar to the *GO Solve* curriculum. The pre- and post- tests were created to both have similar content as well as contain similar difficulty. In this case, the term “parallel” is used to indicate that the content representation of the forms was the same and the test characteristic curves (TCCs) of the resulting forms were as similar as possible. As a consequence, the difficulties of the two forms were nearly identical. Further, since the information functions of the two forms were nearly identical, the two forms were relatively equally reliable, in the IRT context. It was possible to use these two forms interchangeably for the purposes of the research conducted here. The Test Characteristic Curves (TCCs) and descriptive stats on item parameters can be found in the Appendix B and the TCC can be found in Appendix C.

Both the pre- and post-tests consisted of nine multiple choice questions and two open-response questions. Both pre- and post- tests consisted of a total of 11 questions. Nine of the questions were in a multiple choice format and if answered correctly, were each given a score of four points. The remaining two questions were open-ended; each open-ended question was worth four points. If all of the questions were answered correctly, the highest
total score obtained was 17 points. Both the pre- and post-tests were untimed, although most students finished within 30 mins. Administration instructions and the pre-test can be found in Appendix D; the post-test can be found in the Appendix E.

**Group Mathematics Assessment and Diagnostic Evaluation (GMADE)**

The GMADE is a norm-referenced, group- or individually-administered, standards-based assessment of mathematical skills. The GMADE was created to provide a broad sampling of appropriate mathematical tasks. In addition, the GMADE was developed as a diagnostic tool to determine what mathematical skills individuals have and what skills they need to be taught. The GMADE includes 9 test levels. Each of the levels has two parallel forms (A and B). Raw scores from both forms can be converted to grade-based normative scores using fall or spring norms or age-based norms. The test was developed based upon the National Council of Teachers of Mathematics Standards (NCTM, 2000). In this study, raw scores were used.

The GMADE is an untimed, powered test comprised of three subtests: Concepts and Communication, Operations and Computation, and Process and Applications. However, just the Process and Application subtest was administered.

The Process and Applications subtest measures a student’s ability to take the language and concepts of mathematics and apply the appropriate operation(s) and computation(s) to solve a word problem (Williams, 2004). Students on this subtest must apply appropriate strategies when solving problems, and reason and estimate an answer. Each test item within the subtest contains a short passage of one or more sentences and four choices. Most often, the choices are numbers and some are given as pictures or symbols. The Process and Applications items in the lower levels are generally only one-step problems and in the upper levels, more multiple-step problems are included. Some of the problems
included in the upper levels do not require an answer or solution, but rather, the identification of a process or application that would be used to derive an answer (William, 2004). Each of the items consists of a short passage of one or more sentences and four answer choices. The following is a sample item:

In the first year of production, a play sold 1,572 tickets. In its second year, it sold 1,780 tickets, and in its third year, it sold 134 less than in its second year. How many tickets were sold in 3 years?

A) 1,646  
B) 4,998  
C) 3,897  
D) 5,266

The GMADE was standardized on over 1,000 students and testing took place at 143 sites in the United States. Most students in the standardization sample were tested in a group format. A number of quality control procedures were implemented before, during, and after testing. The GMADE did not demonstrate adequate split form and alternative form reliabilities for Fall Form A; the split half reliability was .74 (Williams, 2004). The test-retest reliability for Level 5 was .93. Table 2.1 reports the reliability coefficients for the Level 5 GMADE Process and Application Subtest.
Table 2.1

Level 5 GMADE Process and Application Subtest Reliability Coefficients

<table>
<thead>
<tr>
<th>Type of Reliability</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Split Half Reliability</td>
<td></td>
</tr>
<tr>
<td>Fall Form A</td>
<td>.74</td>
</tr>
<tr>
<td>Fall Form B</td>
<td>.81</td>
</tr>
<tr>
<td>Spring Form A</td>
<td>.84</td>
</tr>
<tr>
<td>Spring Form B</td>
<td>.83</td>
</tr>
<tr>
<td>Alternate Form Reliability</td>
<td>.87</td>
</tr>
<tr>
<td>Test-Retest Reliability</td>
<td>.93</td>
</tr>
</tbody>
</table>

The GMADE showed content validity as it was developed based on the national standards (Principles and Standards for School Mathematics, NCTM, 2000). Concurrent validity was assessed by comparing performance on the GMADE to similar math tests of the Iowa Tests of Basic Skills (ITBS), the TerraNova, and the Iowa Tests of Educational Development (ITED). However, no studies occurred at Level 5 that included the Process and Application subtest.

Examiner-made Progress Monitoring Probes

For a more sensitive measure of change over time, examiner-made probes were created that reflected all three modules in GO Solve Word Problems. Probes consisted of 12 applied problems directly related to problems seen in the GO Solve Word Problems intervention. Specifically, probes contained four problems on Addition & Subtraction, four problems on Multiplication & Division, and four on Advanced Multiplication & Division. Probes consisted of 12 problems which students were given 8 mins to solve. Questions on the probes were similar to those seen on GO Solve Word Problems, but were unique and
unfamiliar to students. Overall, seven probes were created containing 12 problems were administered every other week for 8 min to both the experimental and control groups.

Every other week both the experimental and control group completed the probes in small groups. Students were instructed to work on each problem until the examiner told them to stop. Students had 8 mins to complete as many problems as possible. They were instructed to try every problem, but if they came to a problem they did not know how to complete, they were to draw an “X” through the problem and move on to the next. After 8 mins, students were instructed to stop. (See Appendix F for the instruction for completing the probes.)

The probes were scored manually. Students were given a point for solving a problem correctly and were awarded no points if they got the problem wrong. Students were not awarded partial credit for any problems. Probes can be found in Appendix G.

**Social Validity**

Pre- and post-test measures of social validity were given to both the treatment and control group. Foster and Mash (1999) define social validity as the value, importance, or acceptability of an intervention’s goals, procedures, and outcomes by the “client, and by significant individuals in the participant’s life.” Further, social validity is regarded as a desirable supplemental measure (Wolf, 1978). In the study, the “clients” were the participants in the study and the “significant individual in the participant’s life” was their classroom teacher.

According to Foster and Mash (1999), two methods are used to assess the importance of the intervention’s goal as well as its outcomes: normative comparison and subjective evaluation. Normative comparison refers to comparing the participant’s performance levels
with the performance levels of his or her peers; subjective evaluation refers to qualitative evaluation for instance input or feedback.

Subjective evaluation occurred during the post-testing. All students were asked to complete a mathematics anxiety scale adapted from Wigfield and Meece (1988). Students were asked to complete a 7-point Likert scale -- 1 indicating “not at all” and 7 indicating “very much”. Some of the actual questions were:

1) When the teacher says he/she is going to ask you some questions to find out how much you know about math, how much do you worry that you will do poorly?

2) When the teacher is showing the class how to do a problem, how much do you worry that other students might understand the problem better than you?

The mathematic anxiety scale can be found in Appendix H.

All students in the experimental group were asked to complete a Likert rating scale as well as respond to open-ended response questions. The rating scale was adapted from one created by Lane and Beebe-Frankenberger (2004). Students in the experimental group completed a 17 item survey regarding GO Solve Word Problems. Students responded by circling ratings ranging from 1-7, with 1 indicating that they “disagreed or no” and 7 indicating that they “agreed or yes.” A response of 4 represented “somewhat or so-so.” Items consisted of whether participants: learned a great deal from the intervention, found the intervention useful, and identified some characteristics that they may or may not have liked about the intervention, for instance, being able to personalize the word problems. Some of the questions were:

1. taught me to solve word problems? 1 2 3 4 5 6 7

2. liked the images/graphics? 1 2 3 4 5 6 7
The questionnaire contained 7 open-response items relating to what the participants liked and disliked about the intervention. Also, participants were asked whether they found the graphic organizers and the feedback they received from the computer to be helpful. The researcher explained the instructions to students and clarified any questions that participants had. The actual questionnaire can be found in Appendix I.

Table 2.2

Sequence of the Administration of Dependent Measures

<table>
<thead>
<tr>
<th></th>
<th>Pre Test GMADE/ MCAS/ Probe 1/ DIBELS/ Social Validity Measures</th>
<th>Prob e 2</th>
<th>Probe 3</th>
<th>Probe 4</th>
<th>Probe 5</th>
<th>Probe 6</th>
<th>Post Test GMADE/MCAS/ Probe 7/ DIBELS/ Social Validity Measures</th>
</tr>
</thead>
<tbody>
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<td>Experimental Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Independent Variable**

Participants in the experimental group participated twice a week during their 45 min extra math period called “MCAS Mathematics.” During this time, students received the *GO Solve Word Problems* intervention as well completed examiner-made progress monitoring probes on a bi-weekly basis. Students were given the intervention starting with the 3rd grade Addition and Subtraction problem-solving module and some completed modules up to and
including the Advanced Multiplication and Division. Each student worked at his or her own pace.

*GO Solve Word Problems* is an intervention program developed by Tom Snyder Productions and released in 2005, designed to address the issues students display in math problem-solving. The program attempts to teach students how to better understand word problems before solving them. The program is designed to help students see the underlying mathematical models or situations represented in arithmetic word problems by incorporating research-validated methods that produce good problem-solving habits and improve performance.

More specifically, *GO Solve Word Problems* claims to teach students to become better problem-solvers in math. The program aims for students to better understand and recognize mathematical models or situations represented in arithmetic word problems. The program claims to include and consist of anchored instruction with the research-based approach known as worked examples to illustrate and give students practice using graphic organizers. The purpose of using graphic organizers is to help students represent the information and situation in each word problem. In addition, the graphic organizers attempt to assist the students to construct a concrete, generalizable mental model of the problem that highlights the mathematical relationships among the quantities and values. Also, *GO Solve Word Problems* allows problem personalization, which is thought to build engagement.

The *GO Solve Word Problems* intervention program contains three modules: Addition and Subtraction, Multiplication and Division, and Advanced Multiplication and Division. The program puts forth the following Universal Time Guidelines and Recommendations for use to plan for instruction. The universal time guidelines as stated by the *GO Solve Word Problems* program are as follows:
• Identify a total of five hours of instructional time to be used in 30 or 40 min sessions. Ideally, these five hours will occur within a two to four week timeframe. (This is the amount of time needed for one module.)

• Spend time before and after student software use to discuss new concepts and student questions.

• If needed, use the print resources to extend the concepts beyond software use.

• After students complete the five hours of instructional time, follow up with occasional use of the program (twice per month for 30 or 45 min sessions) to provide students with ongoing problem-solving practice.

As stated previously, *GO Solve Word Problems* contains three modules: Addition and Subtraction, Multiplication and Division and Advanced Multiplication and Division. The Addition and Subtraction Module contains the following topics: adding and subtracting whole numbers, and addition and subtraction problem-solving with whole numbers and decimals as well as fractions. Assignments in this module had students complete practice examples and practice with 1- and 2-digit whole numbers as well as mixed practice problems.

The Multiplication and Division Module covers the following topics: multiplication with whole numbers and decimals, division with remainders, multiplication with rates, area, rectangular arrays, multiplication arrays, and multiplication and division problem-solving with whole numbers, fractions, and decimals. This module contained assignments in which students practiced multiplication and division, multiplication and division with remainders, rates and problems pertaining to area models for multiplication, and geometric area. In this given module, students worked on word-based problems involving multiplication and division. The problems in this module were not straightforward calculation problems.
The Advanced Multiplication and Division Module covers the following topics: finding parts of whole, multiplication with fractions, percent, using scale, ratio, proportion, and multiplication and division problem-solving with whole numbers, fractions, and decimals. Students work with elements of fraction relationships (part, whole, and fractions) and operations with fractions to solve for unknown elements. A subtest of problems involving percents as well as whole number multipliers and working with fractions to understand reciprocal relationships was also given. Students were also presented with problems from earlier modules to ensure cumulative accountability.

The Assignment Sequence

The GO Solve Word Problems program led students through an assignment sequence for each module. Each student worked at his or her own pace to complete targeted tutorials and focused practice. Each module contained mixed practice, enabling students to gain additional experience with problem types. On average, the manual indicates that students would reach the mixed practice assignment after three to five hours of program use.

The Tutorials

The GO Solve Word Problems tutorials provide the instructional foundation for the program. Every tutorial explains a word problem situation and demonstrates its corresponding graphic organizer. GO Solve Word Problems has three modules available; therefore, three tutorials correspond with each given module.

A tutorial sequence is made up of short animations (2 to 3 mins each) and interactive guided practice activities. According to the publisher’s manual of GO Solve Word Problems, the purposes of the instructional sequence are to:
• introduce the word problem situation and its graphic organizer,

• identify the variety of questions that arise in this word problem situation and how the graphic organizer helps to understand them,

• explain specific complexities of the word problem situation and how to use the organizer for more complex problems.

**Completing the Activities**

The interactive activities in the tutorials are examples with familiar contexts and accessible numbers that illustrate a particular word problem situation. Students used graphic organizers throughout the activities. The manual indicates that the organizers should be used to help students sort out the language and numbers in word problems to develop understanding. The program produces ongoing records of students’ work and reports students’ performances in numerous skills, including:

• understanding a word problem situation, particularly in the accurate use of labels and descriptions,

• identifying the known and unknown information in a particular word problem,

• solving the problems posed in these activities.

*GO Solve Word Problems* teaches students how to use a variety of graphic organizers. The problem type and the numerical operation being taught will determine which graphic organizer will be used. The graphic organizers that *GO Solve Word Problems* teaches are illustrated in Figure 2.1.
The Practice Environment

In the practice environment, students were presented with word problems and asked to solve them. The practice environment drew upon a database of problems with many characteristics and levels of difficulty. At times, a problem appeared more than once in the practice environment, but contained different values. When students solved problems in the practice environment, the program captured data about their work, which was then used in two ways. One use is by the researcher, to monitor student practice in solving word problems by printing reports. The second was by the program, to adapt the level of problem difficulty directly in response to student performance.
As a student demonstrated a high level of success in solving problems, the program adjusted the problem difficulty slightly upward to keep the student challenged. If a student demonstrated a lack of success in solving problems, the program adjusted the problem difficulty slightly lower to present simpler problems. Also, at times, problems posed two different kinds of answer formats: a selected response (multiple-choice) or a composed response (type-in answer).

Students used the program’s practice environment at key points in the assignment sequence: to practice a specific set of word problems immediately following a tutorial, and to practice a mixed set of word problems at the end of the assignment sequence. Students also had the ability to practice what they’ve learned by going to the Review and Practice Menu.

**Performance Feedback**

Upon completion of a tutorial, students saw a “Tutorial Complete” screen with a performance indicator. The indicator on the screen is a broad measure of the student’s performance during a tutorial; the print report had more specific measures on a skill-by-skill basis. Performance was reported as “excellent,” “good,” or “needs work.”

According to the *GO Solve Word Problems Manual*, one of the most important measures of student performance is the ability to answer the problem correctly on the first attempt. This measure appeared prominently on most practice performance reports. Students had the opportunity to make as many attempts as they liked to answer a problem. After the second incorrect answer, the feedback included an option to skip the problem. Students earned points while solving problems in the practice environment. A student could earn:

- 2 points for solving a problem correctly on the first try
- 1 point for solving a problem on the second try
• 0 points for solving a problem on a later try.

Students accumulated points throughout the program. Upon completing a set of practice problems, a student saw a screen about his or her performance. Several indicators appeared:

• a text message about the student’s performance
• the percentage of problems answered correctly on the first attempt
• the tutorials covered
• the number of problems solved and problems attempted
• the number of points earned and points possible.

**Mixed Practice**

Modules concluded with an assignment to practice solving a mixed set of word problems. The final stage of the assignment challenged students to solve word problems from all the situations that had been covered in the tutorials; the Mixed Practice drew from all earlier types of word problems within the module. The assignment remained at Mixed Practice once it had been reached. Therefore, a student may have continued to solve Mixed Practice word problems for quite some time.

**Research into Practice**

According to the creators of *GO Solve Word Problems*, the program incorporates five research-validated tenets that have been shown to produce good problem-solving habits (*Go Solve Word Problems*: Teacher’s Guide, 2005).

1) **Schema-based instruction helps develop the ability to generalize problem-solving.**
   
   *GO Solve Word Problems* introduces students to the most common types of arithmetical situations reflected in word problems. Students learn to think about categories of problems rather than to attack each problem as a new and separate task.

2) **Drawings and diagrams effectively support the creation of mental models.**
*GO Solve Word Problems* presents a different graphic organizer for each problem situation. Using these diagrams to represent the problem, students gain and retain word problem-solving skills.

3) **Animated anchors teach students how to transfer their understanding.**

*GO Solve Word Problems* offer multiple visual examples for each mathematical situation. Students learn to connect the abstract organizers to a range of problem contexts.

4) **Breaking the problem-solving process down into sub-tasks improves mastery of learning.**

Students first parse a mathematical situation into the organizer. Next, students identify known and missing information. Finally, students compute the answer.

5) **Personalizing problems enhances motivation and access to problem context.**

To make the word problems more relevant and motivating for the students, *GO Solve Word Problems* allows students to personalize their word problems.

**Procedure**

In December and January, the GMADE was administered to all 5th grade students during MCAS Mathematics. Once students were identified as meeting the Inclusion/Exclusion criteria described above, the following occurred. In the middle of February, invitations and consent forms to participate in the study were sent to all 5th grade students who met the inclusion criteria. Classroom teachers distributed the invitations and consent forms to students in their classrooms and recommended to their students and parents to participate in the study. The assistant principal then followed up with phone calls to families who had not returned their consent forms. (See Appendix A for consent form sample).

Once all the consent forms were received, children completed all pre-testing measures, which included the MCAS problems, the Process and Application subtest from the GMADE, DIBELS, and math anxiety scale. Students then were randomly assigned to the treatment (*GO Solve Word Problems* intervention) and the control (no treatment) groups. Once the students in the experimental group were randomly chosen, they no longer attended
the two periods of MCAS mathematics. Students instead received the *GO Solve Word Problems* intervention, and the control group continued with the two periods of MCAS mathematics per week. The *GO Solve Word Problems* intervention started in March and ended in June. Below is a detailed timeline for screening, pre-testing and post-testing.

Table 2.3

*Timeline for Screening, Pre-testing, Intervention, and Post-testing*

<table>
<thead>
<tr>
<th>December/January</th>
<th>February</th>
<th>March</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening/the GMADE administered to all 5th grade students</td>
<td>Students invited to participate</td>
<td>Pre-testing all participants: Pre-test subtest of MCAS math problems, Examiner-made Probe 1, and DIBELS 3rd grade oral reading fluency</td>
<td>Experimental Group Completed the <em>GO Solve Word Problems</em> intervention</td>
</tr>
<tr>
<td>Researcher scored GMADE and identified students who meet inclusion criteria</td>
<td>Assistant Principal contacted parents and encouraged them to have their child participate</td>
<td>Participants randomly assigned to experimental and control groups</td>
<td>Post-testing all participants: Post-test subtest of MCAS math problems, GMADE Process and Application subtest, and Probe 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experimental Group started the <em>GO Solve Word Problems</em> intervention</td>
<td></td>
</tr>
</tbody>
</table>

**Criteria for Moving on**

The *GO Solve Word Problems* program did not have specific criteria for recommending students to move on from one module to the next. Therefore, it was decided that children would have to receive three weeks of the intervention before they could move on to the next module. Moreover, in order to move on to the next module, students had to score at least an 85% on mixed practice problems for at least two consecutive sessions.
Prizes for Participation

Every other week, prizes were given to students after they completed the examiner-made probe. Students were given pencils and highlighters for completing the probes. At the end of the study, all participants were given an ice cream party as well as additional prizes.

Control Group

Students who were in the control group continued in their two regular extra math periods, MCAS Mathematics, each week. At both the start and completion of the study, students completed the subset of MCAS problems, form A and B of the Process and Application subtest of the GMADE, and the math anxiety scale. In addition, students in the experimental and control groups completed a 12 problem examiner-made probe every other week during their MCAS mathematics class.

Data Analytic Plan

This research study was a 2x2 mixed design study. To address the research questions in this study, several analyses were used. Analysis of Covariance (ANCOVA) was performed on the gain scores (post-test- pre-test) using the pretest as the covariate scores to assess whether the treatment group improved more than the control group on MCAS and GMADE separately. The purpose of using the covariate was to increase power through the reduction of error. To control the type 1 error rate for testing conceptually related dependent variables, the Holm (1979) sequential rejection procedure was used. Also, as a result of the study’s directional hypothesis, statistical tests were conducted using one-tail significance.
criteria. Since SPSS provides statistics at the .05 alpha level; two tailed p-values were divided by two to yield one-tailed p-values.

Linear and quadratic trend across the seven probes were examined. Again, the Holm (1979) sequential rejection procedure was used. In addition, Analysis of Covariance (ANCOVA) was used to examine levels of anxiety between the treatment and control groups; pre-anxiety scores were used as the covariate.
CHAPTER 3

RESULTS

This chapter will present the following material: (1) the rationale for the use of one-tailed tests, (2) descriptive statistics (means and standard deviations) for the dependent measures for both the control and experimental groups, (3) analysis of both dependent variables (items from previous MCAS tests and Process and Application subtest from the GMADE), (4) analysis of Progress Monitoring Probe data, (5) analysis of Social Validity data, (6) report of students’ self-rating of their experiences with the GO Solve Word Problems intervention, and (7) report of students’ levels of anxiety. As a reminder, the hypotheses being tested in this study are:

**Ho1:** There is no difference in math problem-solving skills as measured by a subtest of MCAS items taken from previous MCAS tests for students who received the GO Solve Word Problems compared to an equivalent group of students who received the standard mathematics curriculum.

**Ha:** Grade 5 students who received GO Solve Word Problems will show a statistically significant improvement in math problem-solving skills as measured by a subset of word problem items taken from previous MCAS tests compared to an equivalent group of students who received the standard mathematics curriculum.

**Ho2:** There is no difference in math problem-solving skills as measured by the Process and Application subtest of the GMADE for students who received the GO Solve Word Problems as compared to an equivalent group of grade 5 students who received the standard mathematics curriculum.

**Ha:** Grade 5 students who received GO Solve Word Problems will show a statistically
significant improvement in math problem-solving skills as measured by the Process and Application subtest of the GMADE compared to an equivalent group of students who received the standard mathematics curriculum.

**Ho3:** There is no difference in math problem-solving skills as measured by examiner-made probes for students who received the *GO Solve Word Problems* intervention as compared to an equivalent group of grade 5 students who received the standard mathematics curriculum.

**Ha:** Grade 5 students who received *GO Solve Word Problems* will show a statistically significant improvement in math problem-solving skills as measured by examiner-made probes compared to an equivalent group of students who received the standard mathematics curriculum.

### Use of One-Tailed Tests and Reducing Risk of Type 1 Family-wise Error

In this study, one-tailed tests were conducted because the treatment group was expected to have greater gains pre- to post-test. Since SPSS computes statistics at the .05 alpha level, two-tailed p-values were divided by two to produce one-tailed p-values. In addition, to decrease the chances of a Type 1 error, the Holms Sequential Rejection procedure (Holm, 1979) was used. The Holm step down procedure required the ordering of the p-values from the smallest to largest (p1, p2,…etc.) the p-values of the statistical tests in a given family/hypothesis. Next, the first p-value was compared to the conservative alpha: alpha divided by the number of tests that were in the family.

### Descriptive Statistics

#### Means and Standard Deviations for Pre-Test Measures

The means and standard deviations for the pre-test measures are presented in Table 3.1. These statistics provide a picture of how these two groups of students were functioning on math problem-solving prior to the onset of the intervention. As seen in Table 3.1,
students in the experimental group earned slightly lower scores on average than students in the control group on the MCAS test administered at pretest (3.94 and 4.56 respectively). Given that students could earn a maximum of a total of 17 points on the pre-MCAS test, these results suggest that students in both the experimental and control groups were performing poorly on this measure of word problems taken from previous 5th grade MCAS tests. Table 3.1 also shows that students in the experimental group earned similar scores on average as compared to students in the control group (9.19 and 9.44 respectively) on Form A of the GMADE. Students could have earned a possible 30 points on the GMADE; results suggest that students across both groups were answering less than a third of the question correctly on average. Pre-test scores on the first of the seven probes administered are also presented in Table 3.1. Students in the experimental group obtained an average score of 3.19 as compared to students in the control group who obtained an average score of 3.63. Students were able to earn a total of 12 possible points on each of the probes administered; again, this indicates that students answered less than a third of the questions correctly on average prior to the onset of the intervention. Pre-test anxiety scores also showed small differences between the groups, with the experimental group earning an average score of 39.75 and the control group earning an average score of 34.69. This indicates that students in the experimental group were exhibiting higher levels of anxiety on average than students in the control group.
Table 3.1

Descriptive Statistics at Pre-test

<table>
<thead>
<tr>
<th>Pre-test Measure</th>
<th>Experimental Group Mean (SD)</th>
<th>Control Group Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAS</td>
<td>3.94 (4.33)</td>
<td>4.56 (1.63)</td>
</tr>
<tr>
<td>GMADE</td>
<td>9.19 (2.04)</td>
<td>9.44 (1.97)</td>
</tr>
<tr>
<td>Probe 1</td>
<td>3.19 (1.83)</td>
<td>3.63 (2.36)</td>
</tr>
<tr>
<td>Anxiety</td>
<td>39.75 (13.7)</td>
<td>34.69 (11.43)</td>
</tr>
</tbody>
</table>

Means and Standard Deviations for Post-test Measures

The means and standard deviations for the post-test measures are presented in Table 3.2. These statistics provide a picture of how these two groups of students were functioning on math problem-solving after the intervention was completed. As seen in Table 3.2, students in the experimental group earned a score of 8.19 on average and students in the control group on the MCAS test administered at post-test earned a score of 6.13. Table 3.2 also shows that students in the experimental group earned a score of 12.69 on average as compared to students in the control group who earned a score of 11.38 on average on Form B of the GMADE. Table 3.2 shows the post-anxiety scores for the experimental group averaged 35.88; the control group earned an average score of 36.25.

Table 3.2

Descriptive Statistics at Post-test

<table>
<thead>
<tr>
<th>Post-test Measure</th>
<th>Experimental Group Mean (SD)</th>
<th>Control Group Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCAS</td>
<td>8.19 (3.06)</td>
<td>6.13 (3.69)</td>
</tr>
<tr>
<td>GMADE</td>
<td>12.69 (3.79)</td>
<td>11.38 (3.79)</td>
</tr>
<tr>
<td>Anxiety</td>
<td>35.88 (8.68)</td>
<td>36.25 (10.89)</td>
</tr>
</tbody>
</table>
MCAS Pre-Post Test Analysis

The means and standard deviations for the gain scores on the MCAS measure are presented in Table 3.3. Students in the experimental group on average gained 4.25 points from pre- to post-test, while students in the control group gained only 1.56 points on average. These descriptive statistics suggest the experimental group demonstrated higher levels of improvement than the control group.

Table 3.3

*Means and Standard Deviations for Gain Scores by Group*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>ADJ M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>16</td>
<td>4.25</td>
<td>4.15</td>
<td>3.02</td>
</tr>
<tr>
<td>Control</td>
<td>16</td>
<td>1.56</td>
<td>1.66</td>
<td>3.35</td>
</tr>
</tbody>
</table>

To determine whether the intervention produced higher adjusted gain scores (relative to the control condition), an analysis of covariance (ANCOVA) was conducted to examine differences in the gain scores controlling for pre-treatment differences between the groups. The adjusted gain scores on the MCAS measure were significantly higher for the treatment group compared to the control group, t=2.16, p=.019. The alpha level was .025 after controlling for family-wise error rate using the Holms Sequential Rejection procedure. The standardized mean difference was .78, which indicated a moderate to large effect size. These results suggest that the experimental group who received the GO Solve intervention...
performed better on MCAS problems than students in the control group. Given these results, the null hypothesis Ho1 is rejected, indicating the *Go Solve Word Problems* intervention did improve word problem-solving in this sample of 5th grade students as compared to those students who received the standard mathematics curriculum.

**GMADE Pre-Post Test Analysis**

The means and standard deviations for the pre- gain scores on the GMADE measure are found in Table 3.3. Students were able to earn a possible raw score of 30 on the post-test of the GMADE. These results indicate that students in the experimental and control groups were still getting less than half the questions correct on average. Students in the experimental group on average gained 3.50 points from pre- to post-test, while students in the control group gained only 1.94 points on average. These descriptive statistics suggest the experimental group demonstrated higher levels of improvement than the control group.

Table 3.3

*Means and Standard Deviations for Gain Scores by Group*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>M</th>
<th>ADJ M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>16</td>
<td>3.50</td>
<td>3.43</td>
<td>3.56</td>
</tr>
<tr>
<td>Control</td>
<td>16</td>
<td>1.94</td>
<td>2.01</td>
<td>4.15</td>
</tr>
</tbody>
</table>

To determine whether the intervention produced higher adjusted gain scores (relative to the control condition), an analysis of covariance (ANCOVA) was used to examine the gain scores controlling for pre-treatment differences between the groups. After adjustment by the covariate, gain scores on the GMADE measure were not significantly higher for the
treatment group as compared to the control group, $t= 1.06$, $p=.075$. This indicates that no significant difference was found between the performance of the experimental and control groups on the word problem-solving skills as based on the GMADE. Given these results, the null hypothesis $H_0$ is not rejected, indicating that students who received the *GO Solve Word Problems* intervention did not show a statistically significant improvement on the Process and Applications subtest of the GMADE as compared to those students who received the standard mathematics program.

**Probe Data Analysis**

Seven examiner-made probes were administered every other week to all students participating in the study. Each probe contained 12 word problems similar to problems found in the *GO Solve Word Problems* modules. Children were given 8 mins to complete each probe. The means and standard deviations of the scores on the 7 probes for the experimental and control groups are presented in Table 3.4. Visual inspection of Table 3.4 shows that both the experimental and control groups showed similar scores for the first four probes; however, after the fourth probe, a noticeable increase in number of questions answered correctly by the experimental group emerged.

Table 3.4

*Means and Standard Deviations of Examiner-Made Probes at Seven Time Points*

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
</tr>
<tr>
<td>Probe 1</td>
<td>3.19 (1.83)</td>
<td>3.63 (2.36)</td>
</tr>
<tr>
<td>Probe 2</td>
<td>3.00 (1.75)</td>
<td>3.63 (2.16)</td>
</tr>
<tr>
<td>Probe 3</td>
<td>2.94 (2.11)</td>
<td>3.44 (1.93)</td>
</tr>
<tr>
<td>Probe 4</td>
<td>4.13 (1.82)</td>
<td>4.25 (2.24)</td>
</tr>
<tr>
<td>Probe 5</td>
<td>4.88 (2.42)</td>
<td>3.69 (2.18)</td>
</tr>
<tr>
<td>Probe 6</td>
<td>5.63 (2.31)</td>
<td>4.44 (2.83)</td>
</tr>
<tr>
<td>Probe 7</td>
<td>6.25 (2.70)</td>
<td>4.56 (2.50)</td>
</tr>
</tbody>
</table>
To examine the relationship among the scores of the probes as a function of group membership, a multivariate analysis of covariance (MANCOVA) was conducted, controlling for pre-treatment differences on the MCAS scores. The dependent variables in these analyses consisted of seven examiner-made probe scores that were administered at two week intervals.

Since a significant interaction was found between group membership and performance on the probes, trend analyses were conducted to determine whether a polynomial function fit the data. Specifically, the relationship among the dependent variables was examined for significant linear and quadratic trends by group. Mean probe scores for each group across the seven time points are presented in Figure 3.1.

Figure 3.1 Estimated Marginal Means of Measure

In addition, there was a significant interaction between probe and group, indicating that the linear relationship was different for the experimental and control groups (F = 18.37, df = 1, p=.000).
A test of within subject contrasts on the probe data indicated that the probe data were not quadratic overall ($F = .97$, df = 1, $p = .33$). In addition, there was no significant interaction between probe and group, indicating that the quadratic relationship was not different for the experimental group and control groups ($F = 1.41$, df = 1, $p = .25$).

Both the experimental and control groups showed improvement on the seven probes. However, the slope for the experimental group was steeper than the slope for the control group. Trajectory of the slope was dependent on group assignment. Students in the experimental group were answering more word problems correctly than students in the control group.

Based on these analyses, Ho3 is rejected, indicating that students who received the *GO Solve Word Problems* intervention showed a significant improvement over time as measured by the above probes compared to students in the control group.

**Math Anxiety Analysis**

The adjusted means scores on the Math Anxiety scale measure are in Table 3.5. Students in the experimental group earned an average score of 39.75; students in the control group earned an average score of 34.69.

**Table 3.5**

*Means and Standard Deviations for Gains on the Mathematics Anxiety Rating Scale*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Gain M</th>
<th>ADJ M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>16</td>
<td>-3.88</td>
<td>-2.17</td>
<td>16.23</td>
</tr>
<tr>
<td>Control</td>
<td>16</td>
<td>1.56</td>
<td>-.15</td>
<td>6.47</td>
</tr>
</tbody>
</table>
To determine whether the intervention produced higher adjusted gain scores (relative to the control condition), an analysis of covariance (ANCOVA) was used to examine the gain scores controlling for pre-treatment differences between the groups. The results of this analysis indicate that while the experimental group reported less math anxiety on average at the end of the 12 week intervention, adjusting for the covariate, there was no statistically significant difference between the groups \((F=1.55 \ df \ 1, 30, p=.11)\). Given these results, the null hypothesis \(H_04\) is not rejected, indicating that students who received the \(GO\ Solve\ Word\ Problems\) intervention did not show a statistically significant decrease in anxiety as compared to those students who received the standard mathematics program.

**GO Solve Student Survey**

The \(GO\ Solve\ Word\ Problems\) student intervention examined the degree to which participants enjoyed the program, and which components they found most helpful. Students responded to a total of 17 items by circling ratings ranging from 1-7, with 1 representing “disagree” or “no” and 7 representing “agree” or “yes.” Items in this survey contained questions relating to the value of the intervention (e.g., taught me to solve word problems), and likeability of different features the intervention contained (e.g., liked that I could personalize the problems). Table 3.6 shows the means and standard deviations of the \(GO\ Solve\ Word\ Problems\) student survey.

Table 3.6 continued on the next page

*Means and Standard Deviations of the GO Solve Student Survey*

<table>
<thead>
<tr>
<th>Item</th>
<th>Response Mean (M)</th>
<th>Standard Deviation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The program was fun for me to use?</td>
<td>5.40</td>
<td></td>
</tr>
</tbody>
</table>
Most students agreed that they learned a great deal from the intervention and that it taught them to solve word problems. Also, most students agreed that they liked the fact that the intervention was on the computer and they could personalize the word problems. Students reported that they found the graphic organizers to be somewhat helpful in solving word problems. Students also responded to open-ended questions. For example, students when were asked: “What did you like about GO Solve Word Problems?” one student responded: “It helped a lot with my division of fractions.” Another student commented: “I liked the graphics and that problems could be personalized.” Many students alluded to the fact that they liked going on the laptops each week. Students were also asked what they did not like about GO Solve. Numerous students indicated that the fraction problems were really difficult for them. Also, students indicated that they did not like the way the program calculated their progress. Students indicated that they found the graphic organizers
helpful, but a few students reported they found them confusing. Furthermore, a majority of the students reported wanting to use *GO Solve* next year.
CHAPTER 4

DISCUSSION

First, this chapter will summarize the results of the current study and offer potential theoretical explanations of the obtained results. Second, the limitations of this study will be discussed and future research questions will be discussed. Finally, suggestions will be made for ways to better teach children problem-solving math skills in middle school.

Results Summarized

The current investigation examined the effects of GO Solve Word Problems, a computer-based intervention program that teaches students schema-based strategies for solving word problems. The GO Solve Word Problems intervention program was tested on 5th grade students who struggled in the area of problem-solving. Results of pre- post-test analyses showed that there was a statistically significant difference in gain scores between the experimental group and the control group on a subtest of MCAS questions, using the pre-MCAS score as a covariate. However, the results of the pre- post-test analyses did not show a statistically significant difference between the experimental and control groups on the Process and Application subtest of the GMADE. Also, an analysis of examiner-made probes revealed a statistically significant difference between the experimental and control groups on the seven probes administered. On a mathematics anxiety scale, results indicate that while the experimental group did report less math anxiety at the end of the 12 week intervention, there was no statistically significant difference between the two groups.

Despite the fact that a statistically significant difference was found on a subset of MCAS questions, no statistically significant difference between the experimental and control groups was found on the GMADE. These results may be explained by a variety of reasons.
First, the reliability of Forms A and B of the GMADE has come into question (Williams, 2004). Another reason is that MCAS questions were specifically selected to mirror those found on the GO Solve Word Problems intervention. Therefore, the MCAS measure was thought to be a more sensitive measure of student progress in math word problem-solving skills than the GMADE. Also, the GMADE contained some questions that the GO Solve intervention did not address, for example, questions on measurement. Therefore, these questions were irrelevant given that the intervention did not target this skill.

**Theoretical Explanations**

A host of theories could explain why improvements in the experimental group’s problem-solving skills were observed. The results of this study are consistent with the work of Jitendra and her colleagues on schema-based learning (Jitendra et al., 2002; Jitendra et al., 1998; Xin and Jitendra, 2006; Fuson and her colleagues (Fuson, 2003; Fuson, Carroll, & Landis, 1996; Fuson, & Willis, 1989) and the work of Greer (Greer, 1997; Greer, 1992). Research has shown the benefits of Schema-based Instruction (SBI) versus General Strategy Instruction (GSI) for teaching children how to become effective problem-solvers.

SBI instruction explicitly teaches students how to analyze the problem and then helps them establish links between information in the word problem and different parts of the schema. The links made are essential for helping children select the appropriate operation to solve the word problems (Xin & Jitendra, 2006). Jitendra et al. (1998) compared schema-based instruction to a traditional basal strategy with learning-disabled students in the elementary grades. Results indicated that teaching students’ schema-based instruction could raise the achievement of learning-disabled and at-risk students to the levels of their non-disabled peers. Jitendra et al. (2002) extended this research on teaching schema-based strategies to the middle school level. Research conducted at the middle school level has
focused on teaching students schema-based strategies relating to multiplication and division. Jitendra et al. (2002) found that when middle school students were taught schema-based strategies, they gained and retained problem-solving skills they had learned. Furthermore, Jitendra and her colleagues have shown that students are able to generalize the skills they learn through SBI instruction to other novel word problems.

During the 1990s, cognitive research showed that teaching students to search for a keyword, for example, every time they see the word “more”, it means to “add”, was limiting (Woodward, 2006). In addition, research by Hegarty and her colleagues found that when students are taught the typical strategy to search for a keyword and do not spend ample time representing the problem, they are prone to a significant number of errors (Hegarty et al., 1992). The recent research on teaching problem-solving to students suggests a shift away from translation methods toward strategy-based instruction and problem representation (Jitendra, 2002; Woodward, 2006). The results of this study support the efficacy of this recent trend. The GO Solve intervention program aids students in understanding the mathematical models represented in arithmetic word problems by using research-validated methods. For example, the program teaches students to develop a “mechanism for thinking about classes of problems rather than attacking each problem as a separate and distinct task” (Snyder, 2005 p. 5). Teaching this problem-solving strategy has been found to be successful with a range of students.

The GO Solve Word Problems intervention program builds upon previous research by Fuson (1996) and Greer (1992), who have determined that word problems can be characterized according to the set of relationships among the quantities in the problem. Fuson (1996) identified three main categories of addition and subtraction problems: those involving a change in quantities, those involving a combination of two groups, and those
involving a comparison of two quantities. Similarly, when teaching students story problems requiring them to use multiplication and division, Greer (1992) found that the strategy of identifying three whole-number situations, in particular, equal groups, multiplicative comparisons and areas and arrays increased their problem-solving skills. One reason for the success of *GO Solve* may be that it capitalized on this research, teaching students to recognize a problem as one of these problem types. Students then execute a solution strategy specific to the problem type, rather than treating each problem as a word situation.

Another possible explanation for the improvement in problem-solving skills of students who received the *GO Solve* intervention program was because it taught them how to incorporate visual representation in solving mathematical word problems. According to Shigematsu and Sowder (1994), a recommended strategy for solving mathematical word problems is drawing a picture. Researchers have hypothesized that having students draw a diagram will make the relationship in the word problem clearer for students (Diezmann & English, 2001). Willis and Fuson (1988) worked with students as young as 2nd grade, teaching them drawings which reflected three addition and subtraction situations. They found students who created a correct drawing almost always selected the correct solution strategy. The *GO Solve* intervention incorporated the use of differentially sized boxes for additive compare problems that have been shown to be successful (Willis & Fuson, 1988). Therefore, the *GO Solve* intervention program introduced students to graphic organizers matched to the problem types that were reviewed and guided by leading mathematical research experts Fuson and Greer.

Another possible explanation for the success of the *GO Solve* intervention is that the participants enjoyed having the ability to personalize their word problems. Research has shown that when children are given the opportunity to personalize word problems, they are
more likely to learn and to have an increased motivation to learn (Davis-Dorsey et al., 1991).

Typically, students encounter word problems that have little or no connection to their daily lives. However, through the use of technology, *GO Solve* gives students the opportunity to personalize word problems. Students could enter in familiar people, places and things, and then their contributions would be immediately incorporated into the word problem. For example, students were able to type the name of their school into the word problem, or enter in the names of a favorite rock band, or their best friend. Once entered, this information would immediately be incorporated into the worked example problem. For instance, one student entered that her favorite performer was “Britney Spears.” The problem then read:

```
For concerts, customers can usually buy concert tickets with either cash or credit card. A total of 660 concert tickets were sold to see Britney Spears. 390 of the tickets were paid for with cash and ___ were paid for with credit cards.
```

She then went on to solve the problem with the performer of choice incorporated within the context of the problem. Students had various opportunities throughout the program to personalize the word problems. They were given a specified amount of time to personalize their word problems; this prevented them from spending too much time on personalizing the problems. Giving students the opportunity to personalize their word problems increased their motivation and desire to perform well.

Researchers have shown the benefits of providing anchored instruction to students (Cognition and Technology Group at Vanderbilt University, 1990). Anchored instruction attempts to enhance learning by centering lessons around a concept, situation or idea that is of interest to students. *GO Solve* employed the use of anchored instruction to help students visualize the relationship between the graphic organizers and the actual, real-world problems they represent. In addition, the program used multiple visual examples to help students
construct mental models of what the words and diagrams meant. Research by the Cognition and Technology Group at Vanderbilt University (1990) has shown that students are in need of clear mental models to make sense of the problems they encounter, and that there is a preference for video rather than text formats for building those mental models. Through the use of videos in GO Solve, students are able to create better mental models. For instance:

an animated marching band facilitates students’ construction of a mental model of an array situation in multiplication. A school bus that picks up students on its way to school depicts a change situation in addition. One teacher giving three times as much homework as another illustrates a multiplicative relationship captured by the multiplicative comparison graphic organizer. (Snyder, 2005, p. 8)

Also, Shyu (2000) investigated the effects of computer-assisted videodisc-based anchored instruction on attitudes toward mathematics and instruction as well as problem-solving skills among elementary students. Results of the study revealed students’ problem-solving skills improved significantly with anchored instruction. In addition, results showed that all the students benefited from the effects of anchored instruction on their problem-solving performance regardless of their mathematics and science abilities. The results of this study on the effectiveness of the GO Solve intervention, coupled with the research of Shyu (2000), show that video-based anchored instruction can create an environment that motivates and enhances students’ problem-solving skills.

The GO Solve program also draws on the research of Cooper and Sweller’s (1987) worked examples in schema-based problem-solving. Worked examples involve presenting students with a thorough demonstration of working through specific problems by breaking the process into clear subgoals, specifically highlighting the relationship to the problem situation, schematic organizer, and the solution strategy (Atkinson, Derry, Renkl, & Wortham, 2000). Research has shown that worked examples increased instructional
efficiency and improved transfer of learning (Cooper & Sweller, 1987). Providing students with worked examples helped them to gain a more thorough understanding of what they were learning. In GO Solve, worked examples were provided regularly in the module tutorials. Then the students were able to continue with solving problems within the module. For instance,

for Equal Parts situations, the program focuses on variations of the number of cans of paint it takes to paint a house. Students start by placing the words in the graphic organizer -- the total number of houses, the total number of cans of paint and the number of cans of paint per house. Next, students replace the words with numbers, identifying what information is missing. The problem starts simply with 5 houses each requiring 3 cans of paint. Then the numbers get bigger, 73 large houses each needing 12 cans of paint. What if it’s 6 dog houses that each only needs ½ of a can of paint? Each example follows the same process, regardless of the size of form of the numbers. Students compute the answers as a final step, after they demonstrate an understanding of each problem through the help of the graphic organizer. Working deeply through an example helps students gain a more thorough understanding of what they are learning.

(Snyder, 2005, p. 9)

NCTM (2000) produced mathematics standards, including six principles: equity, curriculum, teaching, learning, assessment, and technology. The technology standard stands out, given that GO Solve was a computer-based intervention. Researchers such as Bouck and Flanagan (2009) identify technology as one means of leveling the playing field for struggling students, particularly students with disabilities. The technology principle in Principles and Standards for School Mathematics (NCTM, 2000) stipulated that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p.24). Blackhurst (2005) noted an assortment of benefits regarding technology use with students with disabilities. Furthermore, Bender (2001) reported that technology can be a motivating factor for all students, especially students with disabilities. GO Solve offered students the benefits of technology. According to Edyburn (2003), the
field of mathematics has not realized all of the benefits of technology in the domain of mathematics teaching and learning, particularly in considering assistive technology and its potential to support and enhance learning.

The use of assistive technology, particularly *GO Solve*, provided students with numerous opportunities to respond (OTR). Providing students with opportunities to respond is an important component of effective instruction. An OTR can be defined as the interaction between a teacher’s academic prompt and a student’s response (Haydon, Mancil & Van Loan, 2009). *GO Solve* provided students with ample opportunities to respond. When students correctly responded to a problem, the computer provided them with immediate feedback that they were correct; however, when students answered a problem incorrectly, the computer indicated the response was incorrect. Students were able to retry the problem. Greenwood, Delquadri, and Hall (1984) have shown that increasing OTRs results in increased problem-solving performance. Perhaps students in the experimental group were given more opportunities to respond and/or given more corrective feedback than they would have received from their classroom teacher in class with approximately 25 other students.

The use of assistive technology also provides students the opportunity to work at their own pace. As previously stated, *GO Solve* contained three modules and once students received a grade of 85%, they were able to advance to the next module. In addition, depending on how many answers the student was getting correct or incorrect, the computer would adjust the difficulty of the problems. Therefore, students in the experimental group benefitted from having the pacing of instruction directly at their level.

Although participants in the experimental group showed statistically significant results on the subtest of MCAS questions and examiner-made probes, they did not show
statistically significant results on the mathematics anxiety scale or the Process and Application subtest of the GMADE. Researchers have been examining the negative effects of math anxiety on student achievement (Wigfield & Meece, 1988). The GO Solve intervention did not reduce students’ levels of anxiety. Students’ level of anxiety during math class and taking math tests did not change. Perhaps no change in anxiety levels can be expected, since students still had to complete all their mathematics work and take tests in their regular mathematics class. Also, the GO Solve intervention did not directly target reducing students’ level of mathematics anxiety. With respect to the results on the GMADE, the MCAS problems were more closely aligned with the word problems presented on the GO Solve Word Problems intervention.

Overall, GO Solve draws upon many lines of research that identify effective strategies to improve student achievement. GO Solve incorporated many successful learning strategies including schema-based instruction, visual representation, anchored instruction, worked examples, problem personalization, self-paced instruction, providing numerous opportunities for students to respond, and the use of assistive technology. GO Solve used an array of strategies and techniques that previous research has shown to be successful. Therefore, it is difficult to identify and determine exactly which strategy was more effective in helping students learn word problems, if it had been a compilation of all, or if some students benefitted from a specific strategy or certain set strategies whereas others benefitted from an entirely different subset of instructional methods.
Limitations

Selection

This study examined a narrow group of individuals who may have benefited from *GO Solve*. In this study, students were selected based upon their scores on the Process and Application subtest of the GMADE. Therefore, students had to score below the 30th percentile on this given subtest. Ultimately, the adoption of such a stringent selection criterion may have limited the generalizability of these findings. Previous MCAS math scores may have been a better screening instrument to have used for this study, given that schools are most interested in improving achievement on these high-stakes tests. In addition, using some form of teacher rating scale may have been helpful, given that the teachers had known these students for almost half a year and were familiar with their strengths and weaknesses. Perhaps students who scored above the 30th percentile on the Process and Application subtest could have benefited from the program, but due to the selection criterion, results from this study could not inform this point. Previous MCAS math scores could have resulted in a broader target group and could have changed the results obtained.

Also, students’ computer literacy skills were not assessed at the outset of the study. No attempts were made to correlate prior test scores to levels of computing ability. Results of this study may be confounded by familiarity with computer usage and/or the desirability of the *GO Solve* intervention as a computer program rather than the contents of the intervention itself.

Another limitation of this study could lie in the structure of the *GO Solve* intervention itself. The program could have been secondary to the benefits received by presenting students with the mathematical problems in a visual manner.
The *GO Solve Word Problems* intervention was originally developed as a 3rd through 8th grade intervention. Since this study used only 5th grade students, the intervention was not tested on the other grade levels for which it was developed. This study only included 32 5th grade students; perhaps a larger sample size could have impacted the results.

**Resentful Demoralization**

A threat to internal validity present in this study was resentful demoralization. Throughout the course of this investigation, students in the experimental group indicated that they were excited to be exempted from MCAS mathematics. They indicated that they found MCAS mathematics boring and very difficult. Perhaps, participants put forth more effort when receiving the *GO Solve Word Problems* intervention than when they were sitting in their MCAS mathematics class. Also, students were given the intervention in small groups and received more attention from the researcher than they would have in their MCAS mathematics class where, on average, the ratio of students to teacher is 25:1. Therefore, if students were confused by a given question, the researcher could assist them; when they were doing a good job, the researcher could provide them with positive reinforcement. The one-on-one interaction could have impacted the results.

**Financial and other Considerations**

The *GO Solve* intervention is costly. Implementing the intervention can cost $100 per module for one computer or $900 for a single module on ten computers. Therefore, if a school wanted to purchase this program and have three computers which contain all three modules, the cost can reach $2,900. Given budgetary constraints, many districts are facing the reality that this intervention can be too costly to implement. Also, given the results of this intervention, the question of cost in relation to benefit becomes a pragmatic concern. Is
this program worth the cost? In addition to purchasing the intervention, districts must also have the computers – the laptops on which to install the intervention. In this current investigation, students used the program for 45 mins twice a week. The program can also be used as a stand-alone problem-solving unit or tied into an existing curriculum. This investigation used *GO Solve* in conjunction with an existing problem-solving unit that was being used in the classroom. Therefore, this program was never used and studied as a stand-alone math word problem-solving unit.

Given that this intervention lasted only for 12 weeks, many students did not benefit from having an opportunity to complete all modules, although the advanced Multiplication and Division module was targeted more towards 7th and 8th grade. Additionally, since there were no clear criteria for moving a child on to the next module, the researcher decided that students had to get at least 85% of the mixed practice questions correct for two consecutive sessions. As a result, five children only received the Addition and Subtraction module, and eleven received both the Addition and Subtraction and the Multiplication and Division modules. Also, some children took such a long time to meet the criteria for moving on, when they did get to the Multiplication and Division Module, they had only a few sessions left because the research study was almost to its conclusion and the school year was coming to a close.

The current investigation also did not investigate any possible interaction with *GO Solve Word Problems* as a function of students’ sex, ethnicity, and social economic status. Given the sample size, it would have been difficult to assess for any possible interactions with gender. In addition, this study was tested at a lower middle class school; perhaps future research should explore implementing this intervention at a school comprised of students from a lower socioeconomic status. In addition, the sample used for this study did not yield a
very diverse student population. Future research should explore implementing this intervention program with a more diverse student body.

**Implications for Practice**

Many implications for practice stem from the findings of this research investigation. The reauthorization of the *Individuals with Disabilities Act of 2004* (PL-108-446) now allows districts to classify children with a learning disability using Response To Intervention (RTI). States and school districts are now encouraged to use RTI to accurately identify students with learning disabilities and to provide additional supports to struggling students (Gersten et al., 2009). Although some states have already begun to implement RTI in the area of reading, RTI initiatives for mathematics are not as widely used. In addition, the report *Adding It Up*, an 18-month project in which 16 individuals with diverse backgrounds have reviewed and synthesized pertinent research on mathematics learning from pre-kindergarten through Grade 8, indicated that “International comparisons suggest that U.S. schools have been relatively successful in developing skilled reading, with improvements in both instruction and achievement occurring in a large number of schools. Unfortunately, the same cannot be said of mathematics” (National Research Council, 2001, p. 17). The challenge, then, is to find better, more effective ways to teach mathematics and to develop interventions to help students who are struggling. As Hiebert and Carpenter (1992) point out:

One of the most widely-accepted ideas within the mathematics education community is the idea that students should understand mathematics. The goal of many research and implementation efforts in mathematics education has been to promote learning with understanding. But achieving this goal has been searching for the Holy Grail. There is a persistent belief in the merits of the goal, but designing school learning environments that successfully promote understanding has been difficult (p. 65).

More empirical research is needed on evidenced-based mathematics interventions that can be used within an RTI framework. Furthermore, the National Mathematics Advisory
Panel (2008) reports highlight how poorly U.S. students are performing compared to other students internationally. Therefore, more research on effective teaching and evidence-based interventions are needed to help all students in the area of mathematics. Given that GO Solve is research-based and through this investigation has been found to improve mathematical problem-solving skills in middle school students, perhaps it can be considered an intervention that is used within an RTI framework.

The Task Force on Evidenced-based Interventions (EBIs) was spearheaded in 2002 in school by Thomas Kratochwill to identify, review, and code studies of both psychological and educational interventions (Kratochwill & Shernoff, 2003). One of the primary goals of the task force was to improve the quality of research training and extend the evaluation criteria for EBIs. Kratochwill and Shernoff (2003) indicated that the use of EBIs is not always tailored to fit into the schedule of practitioners and that many do not have training to implement EBIs. These factors make it difficult for practicing school psychologists to replicate a study of this kind in their schools.

The Principles and Standards for School Mathematics (National Council of Teachers of Mathematics, 2000) has emphasized the importance for mathematics instruction and assessment to focus more on conceptual understanding than on procedural knowledge (Leh, Jitendra, Caskie & Griffen, 2007). In addition, with the recent accountability movement and greater efforts to teach all children, practitioners have begun to use Curriculum Based Measurements (CBMs) to monitor student progress. According to Hamilton (2004), there is a need to identify assessment tools that are technically adequate, evaluate students’ mathematical competence, provide information that informs instruction, and monitor student’s progress. Foegen (2006) indicated that research on middle school mathematics and progress monitoring is at the early stages, with more research primarily focusing at the
elementary level. Therefore, more mathematics CBM measures need to be developed that incorporate Deno’s (1985) essential characteristics, which are that they should be: 1) reliable and valid, 2) simple and efficient, 3) easily understood, and 4) inexpensive.

Two approaches for developing CBMs in mathematics have been identified. One approach has been “curriculum sampling”, where researchers have developed measures by constructing representative samples of the year’s mathematics curriculum (Foegen, Jiban and Deno, 2007). The curriculum sampling approach has been used in the area of computation, as well as conceptual problems and applied mathematics skills. The second approach uses “robust indicators”, where researchers try to identify measures that represent broadly defined proficiency in mathematics. According to Foegen et al. (2007), the robust indicators approach attempts to parallel in mathematics the kind of “robustness” that oral reading fluency offers in the area of reading. The passages that are used are not directly drawn from the student’s curriculum; however, they offer strong correlations to “host criterion measures of overall subject area proficiency (p. 122).”

More research needs to be conducted using CBM at the middle school level, in particular, in the area of mathematics. With students in the United States struggling in mathematics as compared to students in other countries, the requirements of No Child Left Behind, and the recent emergence of Response To Intervention (RTI), research is desperately needed regarding the use of Math-CBMs at the middle school level.

The National Mathematics Advisory Panel (2008) indicated that there are three critical elements to produce the needed quality and quality research:

1) a sufficient supply of competent researchers dedicated to areas of critical national need,

2) a sufficient supply of willing schools and practitioners who have the time, resources, and motivation to be partners in research and to be partners in research
in decision-making, and

3) a sufficient and stable source of funding for quality research and training with appropriate peer review. (p. 64)

The National Mathematics Advisory Panel (2008) also concluded:

to produce a steady supply of high-quality research that is relevant to classroom instruction, national capacity must be increased. More researchers in the field of mathematics education must be prepared, venues for research must be funded that extends from the basic science of learning, to the rigorous development of materials and interventions to help improve learning, to field studies in classrooms. The most important criterion for this research is to encourage scientific rigor, ensuring trustworthy knowledge in areas of national need. (p. 65)

**Future Directions**

Variations of this study should be conducted to address the limitations that were discussed regarding this investigation. For instance, another intervention should be conducted to examine the effects of *GO Solve* on other grade levels in addition to replicating the current findings with 5\textsuperscript{th} grade students. In addition, future research should explore the use of *GO Solve* as a stand-alone problem-solving unit. Further investigation should examine the effects of implementing the program for a longer period of time. Perhaps using this intervention to help all middle school students who struggle with mathematical problem-solving would be beneficial, given the lack of research on effective interventions for middle school students. Also, additional investigations into other dependent problem-solving measures and other technologies to help middle school students who are struggling should be conducted. Lastly, future research should examine whether the problem-solving skills students learned are retained and carried over to the subsequent school year.
Summary and Conclusions

This current investigation explored whether GO Solve, a computer-based intervention that teaches students schema-based instruction to solve word problems, would increase the word problem-solving capabilities of struggling students. According to Fuchs et al. (2005), not enough is known about effective teaching strategies and interventions in the area of mathematics compared to the area of reading and reading instruction. Given that U.S. students are falling further and further behind their industrialized counterparts, particularly in the area of problem-solving, and students in special education mathematics classes are making minimal progress, more research needs to be conducted on mathematical literacy. In addition, since the workplace is requiring greater knowledge of technology and mathematics, U.S. students need to develop strong mathematical skills in order to be prepared to assume the demands of their jobs.

Difficulties with word problems and problem-solving skills have been well-documented in both special education and general education students in the U.S. More research is needed to identify effective ways and strategies to teach children to solve word problems. For instance, research has shown that other countries teach students multiple ways to solve a word problem, whereas in the U.S., students are usually taught one way to solve a problem. In addition, more research is needed on schema-based instruction versus general strategy instruction and ways in which teachers can begin to implement schema-based instruction into their classrooms.

As researchers have repeatedly documented, compared to the area of reading, research is greatly lacking in the area of mathematics prevention and intervention. As the RAND Mathematics Study Panel (2003) indicated: “The teaching and learning of mathematics in U.S. schools is in urgent need of improvement (p. xi). Specifically, in the
area of mathematics problem-solving, research on effective strategies and evidenced-based interventions in the middle school is clearly lacking. Hopefully, this dissertation will foster future research projects to explore ways to improve mathematics achievement, specifically in the area of word problem-solving at the middle school level.
APPENDIX A

STUDENT AND PARENTAL CONSENT FORMS

Making Math Instruction Count: An Evaluation of a Math Intervention for Upper Elementary Students with Math Difficulties

Investigator: Jessica Fede, M. A.
University of Massachusetts Amherst

We are conducting a research study about how kids respond to a computer-based math program. A research study is a way to learn more about people. If you decide that you want to be part of this study, you will be assigned to a group. One of the groups will continue in their regular math class and occasionally complete a series of short math problems. The other group will receive a computer based math problem solving intervention and also occasionally complete a series of math problems.

There are some things about this study you should know. Regardless of what group you are in, it will be during your extra math class, so you won’t miss any of your regular math class or other academic classes. By participating in this study, you will be contributing to the science of learning. All children choosing to participate will receive prizes on a regular basis. When we are finished with this study, we will write a report about what was learned. This report will not include your name or that you were in the study.

While your parent(s) have expressed a willingness to have you participate in this study, the finally choice is yours. If you decide to stop after we begin, that’s okay too. If you decide you want to be in this study, please sign your name.

I, _________________________________, want to be in this research study.

(Print your name here)

___________________________________
(Sign your name here)  (Date)
Making Math Instruction Count:
An Evaluation of One Math Intervention
for Upper Elementary Students with Math Difficulties
Investigator: Jessica Fede MA

Introduction to the study: I am inviting your child to be in a research study conducted by Jessica Fede of the University of Massachusetts Amherst. The purpose of this study is to evaluate the efficacy of an intervention for students who are having difficulties with math. I hope to use what I learn from the study to make recommendations about math instruction for children who struggle with math performance. It is my intention with the results of this research to publish and present at professional conferences.

The intervention is called GO Solve Word Problems (URL), a computer software program published by Tom Snyder Productions. The program involves teacher directed lessons, paired use of the software program, and individual use of the program for practice. The lessons teach children to recognize the set of relationships among the numbers in a word problem and to apply graphic organizers that assist in solving the problem. This intervention is designed for children in grades 3 to 8 who have difficulty solving word problems independently. While this promising and exciting intervention program is based on educational research, it has not yet been studied experimentally to demonstrate its efficacy.

In place of GO Solve, half of the children in this study will continue in their regular math curriculum and instruction and as such will serve as a comparison group.

What will happen during the study: Your child has been identified (teacher recommendation and math scores, MCAS) as having difficulty solving word problems. Should you allow your child to participate your child will be randomly assigned to either the comparison group or the GO Solve intervention group. Children who will receive the GO Solve intervention will receive it twice a week for 45 minutes each session. Children in the comparison group will receive as their standard 45 minute math periods each week. This study will be approximately 12 weeks, beginning on March 1 and ending in May.

Risks, discomforts, and benefits: I do not know of any personal risk from being in this study. The only possible discomfort might be if your child experiences some frustration during the math testing. Specifically, it is likely that students will improve in their ability to compute or to solve word problems. The study will also contribute to our understanding of evidence-based interventions for students with math difficulties. This will help to inform the development of programs ideally suited to promote math development in all kinds of learners.

How participants’ privacy is protected: We are interested in the aggregate data, not in any one particular child’s score. In addition, no data from this study will be part of the child’s permanent school records. Each child will be given a identification number for the purpose of data entry and analysis.
**Your rights:** We would appreciate you allowing your child to participate in this study; however if you choose not to, then your child will not be treated any differently. While the study is being conducted, you can choose anytime to withdraw your child for any reason.

**Review Board approval:** The local Institutional Review Board (IRB) in the School of Education at University of Massachusetts Amherst has approved this study. If you have any concerns about your rights as a participant in this study, you may contact the Human Research Protection Office via email (humansubjects@ora.umass.edu); telephone (413-545-3428); or mail (Office of Research Affairs, 108 Research Administration Building, University of Massachusetts, 70 Butterfield Terrace, Amherst, MA 01003-9242).

**Questions:** If you have any questions or concerns about being in this study you should contact Jessica Fede School of Education at the University of Massachusetts Amherst via email (jfede@umass.edu; telephone (401-487-1081); or my advisor Dr. William Matthews at 413-545-1192 or mail (Department of Student Development and Pupil Personnel Services, Hills House South 166, University of Massachusetts, 111 Infirmary Way, Amherst, MA 01003).

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**PLEASE READ THE FOLLOWING STATEMENT AND SIGN BELOW IF YOU AGREE**

I understand the purpose of this study and have read the information in this consent form and agree to allow my child to participate.

__________________________  ______________
Signature                Date

__________________________  __________________________
Parent’s Name            Child’s Name

______/______/______
Child’s Birthday and Year

I would like a summary of the results of this study.

Please keep one copy for your records and sign and return one copy to your child’s teacher.
## APPENDIX B

### ITEM RESPONSE THEORY DATA

<table>
<thead>
<tr>
<th>FORM 1</th>
<th>Item Type</th>
<th>Content</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Test Characteristic Curves</th>
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<tbody>
<tr>
<td>35_08</td>
<td>MC</td>
<td>Measure</td>
<td>1.29</td>
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<td>25_08</td>
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<td>Measure</td>
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<table>
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<td>9_07</td>
<td>MC</td>
<td>P,R,A</td>
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<td>-0.6</td>
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<td>15_08</td>
<td>MC</td>
<td>P,R,A</td>
<td>1.26</td>
<td>0.13</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>30_07</td>
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<td>0.82</td>
<td>-0.42</td>
<td>0</td>
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</tr>
<tr>
<td>27_06</td>
<td>OR</td>
<td>P,R,A</td>
<td>0.58</td>
<td>-0.33</td>
<td></td>
<td>-0.35</td>
</tr>
<tr>
<td>31_08</td>
<td>OR</td>
<td>NS&amp;OP</td>
<td>1.16</td>
<td>-0.04</td>
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<td></td>
</tr>
</tbody>
</table>

99
APPENDIX C

TEST CHARACTERISTIC CURVE
Name:__________________________________________

1) The floor in Steve’s room is shaped like a rectangle.

It has an area of 168 square feet.

It has a width of 12 feet.

What is the length of Steve’s room?

A. 14 feet
B. 28 feet
C. 72 feet
D. 84 feet

2) A bookstore had 3,200 copies of a new book.

Every copy was sold for $16 per copy.

What was the total amount of the bookstore’s sales from this book?

A. $22,400
B. $32,000
C. $50,200
D. $51,200
3) There were 123 players at a soccer camp. The players were divided into teams having 11 players each. What was the total number of teams and the total number of players left over?
   
   A. 10 teams, with 3 players left over
   B. 11 teams, with 1 player left over
   C. 11 teams, with 2 players left over
   D. 12 teams, with 3 players left over

4) Angie used 20 \( \frac{3}{4} \) inches of ribbon to wrap a gift. She also used 15 \( \frac{1}{2} \) inches of ribbon to tie a bag. What is the total number of inches of ribbon that Angie used?

   A. 35 1/4 inches
   B. 35 2/3 inches
   C. 36 1/4 inches
   D. 36 1/2 inches
5. A travel company assigns one guide for every 8 tourists who go on a tour, as shown in the table below.

**Guide Assignments**

<table>
<thead>
<tr>
<th>Number of Tourists</th>
<th>Number of Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td>32</td>
<td>4</td>
</tr>
</tbody>
</table>

Based on this table, what is the total number of guides that will be assigned to 40 tourists?

A. 5
B. 6
C. 7
D. 8
6) The poster shown below describes the DVD sale that Martin’s Video is having.

What is the greatest number of DVDs that can be bought for $45 at Martin’s Video during this DVD sale?

A. 6
B. 9
C. 15
D. 30
7) Sam’s printer prints 5 pages in the same amount of time that Heidi’s printer prints 8 pages. What is the total number of pages that Sam’s printer will print in the time it takes Heidi’s printer to print 24 pages?

A. 13  
B. 15  
C. 16  
D. 19

8) Madison started a bicycle trip at 2:00 p.m. At 5:00 p.m. the same day she had completed 75% of the total distance. If Madison continues at the same speed, at what time will she finish the total distance?

A. 6:00 p.m.  
B. 6:30 p.m.  
C. 7:00 p.m.  
D. 7:30 p.m.

9) **Question 9 is a short-answer question. Write your answer to this question below.**

Jerry took $5.00 to the mall. He spent $0.85 for a pack of gum and $3.50 for a comic book. How much money did Jerry have left?
10) Question 10 is an open-response question.

• BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.
• Show all your work (diagrams, tables, or computations) below.
• If you do the work in your head, explain in writing how you did the work.

Write your answer to question 10 in the space below.

Harry planned a rectangular garden that was 40 feet long and 10 feet wide.

a. What was the perimeter, in feet, of the garden that Harry planned? Show or explain how you got your answer.

b. What was the area, in square feet, of the garden that Harry planned? Show or explain how you got your answer.

c. Suppose Harry decided to change the shape of his garden to a square with the same area as the rectangle. What would be the perimeter, in feet, of the square garden? Show or explain how you got your answer.
11) **Question 11 is an open-response question.**

- BE SURE TO ANSWER AND LABEL ALL PARTS OF THE QUESTION.
- Show all your work (diagrams, tables, or computations) below.
- If you do the work in your head, explain in writing how you did the work.

Write your answer to question 11 in the space provided below.

Georgia has some 4-inch cubes like the one shown below.

![Image of a 4-inch cube]

Georgia will put the cubes in the box shown below.

![Image of a larger box]

a. What is the total number of cubes that Georgia needs to exactly cover the bottom of the box with a layer one cube deep? Show or explain how you got your answer.

b. Georgia is going to fill the entire box with her cubes. What is the total number of cubes that Georgia needs? Show or explain how you got your answer.
APPENDIX E

POST-TEST MCAS

Name:_____________________________________

1) The Wilsons have a rectangular patio that is 10 feet wide and 15 feet long.
   What is the area, in square feet, of the patio?
   A. 50 square feet
   B. 75 square feet
   C. 115 square feet
   D. 150 square feet

   What was the total cost of Karen’s 15 folders?
   A. $7.44
   B. $14.40
   C. $17.40
   D. $18.60

3) A baker had 1128 cookies. She put them all in bags, with 24 cookies
   in each bag. What is the total number of bags that she used?
   A. 37
   B. 38
   C. 47
   D. 48
4) Jen uses \( \frac{3}{4} \) cup of butter for every 1 batch of cookies that she bakes. How many cups of butter will Jen use when she bakes 6 batches of cookies?

A. 4 ½ cups  
B. 5 cups  
C. 6 ¾ cups  
D. 8 cups

5) The table below shows the number of milligrams of sodium in each of three different sizes of a soft drink.

<table>
<thead>
<tr>
<th>Drink Size (fluid ounces)</th>
<th>Sodium Amount (milligrams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>12</td>
<td>54</td>
</tr>
<tr>
<td>16</td>
<td>72</td>
</tr>
</tbody>
</table>

Based on the pattern in the table, what is the total number of milligrams of sodium in each of three different sizes of a soft drink?

A. 90 mg  
B. 108 mg  
C. 126 mg  
D. 144 mg
6) Ms. Brown needs 8 eggs in order to make 2 cakes. What is the total number of cakes she could make with 24 eggs?

A. 3  
B. 4  
C. 6  
D. 8

7) To make hot cereal, Macy uses the directions on the back of the cereal box as shown in the table below.

<table>
<thead>
<tr>
<th>Number of Servings of Hot Cereal</th>
<th>Dry Cereal Needed</th>
<th>Water Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/4 cup</td>
<td>1 cup</td>
</tr>
<tr>
<td>2</td>
<td>1/2 cup</td>
<td>2 cups</td>
</tr>
<tr>
<td>3</td>
<td>3/4 cup</td>
<td>3 cups</td>
</tr>
<tr>
<td>4</td>
<td>1 cup</td>
<td>4 cups</td>
</tr>
</tbody>
</table>

Macy wants to make 10 servings of hot cereal. Using this table, what is the total number of cups of dry cereal that she should use?

A. 1 ¼ cups  
B. 2 ½ cups  
C. 5 cups  
D. 10 cups
8) Jordan saves $4 out of every $10 that she earns from baby-sitting.

She saved $28 of her baby-sitting money last summer.

How much money did Jordan earn last summer from baby-sitting?

A. $32
B. $40
C. $62
D. $70

9) The perimeter of an equilateral triangle is 24 centimeters.

How many centimeters long is each side of the triangle?
Jillian has a rowing machine. The table below lists the number of calories she burns when she exercises on her rowing machine.

<table>
<thead>
<tr>
<th>Minutes Exercised</th>
<th>Calories Burned</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>20</td>
<td>140</td>
</tr>
<tr>
<td>30</td>
<td>210</td>
</tr>
</tbody>
</table>

a. Based on the data in the table, what is the total number of calories that Jillian burns in 1 minute? Show or explain how you got your answer.

b. Based on your answer to part (a), what is the total number of calories that Jillian will burn if she exercises on her rowing machine for 25 minutes? Show or explain how you got your answer.

c. Based on your answer to part (a), what is the total number of minutes that Jillian exercised if she burned 385 calories? Show or explain how you got your answer.
11) The fifth-grade marching band includes boys and girls.
   • There are 28 boys in the marching band.
   • The 28 boys are \( \frac{7}{10} \) of the students in the marching band.

   a. What fraction of the students in the marching band are girls? Show or explain how you got your answer.

   b. What is the total number of students in the marching band? Show or explain how you got your answer.
APPENDIX F

ADMINISTRATION INSTRUCTION FOR THE EXAMINER-MADE WORD PROBLEM PROBES

You are going to complete a word problem probe. You will have 8 minutes to complete this probe. If you come to a problem you don’t know, put an “x” through it. You do not have to complete the problems in any particular order.
**APPENDIX G**

**EXAMINER-MADE PROBES**

Probe 1:

<table>
<thead>
<tr>
<th>Name __________________</th>
<th>Date ______________</th>
</tr>
</thead>
</table>

1. Trophies for the winning team cost $9 each. If the coach has $245 in the budget, how many trophies can he purchase?

2. The area of the back wall of the barn measures 2185 square feet. If the width of the back wall is 95 feet, how high is the wall?

3. The Wilson family drove from Springfield to Pleasantville on Saturday, a distance of 379 miles. They drove 278 miles before dinner. How far did they drive after dinner?

4. The town of Richmond is building a new playground. They have been working on the playground for 16 days. They have completed 40% of the playground. How many days will it take in all for the town to build the playground?

5. When raking leaves, Martin can pick-up 25 pounds of leaves every 30 minutes. How many pounds of leaves can he pick up in 45 minutes?

6. On Monday, there were 48 problems on the math test. That was 19 problems fewer than on Friday. How many math problems were there on Friday?
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Last year, Tanya had 15 customers on her paper route. This year she plans on having 6 times as many customers. How many customers does she plan on having?</td>
</tr>
<tr>
<td>8.</td>
<td>Carol, Laura, and Kate sold wrapping paper for their school fund raiser. Carol made $139.50. Laura made $218.25. Kate made $47.75 more than Carol. How much money did Kate make selling wrapping paper?</td>
</tr>
<tr>
<td>9.</td>
<td>Water flows at 250 gallons an hour. How many hours will it take to fill a swimming pool that holds 3750 gallons of water?</td>
</tr>
<tr>
<td>10.</td>
<td>The distance between Boston and Washington, DC is 540 miles. It takes 9 hours to drive in a car between the two cities. How fast is the car going?</td>
</tr>
<tr>
<td>11.</td>
<td>Maria’s swim team sold wrapping paper to make money for new swimming bags. At the beginning of December, the swimmers had earned $675. At the end of December, the swimmers had earned a total of $833. How much money did the swimmers earn during the month of December?</td>
</tr>
<tr>
<td>12.</td>
<td>Jason took a deck of 52 playing cards and dealt them into 4 equal piles. How many cards are in a single pile?</td>
</tr>
<tr>
<td>Name __________________    Date _____________</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1. The Parker family drove from Middleburg to Happytown on Tuesday, a distance of 452 miles. They drove 306 miles after lunch. How far did they drive before lunch?</td>
<td></td>
</tr>
<tr>
<td>2. Wanda reads 110 pages a day. If her new book has 1320 pages, how many days will it take her to read the book?</td>
<td></td>
</tr>
<tr>
<td>3. The Smith family has been refinishing their basement. They have been working for 24 days. They have completed 30% of the basement. How many days will it take in all for the Smith family to refinish the basement?</td>
<td></td>
</tr>
<tr>
<td>4. Last week, Michael practiced his clarinet 15 minutes on Tuesday. He plans on practicing 3 times as many minutes on Wednesday. How many minutes does he practice on Wednesday?</td>
<td></td>
</tr>
<tr>
<td>5. Tom and Jerry were planning a vacation. If they can drive at 65 miles per hour and their vacation home is 1300 miles away. How many hours will they have to drive to reach their destination?</td>
<td></td>
</tr>
<tr>
<td>6. Kyle was saving money for a new bicycle. Before his birthday, he had saved $265. Kyle got some money for his birthday that he added to his savings. In the end, Kyle had $403. How much money did he get for his birthday?</td>
<td></td>
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</tr>
<tr>
<td>7. In the ice cream factory, a machine can fill 24 gallons of ice cream every 15 minutes. How many gallons of ice cream can the machine fill in 45 minutes?</td>
<td>8. The Silver Maple woods cover a rectangular area that is 8060 square acres. If the woods extend 124 acres from north to south, how far do they extend east to west?</td>
</tr>
<tr>
<td>9. Alice, Sue and Vanessa were comparing their shopping receipts. Alice spent $235.80 and Vanessa spent $199.00. Sue spent $15.60 more than Alice. How much did Alice spend?</td>
<td>10. During the summer, 35 families joined the YMCA. This was 17 fewer than the number of families that joined in the fall. How many families joined the YMCA during the fall?</td>
</tr>
<tr>
<td>11. There are 246 children going on the school trip. If each bus holds 50 children, how many busses do they need to have for the trip?</td>
<td>12. Mrs. Jones had 64 eggs to make omelets. If each omelet takes 4 eggs, how many omelets can Mrs. Jones make?</td>
</tr>
</tbody>
</table>
**Probe 3:**

<table>
<thead>
<tr>
<th>Name __________________    Date ______________</th>
<th>1. Jessie was selling tickets to the dance recital. She sold $425 worth of tickets before the day of the show. When she counted her money after the show, she realized that she sold $512 altogether. How much did she sell the day of the show?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Cranes Beach covers a rectangular area that is 8250 square yards. If the beach is 125 yards long, how wide is the beach?</td>
<td>3. The car ride from Boston to New York takes 5 hours. If the distance between Boston and New York is 250 miles, how fast is the car traveling?</td>
</tr>
<tr>
<td>4. The members of the school band needs to raise money for their trip. Each member has raised $40 which is 60% of the cost. How much will the trip cost each member?</td>
<td>5. Sally, Anita and Stacy babysit to make extra money. Sally earned $127.50 last month and Anita earned $138.25 last month. Stacy earned $25.45 more than Anita. How much did Stacy earn?</td>
</tr>
<tr>
<td>6. The Girls Scout troop needs to raise $235. They plan to sell boxes of cookies. If each box of cookies costs $6, how many boxes do they need to sell?</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Question</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7. The radio station owns 2880 different CD’s. They can play 180 different CD’s each month. How many months will it take for them to play all of the CD’s?</td>
<td>8. Last month 47 new students enrolled in the school. That was 16 fewer than the number of students that enrolled this month. How many students enrolled this month?</td>
</tr>
<tr>
<td>9. Last summer, Monica was able to swim 14 laps in the pool. This summer she would like to swim 3 times as many laps. How many laps would Monica like to swim this summer?</td>
<td>10. It is 568 miles between Boston and Baltimore. On a recent trip the Sanchez family traveled the 295 miles between Boston and New York before lunch. How many more miles do they have to travel before they arrive in Baltimore?</td>
</tr>
<tr>
<td>11. John took his collection of 72 transformers and divided them into 6 equal piles. How many transformers are in a single pile?</td>
<td>12. In a factory the machine can fill 12 cartons of juice every 18 minutes. How many cartons can the machine fill in 45 minutes?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Jeremy took his bag of 60 pieces of chocolate and divided them up into 5 equal piles. How many pieces are in a single pile?</td>
<td>2. At the dairy, a machine can fill 22 gallons of milk every 10 minutes. How many gallons of milk can the machine fill in 40 minutes?</td>
</tr>
<tr>
<td>3. The Daytona 500 is a 500 mile car race. During the first hour the lead car travelled 287 miles. How many miles did the lead car have left to travel to reach the finish line?</td>
<td>4. Cathy, Sandy and Jo were comparing their grocery bills. Cathy spent $127.99, Jo spent $185.75, Sandy spent $42.50 more than Cathy. How much did Sandy spend on groceries?</td>
</tr>
<tr>
<td>5. Marissa has been mowing the lawn for 32 minutes. She has completed 40% of the mowing. How long will it take her to mow the entire lawn?</td>
<td>6. The school band wants to buy tee-shirts for the Spring Parade. They can spend up to $218. If each shirt costs $8, how many tee-shirts can they buy?</td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7. Each CD tower holds 250 CD’s. If the music store has 1750 CD’s, how many towers will they need to have to hold all of the CD’s?</td>
<td></td>
</tr>
<tr>
<td>8. The bus trip from Edaville to Franklin takes 7 hours. If the distance between Edaville and Franklin is 420 miles, how fast is the bus traveling?</td>
<td></td>
</tr>
<tr>
<td>9. In the jump rope contest Jeremy jumped for 67 minutes. This was 15 fewer minutes than Robbie. How many minutes did Robbie jump?</td>
<td></td>
</tr>
<tr>
<td>10. Last year, Fran was able to complete 14 pushups. This year, she would like to do 3 times as many pushups. How many pushups would Fran like to do?</td>
<td></td>
</tr>
<tr>
<td>11. When building their new house, Mr. Marks wanted the basement to be 1440 square feet. If the length of the basement is 30 feet, how long is the width of the basement?</td>
<td></td>
</tr>
<tr>
<td>12. Tom delivered the local paper. At the beginning of September he had collected $428 from his customers. At the end of September he had collected a total of $549. How much money did Tom collect during September?</td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1.</td>
<td>A car trip from Boston to Baltimore takes 9 hours. If the distance between the two cities is 540 miles, how fast is the car moving?</td>
</tr>
<tr>
<td>3.</td>
<td>Stuart has memorized 24 lines of a poem. He has memorized 60% of the lines. How many lines does the entire poem have?</td>
</tr>
<tr>
<td>5.</td>
<td>Mr. Miller was comparing his pay stubs for the last three months. In December he made $825.55. In November he made $746.70. In October he made $45.35 less than December. How much more money did he make in November?</td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>7. Sam decided to give away his baseball card collection. He took the 96 cards and divided them evenly among his 6 friends. How many cards does each friend get?</td>
<td></td>
</tr>
<tr>
<td>8. On Thursday, Mr. Sanchez walked 52 laps on the track. That was 14 more than he walked on Tuesday. How many laps did he walk on Tuesday?</td>
<td></td>
</tr>
<tr>
<td>9. Last year, Cindy sold 13 magazine subscriptions. This year she plans to sell 4 times as many. How many does she plan to sell this year?</td>
<td></td>
</tr>
<tr>
<td>10. There are 125 children waiting to ride the swan boats. If each boat holds 15 children, how many boats will there need to be so each child gets a ride?</td>
<td></td>
</tr>
<tr>
<td>11. A standard high school basketball court covers 4700 square feet. If the basketball court is 50 feet wide, how long is it?</td>
<td></td>
</tr>
<tr>
<td>12. There are 510 pieces in a large bag M&amp;M’s. How many bags did Marcy buy if she counted 2550 pieces in all?</td>
<td></td>
</tr>
</tbody>
</table>
1. Last month, Cindy made 15 necklaces. This month she plans to make 3 times as many. How many necklaces will Cindy make this month?

2. Stacy took her pile of 84 M&M’s and divided them into 6 equal piles. How many M&M’s were in each pile?

3. Margaret was selling advertisements for the local paper. At the beginning of November, she had sold $649 of advertisements. At the end of November she counted and found that she sold a total of $778. How much did she sell during the month of November?

4. Jillian, Sara and Michelle were counting their babysitting money. Jillian made $125.75 last month. Sarah made $105.50 last month and Michelle made $35.75 more than Jillian. How much money did Michelle make?

5. The orange grove covers a rectangular area that is 1440 square yards. If the grove measures 24 yards from east to west, how many yards does it measure from north to south?

6. Every year there is a hot dog eating contest. Last year the winner ate 67 hot dogs in 10 minutes. This year the winner ate 12 more hot dogs than the winner last year. How many hot dogs did he eat?
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. The basketball teams wants to buy new socks for the team. They can spend up to $172. If each pair of socks costs $7, how many pairs of socks can they buy?</td>
<td></td>
</tr>
<tr>
<td>8. In the balloon store, the owner can fill 32 balloons every 12 minutes. How many balloons can he fill in 36 minutes?</td>
<td></td>
</tr>
<tr>
<td>9. The Jones family is taking a 3960 mile car trip. If they travel 330 miles each day, how many days will it take them to make the trip?</td>
<td></td>
</tr>
<tr>
<td>10. It takes 4 hours to drive between Boston and New York. If the distance between Boston and New York is 240 miles, how fast is the car traveling?</td>
<td></td>
</tr>
<tr>
<td>11. Jaclyn was going to visit her sister in Baltimore which is 537 miles away. Before lunch she travelled 285 miles. How many miles did she have left to travel?</td>
<td></td>
</tr>
<tr>
<td>12. The town of Hampshire is repaving Main Street. They have been working for 15 days. They have completed 30% of the street. How many days will it take in all for them to repave Main Street?</td>
<td></td>
</tr>
</tbody>
</table>
Probe 7:

<table>
<thead>
<tr>
<th>Name __________________    Date ______________</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The school wants to buy tee-shirts for the fifth grade for field day. They can spend up to $418. If each shirt costs $8, how many tee-shirts can they buy?</td>
</tr>
<tr>
<td>2. In the running race Paul ran for 57 minutes. This was 15 fewer minutes than Jan. How many minutes did Jan run for?</td>
</tr>
<tr>
<td>3. Last year, Mike was able to complete 14 pull-ups. This year, he would like to do 4 times as many pushups. How many pushups would Mike like to do?</td>
</tr>
<tr>
<td>4. Sam delivered flowers. At the beginning of April he had collected $528 from his customers. At the end of April he had collected a total of $649. How much money did Sam collect during April?</td>
</tr>
<tr>
<td>5. The bus trip from Hamilton to Jamestown takes 7 hours. If the distance between Hamilton and Jamestown is 420 miles, how fast is the bus traveling?</td>
</tr>
<tr>
<td>6. Marissa took her bag of 70 marbles and divided them up into 5 equal piles. How many pieces are in a single pile?</td>
</tr>
<tr>
<td>7. When building their store, Mr. Brown wanted the 1st floor to be 1440 square feet. If the length of the 1st floor is 30 feet, how long is the width of the 1st floor?</td>
</tr>
<tr>
<td>8. Lisa has been cleaning the house for 32 minutes. She has completed 40% of the cleaning. How long will it take her to clean the entire house?</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>9. At the ice cream factory, a machine can fill 33 gallons of ice cream every 10 minutes. How many gallons of ice cream can the machine fill in 40 minutes?</td>
</tr>
<tr>
<td>10. Mark is in a speed race which is a 400 mile car race. During the first hour the lead car travelled 187 miles. How many miles did the lead car have left to travel to reach the finish line?</td>
</tr>
<tr>
<td>11. Each book case holds 250 books. If the book store has 1750 books, how many book cases will they need to have to hold all of the books?</td>
</tr>
<tr>
<td>12. Mary, Sandy, Jen were comparing their shopping bills. Mary spent $137.99, Jen spent $187.25. Sandy spent $23.50 more than Mary. How much did Sandy spend on groceries?</td>
</tr>
</tbody>
</table>
# APPENDIX H

## MATH ANXIETY QUESTIONNAIRE

NAME:

<table>
<thead>
<tr>
<th>Math Questionnaire</th>
<th>NOT AT ALL</th>
<th>VERY MUCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When the teacher says he/she is going to ask you some questions to find out how much you know about math, how much do you worry that you will do poorly?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>2. When the teacher is showing the class how to do a problem, how much do you worry that other students might understand the problem better than you?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
<tr>
<td>3. When I am in math, I usually feel</td>
<td>NOT AT ALL RELAXED VERY MUCH RELAXED</td>
<td></td>
</tr>
<tr>
<td>4. When I am taking math tests, I usually feel</td>
<td>NOT AT ALL NERVOUS VERY NERVOUS</td>
<td></td>
</tr>
<tr>
<td>5. Taking math tests scares me.</td>
<td>NEVER FEEL THIS WAY ALWAYS FEEL THIS WAY</td>
<td></td>
</tr>
<tr>
<td>6. I dread having to do math.</td>
<td>NEVER FEEL THIS WAY VERY OFTEN FEEL THIS WAY</td>
<td></td>
</tr>
<tr>
<td>7. In general, how much do you worry about how well you are doing in school?</td>
<td>NEVER FEEL THIS WAY VERY OFTEN FEEL THIS WAY</td>
<td></td>
</tr>
<tr>
<td>9. If you are absent from school and you miss a math assignment, how much do you worry that you will be behind the other students when you come back to school?</td>
<td>NOT AT ALL VERY MUCH</td>
<td></td>
</tr>
<tr>
<td>10. In general, how much do you worry about how well you are doing in math? NOT AT ALL VERY MUCH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Compared to other subjects, how much do you worry about how well you are doing in math? MUCH LESS THAN OTHER SUBJECTS MUCH MORE THAN OTHER SUBJECTS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX I

QUESTIONNAIRE ABOUT GO SOLVE WORD PROBLEMS

Name:

Please circle the number that best tells what you think about GO Solve Word Problems.

<table>
<thead>
<tr>
<th>GO Solve Word Problems…</th>
<th>No Disagree</th>
<th>Somewhat So – So</th>
<th>Yes Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. was fun for me to use?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. learned a lot?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. taught me to solve word problems?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. liked the images/graphics?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. did better in math class?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. helped my confidence in math?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. graphic organizers were helpful?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. my math skills got better?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. liked the feedback from the computer?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. the problems were hard to read?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. liked that I could use a lab top?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. caused me to get frustrated?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. was too difficult for me?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. would recommend to a friend?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. found the calculator helpful?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. helped me get better at fractions?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. liked that I could personalize the problems?</td>
<td>1 2 3 4 5 6 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Please write responses to the following questions:

1. What did you like about *GO Solve Word Problems*?

2. What did you not like about *GO Solve Word Problems*?

3. Would you want to continue using *GO Solve Word Problems* next year? If so why? If not why not?

4. Do you think this program helped you to do better in your math class?

5. If you feel like you have done better, what specifically have you gotten better at? If you feel you haven’t done better, what do you think would help you get better at math?

6. Do you find the graphic organizers helpful in solving word problems? Would you use graphic organizers in the future to help you solve word problems?
7. Was the feedback the computer gave you helpful? If so what about it was helpful?

Thank you for participating!
### APPENDIX J

### SUM OF SQUARES

Sum of Squares for a Subtest of MCAS problems

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>68.047</td>
<td>2</td>
<td>34.024</td>
<td>3.348</td>
<td>0.049</td>
<td>0.188</td>
</tr>
<tr>
<td>Intercept</td>
<td>88.123</td>
<td>1</td>
<td>88.183</td>
<td>8.678</td>
<td>0.006</td>
<td>0.23</td>
</tr>
<tr>
<td>PreMCAS</td>
<td>10.266</td>
<td>1</td>
<td>10.266</td>
<td>1.01</td>
<td>0.323</td>
<td>0.034</td>
</tr>
<tr>
<td>Group</td>
<td>48.241</td>
<td>1</td>
<td>48.241</td>
<td>4.748</td>
<td>0.038</td>
<td>0.141</td>
</tr>
<tr>
<td>Error</td>
<td>294.671</td>
<td>29</td>
<td>10.161</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>633</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>362.719</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES


