

IMPROVING MATH PROBLEM SOLVING STRATEGIES OF MIDDLE
SCHOOL STUDENTS WITH LEARNING DISABILITIES

by

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(Under the Direction of Cecil Fore III)

ABSTRACT

The purpose of this study was to evaluate the effectiveness of an intervention designed to increase the percent correct of word problem solving for math word problems for eighth-grade math students with learning disabilities. The single-subject research methodology consisted of a multiple-probe design across students. The independent variable was instruction in a learning strategy created to assist students in discerning the important information contained in word problems and organizing the information into an understandable and solvable format so that an accurate solution could be obtained. Data was collected on the participants use of the strategy for accurate problem completion. The results indicated that the strategy was effective in increasing the percent of correct responses for solving math word problems for all participants. Additionally, all of the students responded favorably to the intervention. Instructional and research implications are discussed.

INDEX WORDS: Mnemonic learning strategy, Adolescent, Learning disabilities, Single-subject methodology, Multiple probe, Dissertation

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DEDICATION

I would like to dedicate this to the many students who have inspired and enriched my teaching experience. I would specifically like to recognize the individual students who worked with me on this project. Without their participation and enthusiasm, this would not have been possible.

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CHAPTER 1

INTRODUCTION

Current trends in math instruction have shifted instructional emphasis from computational skills to task oriented activities combined with word problems that reflect real world significance (NCTM, 2006; NCLB, 2001). Such performance-oriented instruction applies not only to students in general education, but also to those with disabilities. Assessment of these skills often takes the form of problem solving rather than calculation (Woodward, in press; Bottge, Rueda, LaRoque, Serlin, and Kwon, 2007; Woodward, Monroe, & Baxter, 2001; Rodriguez, & Kitchen, 2005). These trends combine in the current standards and laws, with the implicit intent to raise educational standards in mathematics and therefore competencies for all students.

An important stipulation in the reauthorization of the Individuals with Disabilities Education Act (IDEA) Amendments of 1997 (20 U.S.C. [section] 1400 et seq.) is that students with disabilities have opportunities to learn challenging curricula together with their peers without disabilities. The amendments were finalized at the same time that national initiatives raised achievement goals for all students (Goals 2000: Educate America Act [U.S. Department of Education, 1994]; What Work Requires of Schools: A SCANS Report for America 2000 [U.S. Department of Labor, 1991]). All 50 states have been working to establish their own performance standards (U.S. Department of Education, 1999). Assessment of the skills of students both with and without disabilities is included as a provision of the No Child Left Behind

amendments and initiatives by individual states (NCLB, 2001). Such assessments for all students have taken the form of standardized tests using a word problem format.

In addition to the requirements stated in the federal educational law, the National Assessment of Educational Progress (NAEP) Math Framework calls for assessment of whether students can “Solve mathematical or real-world problems” (National Assessment of Educational Progress, 2005). Furthermore, the focus of “mathematics as problem solving” is the first standard of the National Council of Teachers of Mathematics (NCTM, 2006) for all grade levels. As one example of this emphasis, students in the state of Georgia are required to demonstrate competency in mathematics problem solving at the third, fifth and eighth grades with test items presented in a word problem format (Georgia Department of Education, 2005). Such problem solving skills are stipulated in requirements under No Child Left Behind, and recommendations from the National Mathematics Advisory Panel (NMAP Report, 2007). The NMAP further recommends in their report a blending of both instruction in the use of formulas or algorithms and inquiry-based approaches such as those implemented through situated cognition practices.

In addition to these initiatives, as part of his American Competitiveness Initiative, President George W. Bush has proposed \$260 million in funding for math programs that will focus on strengthening math education in the early grades and middle school so that students enter high school ready to take challenging coursework [Executive Order 13398, April 18, 2006 (Appendix A)]. This initiative has been prompted in part by data collected by the United States Department of Education using the Program for International Student Assessment (PISA), which indicates that

American 15-year-olds are performing below the international average in mathematics literacy and problem solving (US Department of Education, 2006). Researchers have offered several reasons for this undistinguished mathematics performance, including the lack of well-designed intervention studies to validate effective teaching practices (Gersten, Baker, & Lloyd, 2000). In response to concerns over poor performance in mathematics, emphasis has been placed on developing successful math instruction. The NCTM has identified the need for linking research to practice and practice to research (NCTM Research Committee: Heid, Middleton, Larson, Gutstein, Fey, King, Strutchens, & Tunis, 2006).

These national initiatives indicate the need for developing instructional strategies that assist children with disabilities in becoming successful math problem solvers in order for them to compete in the current problem-solving environment. The National Council of Teachers of Mathematics (2006) proposes that all students need to develop a range of strategies for solving mathematical word problems, such as using algorithms, diagrams, looking for patterns or writing equations. Further, these strategies will require significant time commitments for instruction if students are to become skilled in using these tactics (NCTM, 2006). Also, a variety of specific math skills including computational fluency; conceptual understanding; organizing ideas; building problem solving reasoning; and converting symbols, notations and text, are necessary for students to become efficient math problem solvers at all levels (Hasselbring, Lott & Zidney, 2006). Developing skills in the latter of these requires a shift from teacher directed passive learning techniques to active student participation in which reasoning and communication are stressed (Nicol & Szetela, 1992).

Rationale

At the middle school level students with disabilities in general, and those with learning disabilities (LD), often have difficulty meeting academic standards in content areas and passing required state assessments (Maccini and Gagnon, 2006; Thurlow, Albus, Spicuzza, & Thompson, 1998; Thurlow, Moen, & Wiley, 2005). Specifically, students with LD frequently have difficulties with mathematics, including basic skills (Algozzine, O'Shea, Crews, & Stoddard, 1987; Cawley, Baker-Kroczyński, & Urban, 1992), algebraic reasoning (Maccini, McNaughton, & Ruhl, 1999) and problem-solving skills (Hutchinson, 1993; Montague, Bos, & Doucette, 1991). Many students struggle with how to approach math problems, make effective decisions, and carry out the chosen plan (Fogen, Jiban, & Deno, 2007; Maccini & Hughes, 2000; Maccini & Ruhl, 2000). Therefore, providing instruction in structured strategies that students may apply to solve problems is essential to increase student success.

Despite the need for the development of instructional strategies to teach problem solving skills, educators have long noted that mathematics instruction in special education classes is characterized by an emphasis on rote memorization of facts and computational skills, rather than on developing an understanding of higher level concepts, developing logical thinking, and applying mathematics skills to real-world problem situations. This emphasis on rote memory has been shown to be counter productive to the current trends, which emphasize reasoning and problem solving skills in earlier grades (Baroody & Hume, 1991; Bottge, 1999; Parmar, Cawley, & Miller, 1994; Woodward & Montague, 2000, United States Department of

Education, 2006) and to anchoring instruction in real life situations (Bottge, Rueda, & Skivington, 2006; Hasselbring, Lott, & Zydney, 2006; Bottge & Hasselbring, 1993).

Several developments in the literature are driving the discussion for the development of instructional strategies in mathematics. These include universal design for instruction and situated cognition (Hasselbring, T., Lewis, P., Bausch, M., 2005; Orkwis, R., 2003; Acrey, C. Johnstone, C., and Milligan, C., 2005; Bottge, B. A., 2001; Bottge, B. A., 1999; Koedinger, K., Mitchell, M.; 2004; Langone, J., 1988) and response to intervention (Fuchs D., Fuchs, L., Compton, D., Bryant, J., 2005; Kovalski, J., & David P., 2004; Coleman, M.R., Buysse, V., and Neitzel, J., 2006). Universal design involves the concept of designing the instructional environments and tactics such that the concept is universally accessible for all students (Bottge, Rueda, LaRoque, Serlin, and Kwon, 2007; Hasselbring, and Goin, 2005; Bottge, 1999). For example, the Center for Applied Special Technology (CAST) originally presented the concept of universal design to enhance the accessibility and or mobility of individuals in wheelchairs and they then applied the concept to universal design for instruction. Utilizing this concept as a guide for academic support for learning, students with vision impairments should have access to large print books and or Braille readers. Likewise, students with learning disabilities, who may demonstrate problems in conceptualization when confronted with math word problems, should be provided with a strategy for conceptualizing the problem. Thus, the concept of universal design is one overriding concept that drives much of the discussion of teaching tactics to date (Bender, 2007; pp 37-68).

A second research emphasis, which is more directly tied to research in mathematics, is the concept of situated cognition (Bottge, B. A., 2001; Bottge, B. A., 1999; Koedinger, K., Griffen, M., and Griffen, B. 1996; Mitchell, M., 2004; Smith, M. K. 2003; Langone, J., 1988). Situated cognition places the learning constructs for a specific task within the naturally occurring context, thus offering a frame of reference for the learner as well as opportunities for the learner to relate information and the requirements within a given task to previously learned materials or skills. For example, math problems may be placed in the context of the "real world" situation of grocery shopping, by using video of grocery store items in a check-out line, with prices for those items attached. In that way, a math addition problem can be "situated" in a real world scenario. Using situated cognition, students are given the opportunity to work with actual materials and within a related setting to enhance their understanding of the requirements of a given task (Koedinger and Mitchell, 2004; Lee, 2002; Bottge, 2001). This is particularly beneficial for students with learning disabilities who may have difficulty "thinking through" a math problem using only a written description of the problem.

The third major influence, Response to Intervention (RTI), is a model for determining eligibility for special education services in the area of learning disabilities (Fuchs, Fuchs, Compton and Bryant, 2005; Tilley, 2003; Vaughn, 2003; Fuchs, Fuchs, 2001; Ysseldyke, & Marston, 1999). Response to Intervention involves providing math interventions in a multi-tier framework for students with math learning disabilities. A key element in RTI is a provision of early intervention, which is offered when students first experience academic difficulties. While almost all of the

research in RTI has been focused on reading literacy, RTI will also be emphasized for students with learning disabilities in math (Fuchs & Deshler, 2007). These students will require research proven instructional strategies that facilitate learning math word problems, specifically in situations in which students with a suspected learning disability in math are not responding to instruction (Maccini, and Gagnon, 2006; Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005; Kovalski, and Prasse, 2004).

When solving word problems, students with learning disabilities often have difficulty understanding the main thoughts, remembering details from written passages, and making inferences (Graves, 1986). Recent research has suggested that with explicit instruction in use of the necessary tools for problem solving these students can be successful in a problem solving environment (Jitendra, DiPipi and Perron-Jones, 2002). According to a United States Department of Education report submitted by Office of Educational Research and Improvement (OERI) effective instruction for students with special needs provides instruction on specific strategies for problem solving (OERI, 2004). Based on information contained in this report, Mulligan has hypothesized that since students with disabilities lack problem solving strategies, specific instruction in these strategies will improve their problem solving performance (Mulligan, 2007).

Strategy instruction such as schemas, which emphasize conceptual understanding, graphic organizers, which provide a visual format for organization of work, and learning strategies, which provide a format for students to organize, recall and solve problems, can assist students in becoming successful math problem solvers.

These may all be considered universal design strategies as they do assist in the conceptualization of math problems for students with learning disabilities who often demonstrate defects in strategy conceptualization. Strategies for problem solving have the potential to assist students in becoming independent problem solvers. Such strategies may then be applied in a variety of settings including those situated in real life settings known as “situated cognition” (Bottge, Rueda, & Skivington, 2006; Maccini, & Gagnon, 2006; Bottge, 1999) and standardized testing situations alike. Key components for such strategy instruction should include steps that specifically apply to word problem solving skills.

Research Questions

The research above indicates the need for improved instruction in problem solving strategies for students with learning disabilities. Students who are unable to solve problems are also unable to advance through required math curriculum successfully. Although many factors may contribute to the poor math performance of students with disabilities, one promising area of interventions is cognitive methods for teaching students to attack word problems in an organized and systematic approach (Fontanna, Scruggs & Mastropieri, 2007; Harris & Pressley, 1991; Jitendra & Xin, 1997; Mastropieri, Scruggs, & Shiah, 1991; Montague, 1997; Montague & Bos, 1986). Such cognitive interventions frequently have been referred to as strategy instruction. With strategy instruction, students follow a series of steps to assist understanding and problem solving.

A strategy is frequently represented by an acronym, which assists students in completing the steps towards a problem solving strategy. A strategy may be

straightforward with rote application of specific steps to solve a particular type of problem, a broad set of guidelines that provide a general direction to solve a problem (Wong, 1994) or an organized system for approaching problem solving. Instruction in the use of a learning strategy, which has been experimentally validated will be useful to both students with disabilities and educators. The literature reviewed provides a basis for research in improving instruction in problem solving for mathematics. Much of the research points to the need for a strategy that is general enough for students to apply to any problem involving mathematical algorithms, and broad enough to be applicable to a wide variety of examples (Fuchs & Fuchs, 2005; Coleman, Buysse, and Neitzel, 2006; Fogen, Jiban, Deno, 2007; Candace and Michael, 2007). The questions that will be answered by this study include:

1. Will students with learning disabilities be able to acquire a sequential mnemonic strategy for problem solving when provided with specific training in that strategy?
2. Will application of a sequential mnemonic strategy for problem solving lead to improved problem solving competency for students with learning disabilities?
3. Will students be able to maintain use of a sequential mnemonic strategy for solving novel math word problems over time?

The underlying hypothesis of this research is that because students with disabilities do not independently develop effective problem strategies, instruction in a specific strategy will improve their success in problem solving. The research will analyze a set of data consisting of problem solving competence through the application of a

sequential mnemonic problem solving strategy. The results of this study will contribute to a growing body of research supporting the use of specific language based problem solving strategies for improving the success of students with disabilities problem solving skills.

CHAPTER 2

LITERATURE REVIEW

Educational investigators have noted the dearth of research related to math problem solving among students with learning disabilities (Montague, (in press); Hasselbring, Lott, & Zydney, 2006; Owen & Fuchs, 1992; Jordan & Hanich, 2000). This lack highlights the need for research in the area of math problem solving that presents empirically based instructional strategies. In order to establish a basis for this study, the review of literature initially considers the limited abilities of students with disabilities for solving problems. This focus is a key component for meeting the current requirements under the reauthorization of IDEA (2004) that moves from a discrepancy model to one that focuses on instruction and educational outcomes. This review then investigates the strategies that have been successfully implemented with students and considers the measured effectiveness.

To address the issue of difficulty in solving math word problems among middle school students with disabilities a computer search was undertaken of the established the research search engine *Galileo*. Additionally, online digital libraries including ERIC, Questia and Looksmart were also utilized. Initial parameters included the previous 10 years and the keywords of learning strategies, problem solving, math concept development, schema instruction, math instruction and learning disabilities, and graphic organizers for math. The results were somewhat limited so the search was expanded to include articles completed since 1985. This broader search yielded a more complete picture of the issues surrounding students with disabilities and math problem solving. In addition, a hand search of the important

research journals in special education including: *Learning Disabilities Research*, *Learning Disabilities Quarterly*, *Journal of Special Education*, *Exceptional Children*, *Current Issues in Education*, and the *Journal of Learning Disabilities* was completed early in researching this topic and again in December of 2007. This search resulted in 16 empirical articles that investigated word problem solving abilities among middle school math students with learning disabilities.

The literature revealed that problem solving skills of students with learning disabilities has been discussed and analyzed from a number specific perspectives. First researchers have looked at the success of strategies chosen by students with disabilities as compared to general education students (Parmar, Cawley & Frazita, 1996; Montague & Applegate, 2000; Gonzalez & Espinel, 2002). Next, research on situated cognition evaluated the effects of this strategy focusing on certain areas of math (Koedinger, and Nathan, 2004; Bottge, 1999; Bottge, Reuda, Serlin, Hung and Kwon, 2007). Researchers then measured the effects of teaching specific strategies including graphic organizers (Brunn, 2002; Maccini, Gagnon, 2006; Bottge, 2001); schema based instruction (Jitendra, Griffen, McGoey, Gardhill, Bhat & Riley, 1998; Jitendra, DiPipi and Perron-Jones, 2002; Xin, Jitendra & Deatline-Buchman, 2005), and specific learning strategies (Owen and Fuchs, 2002; Hohn and Frey, 2002; Montague and Bos, 2001). Research in each of these areas is synthesized below.

Math Problem Solving Tactics of Students with Learning Disabilities

The math problem solving tactics of students with learning disabilities differ from those of non-disabled students and are often ineffective for problem solving tasks such as mathematical word problems (Parmar, Cawley & Frazita, 1996;

Montague & Applegate, 2000; Jimenez Gonzalez & Garcia Espinel, 2002). These studies are presented in Table 1 and are discussed below. For example, research by Parmar, Cawley and Frazita (1996) measured the success of students with disabilities in word problem solving as compared to their non-disabled peers. Students with disabilities from grade levels 3 through 8 were included in the study. Thirty-five students at each grade level were randomly sampled from a larger pool of students without disabilities, for a total of 210 students. There were 197 students with mild disabilities, with the number per grade ranging from 20 to 39. All students were administered four sets of word problems, each set composed of problems including the four arithmetic operations, use of direct and indirect problem statements, the presence of extraneous information, and both one and two step problems. Students were required to reach a final solution. All problems were constructed with minimum reading requirements, and all included single digit computation items. With the exception of the simplest form of word problem, simple action problems using addition, students with disabilities failed to attain a more than 50% passing rate on any type of word problems at any age. They showed more difficulty with indirect problems than those containing extraneous information, and were largely unable to solve problems involving more than one step or one operation. In comparison to students without disabilities, students with disabilities showed a significantly lower rate of performance for each type of problem. This research indicates that students with learning disabilities lack the strategies necessary for successfully attacking math word problems as compared to peers without disabilities. Further, given this difficulty

Table 1. *Math Problem Solving Tactics of Students with Disabilities*

Citation	N	Participants	Targeted Skills	Dependent Variable(s)	Independent Variable(s)	Research Design	Results Summary
Parmar, Cawley & Frazita (1996)	407	-Grades 3 – 8 -Average achieving students, 35 in each grade -Student with LD, 20-39 in each grade	-Solving 1 and 2 step word problems with single digit calculation	- Total word problem score	-Presentation of word problem sets	Comparison of scores of students with LD to non-disabled peers	Students with LD have poor success on simple, direct word problems. They showed more difficulty with indirect problems than those containing extraneous information, and were unable to solve problems with more than one step. They showed a significantly lower rate of performance for every factor.
Montague & Applegate (2000)	54	-Urban middle school students -with learning disabilities -average achievement -gifted	-Solving word problems silently and aloud	-Total word problem score -computation accuracy -problem solution time -problem difficulty rating --total problem solving strategies -problem solving method, silent or aloud	-Training in <i>Think Aloud</i> problem solving strategy	Comparison of scores of students with LD to non-disabled peers	Students with LD rated problems as significantly more difficult and had a significantly lower total word problem score than both average and gifted students. Average students rated problems as significantly more difficult than gifted students but did not differ significantly on total word problem score. There was no significant difference between students with LD and average achievers in the length of time they spent solving problems Both groups took significantly longer than the gifted students. Students with LD used significantly fewer problem-solving strategies. Students with LD perceive problems as more difficult than their peers, and they do not spend more time solving problems.
Gonzalez & Espinel (2002)	148	-Spanish urban middle school students -average social-economic -7 to 9 years old -60 participants with LD	-Completion of word problems during 3 individual session	-Total word problem score	-Oral presentation of word problems	AB design	Students with LD in math used less developed strategies than typically achieving children, such as counting and occasionally modeling, but not mental strategies.

with the simplest type of word problems among students with disabilities, future research should focus initially on those with straightforward problems as this is a prerequisite skills necessary for correct resolution of the more complex types of word problems.

Montague and Applegate (2000) explored middle school students' knowledge and use of problem solving strategies in solving mathematical word problems. Participants were students in an urban South Florida middle school who met both district and research eligibility criteria for special education services participated in the study. Students were selected from three groups: learning disabled (LD), average-achieving, and gifted. These students were obtained from two grade levels, seventh and eighth grade. Students solved three of the six word problems silently and three aloud. The type of problem (number of steps) was counterbalanced within solution method (silent, aloud), which was then counterbalanced to control for order effects. Before solving the think-aloud problems, students received training in which the examiner first modeled thinking aloud while solving a verbal reasoning problem and then had students think aloud while solving a similar problem. During the training and testing, students were cued at 5-second intervals if they were not verbalizing and told to, "say everything you are thinking and doing." The dependent variables in the study were (a) total word problem score, (b) computation accuracy, (c) problem solution time (in seconds), (d) problem difficulty ratings, (e) total problem - solving strategies, (f) total problem representation strategies, and (g) problem - solving method (silent vs. aloud). To analyze differences in computation accuracy, the number of operations completed and the number of computational errors per problem

were determined. Then, accuracy per problem was calculated by dividing the number of errors by number of operations and subtracting from one. As expected, the students with learning disabilities performed more poorly on the six mathematical problems than their average and gifted peers. In addition, students with learning disabilities rated problems as significantly more difficult and had a significantly lower total word problem score than both average and gifted students. In comparison, students with average ability rated problems as significantly more difficult than gifted students did but did not differ significantly on total word problem score. There was no significant difference between students with learning disabilities and average achievers in the length of time they spent solving problems. However, both groups took significantly longer than the gifted students took. Students with learning disabilities used significantly fewer problem-solving strategies on the two- and three-step problems than both the average and the gifted students. The latter two groups did not differ on that variable. Findings suggest that although students with learning disabilities perceive problems as more difficult than do their more successful peers, they do not spend more time solving problems. In addition, in this study, thinking aloud when describing their own problem solving strategies, was not a successful strategy. However, cognitive modeling and overt verbalization of the problem-solving process were effective, and thus, seem to be necessary parts of cognitive strategy instruction for students with learning disabilities when they are first learning and practicing strategies for solving mathematical problems (Montague, 1992; Montague, Applegate, & Marquard, 1993). The researchers stated that even with greater persistence, students with LD would still be at a serious disadvantage compared with

better problem solvers because they seem to lack important problem-solving strategies for effective and efficient mathematical problem solving. Because there were no significant differences in scores on the reading achievement, cognitive ability, and computational accuracy measures between students with learning disabilities and that of average or high achievers, it can be assumed that their poor performance was due to factors other than poor reading, low ability, or computation errors. These other factors may include an inability to judge the difficulty level of the problems, poor perceptions of their ability to solve the problems, lack of persistence, and strategy deficits. The poor performance and lack of the use of successful strategies by students with disabilities indicates the need for research in the area of successful strategy instruction. Finally, the fact that students with learning disabilities used fewer strategies on the two and three step problems suggests again the need to control for the types of problems used in future research.

Jimenez Gonzalez and Garcia Espinel (2002) designed a study to test whether there are differences between children with arithmetic learning disabilities, children exhibiting poor performance in math and typically achieving children in strategy choice when solving arithmetic word problems. Participants consisted of 148 Spanish children from urban zones and from average socioeconomic backgrounds and from several state schools. Their ages ranged from 7 years 1 month to 9 years 4 months. Of the 148 children 24 males and 36 females were diagnosed as having an arithmetic learning disability. The students completed all of the word problems in three individual sessions of 20 minutes each. Each word problem was read to the participant, whose task it was to tell how he or she would solve the problem and carry

out any actual arithmetic operations. Subjects were instructed to listen to the single auditory presentation of each problem. They were then allowed to make notes while the examiner read each problem. No time limitations were imposed. Sentence length, syntactic complexity and vocabulary difficulty were controlled when the arithmetic word problems were designed. The quantity magnitude was also controlled because all word problems always included combinations of units and tens. Solutions to the word problems were considered correct when the child carried out counting procedures correctly and there were no operation errors. Individuals with average performance had significantly higher scores than both students with arithmetic learning disabilities and those with poor math performance in the use of counting to solve the four operational categories of arithmetic word problems. This study illustrates that students with disabilities lack necessary skills in selecting and implementing strategies to solve word problems successfully.

In each of these studies, the performance of students with disabilities was shown to be significantly below that of their non-disabled peers (Parmar, Cawley & Frazita, 1996; Montague & Applegate, 2000; Gonzalez & Espinel, 2002). Since in each of these studies students were selected from the same educational settings and researchers controlled for reading level, factors other than instruction or reading ability must be responsible for the poor performance of the students with learning disabilities as compared to their non- disabled peers. The outcomes of these studies indicate that students with disabilities do not independently develop successful problem solving strategies for word problems and therefore are less successful in problem solving tasks. In addition, students with learning disabilities in math do not

increase the number of strategies they use for multi-step word problems (Montague, 2004). This is likely to lead to failure. As a result, students with disabilities lag significantly behind their non-disabled peers in math performance.

The concept of universal design would suggest that work on math word problems should include the types of supports that will assist students with learning disabilities in overcoming these barriers. For example, these students seem to require explicit instruction in problem solving strategies to be able to meet the demands of the new problem solving oriented classroom. Research is needed to evaluate the types of strategies that should be explicitly taught to students with learning disabilities in math (Montague & Applegate, 2000; Parmar, Cawley & Frazita, 1996; Owen and Fuchs, 2002; Hohn and Frey, 2002). Also, researchers must continue to control for the type of word problem in future research.

Situated Cognition, Situated Learning and Anchored Instruction in Mathematics

Situated cognition has emerged as a powerful perspective in providing meaningful learning and promoting the transfer of knowledge to real-life situations. This conceptual framework centers on four basic issues related to the successful completion of math problems: the role of context, the role of content, the role of facilitation, and the role of assessment. Each of these components assist learning (Brill, 2001; Lave, 1993; Scardamalia, & Bereiter, 1985).

Context relies on the premises that people reason intuitively based upon experiences within specific contexts and use a variety of methods to solve problems. Learners also respond best to coherent, meaningful and purposeful activities that

represent ordinary practices. They are then able to transfer knowledge and skills most effectively when situated learning environments are used for instruction. Learners are also more likely to transfer acquired skills to real-life problem solving (Bottge, Reuda, Serlin, Hung and Kwon, 2007).

Content refers to the idea that learners need to acquire both knowledge and a sense of when and how to use it. The best way to achieve this may be through content diversity and transfer. For example, concepts need to be represented through various content in order for students to apply knowledge in various setting to discriminate similarities and differences among settings. This may be achieved through educational apprenticeships to provide the opportunities for the learners to internalize learning and develop self-monitoring and self-correcting skills and through anchored instruction to create authentic, problem-rich environments that encourage exploration and variety of perspectives.

Facilitation can be described with regard to situated learning environments as an attempt to help students improve their cognitive abilities, self-monitoring and self-correcting skills, encourage active learning and provide opportunities to internalize information and apply strategies. Facilitation is less directive, more continuous, and highly interactive. Facilitation may include coaching, modeling, scaffolding, collaboration and the use of manipulatives (Im & Hannafin, 2007).

The final component, assessment, emphasizes the need to focus on the ability to diagnose and manage cognitive growth rather than achievement. Lave (1988) argues that learning as it normally occurs is a function of the activity, context and culture in which it occurs. This contrasts with most classroom learning activities,

which involve knowledge that is abstract and out of context. Researchers have begun to look at ways to apply a situated cognition framework in the area of mathematics (Koedinger, & Nathan, 2004; Bottge, 1999; Bottge, Reuda, Serlin, Hung and Kwon, 2007). Results of this research are summarized in Table 2.

Koedinger and Nathan (2004) investigated how differences in math problem representations change the performance and underlying cognitive process of beginning algebra students where quantitative reasoning is involved. The researchers hypothesized that improved problem solving is not simply a function of situated world knowledge facilitating performance but rather a consequence of student difficulties with comprehending formal symbolic representation of quantitative relationships. This research therefore attempts to test whether algebra students have more difficulty with story or word problems than with the symbol equations on which the problems were based. Story problems were described as problems which were situated in a specific story context using an anchored instructional video. Word problems were similar to those found in standard math textbooks. Two separate studies were implemented. For both of the investigations reported herein 96 problems were created using four cover stories that systematically varied the difficulty factors. The difficulty factors included three levels of problem presentation. These were the story problems, word problems, and symbol equation. This was measured against two placements for the variable either to the right or to left side of the equal sign. Two combinations of arithmetic types were used. These were either addition with multiplication or subtraction with division. The problems were distributed onto 16

Table 2. *Situated Learning and Anchored Instruction in Mathematics*

Citation	N	Participants	Targeted Skills	Dependent Variable(s)	Independent Variable(s)	Research Design	Results Summary
Koedinger and Nathan (2004)	76	-Beginning algebra and geometry students -Urban high school	-Completion of 3 types of problems: story problems, word problems, equations	-problem type -variable placement -types of calculations	-Presentation of 18 minute quiz	-Three factor ANOVA	Students performed better on story and word problems. Students also performed better with the variable on the right (results unknown) and on problems that contained whole numbers. Verbal representation appeared to account for differences.
Koedinger and Nathan (2004)	171	-Beginning algebra students -Sampled from 24 classrooms -Urban high schools	-Completion of 3 types of problems: story problems, word problems, equations	-problem type -variable placement -types of calculations	-Presentation of 18 minute quiz	-One factor repeated measure ANOVA for three difficulty factors	Results supported first portion of the study (above). Strategy use was more prevalent with word problems, but more successfully employed by higher achieving students.
Bottge (1999)	66	-17 students middle school in remedial math, 6with LD -49 students in pre-algebra classes	-Problem solving for contextualized problems or word problems	-Scores on word problem, contextualized problem and calculation tests	-Contextualized Group: Montague's cognitive strategy training model and practice w/contextualized problems -Word Problem solving practice	Pretest-posttest experimental design	All groups remained at the same level for calculation. All groups did improve in both word problem and conceptual problem tasks. There was a significant effect for the contextualized problem group on the conceptual problem test.
Bottge, Reuda, Serlin, Hung and Kwon (2007))	128	-7 th grade math students in 6 middle schools from inclusion and typical classroom settings	-Problem solving for anchored	-Scores on each test following instruction	-Instruction in anchored problem solving -Lessons on related concepts	Repeated Measures	There was no difference in achievement between tests 1 and 2. Students in the anchored instruction group did improve on test 3 and 4. Students with LD continued to score lower than typical classroom peers.

forms with eight problems each. The forms were designed to counterbalance problem type because prior testing revealed that student performance tended to decline on problems near the end of the test. Although the base equations differed on each form the difficulty factor was identical. Students performed better on both story problems and word problems than on symbol equations. In addition, they performed better on problems with the variable on the right of the equal sign, which did not require them to manipulate the order of the equation. Finally, they performed better on whole number problems. The researchers had hypothesized that symbolic representation in the form of equations would be easier however; the results did not support this hypothesis. The second hypothesis verbal facilitation in the form of word equations would improve problem solving performance was supported because students had greater success in solving this problem type. Overall, the story and word problems were significantly easier for the students to solve than the equations. Likewise, students were more successful on the whole number problems than the decimal problems. The result led the researcher to conclude that situational facilitation, in this case using familiar language to express problems, does both exist and improve performance in problem solving but efficacy is limited to some degree. Students did perform better on the story problems but also performed better on the word problems than on the symbolic equations. In addition, the researchers' rejected the common belief that story problems are more difficult for students to solve than equations. They noted that while students used a variety of strategies to solve the story problems and word equations such as a guess-and-test strategy, working backwards, and drawing diagrams or pictures, these strategies were applied by students more often to the story

problems than to the equations. This would indicate that students have a better understanding of the need for strategy use in solving math problems when the problems are situated within a specific context. In addition, students appeared to have a better understanding of the language involved in the story problems over the symbolic language in the equations. This would indicate that strategy instruction for solving equations would assist students in solving these types of problems.

It should be noted that the strategies students used to solve both problem types were often the same indicating that the underlying cognitive processes were also the same. In addition, the strategies students chose to solve these problems did not consist of equations, but rather strategies not generally taught in formal math classes such as guess and test. This finding is supported by other researchers who note that students who perform well in math classes, such as the students in this study, independently develop problem solving strategies (Fogen, Jiban, Deno, 2007; Maccini & Hughes, 2000; Maccini & Ruhl, 2000). Since students with learning disabilities do not independently develop problem solving strategies these studies highlight the need for explicit instruction in problem solving strategies.

Bottge (1999) investigated the effect of contextualized math instruction on the problem-solving performance of 17 middle school students in one remedial class and 49 middle school average-achieving students in two pre-algebra classes. Seventeen of the students attended a remedial math class with six of these having a learning disability. A pretest-posttest experimental design was used with the remedial math groups and a quasiexperimental, nonequivalent control group pretest-posttest design with the prealgebra classes. Students were assigned to one of two instructional groups

either a word problem group or a contextualized problem group based on a math assessment. On four successive school days prior to intervention, students took computation, word problem, and contextualized problem tests, and completed a questionnaire. The contextualized problem test was based on an 8-minute video anchor, *Bart's Pet Project*, written for a previous study. This problem required a solution based on the calculation of several subproblems involving buying a small pet and building a home for it. After viewing the video, students showed their work on the problem response form. On each test item, students were awarded one point for showing correct procedures and one point for the correct answer, in keeping with theory that math problems can be partitioned into procedural and conceptual knowledge (Goldman, Hasselbring, and the Cognition and Technology Group at Vanderbilt, 1997). Following the ten school days of instruction, students again took the computation, word problem and contextualized problem tests. Two video-based, contextualized math problems, *The 8th Caller* and *Bart's Pet Project*, from Cognition and Technology Group at Vanderbilt University (1997) in the Adventures of Jasper Woodbury the Jasper series. *The 8th Caller* was shown first to familiarize students with the nature of the contextualized problems and to acquaint them with videodisc technology. On the first day of intervention students received instruction in a modified version of Montague's cognitive strategy training model (Montague, 1997). This included practice applying the model to an anchored instruction problem, *The 8th Caller*. On Days 2 and 3, students reviewed the five steps for solving problems. Then they spent half of the class period discussing how to solve the video problem in their groups. When the teacher was sure that each group had reached a plausible solution,

she asked representatives to explain the group's solution to the class. During this early stage of instruction, the teacher assisted students in clarifying and paraphrasing their findings. On the following 6 days, students reviewed the five-step strategy frequently and worked on solving Bart's Pet Project. The teacher told students they would earn more credit if they included a detailed account of how they arrived at their solution. Groups shared the videodisc controller, searched the video, discussed ideas, and recorded their procedures on a recording form. The teacher answered questions to help clarify obvious misconceptions about the problem but did not provide specific ways to solve it. When the teacher noticed that students had reached a reasonable solution, she asked groups to describe their findings. Then they were encouraged to find the other two solutions. On the last day of instruction, when students had successfully solved the problem in at least two ways, the teacher asked a series of "what if" questions. Instruction for the Word Problem control group included a series of standard single and multi-step word problems that paralleled the content of *Bart's Pet Project*. The problems looked like typical word problems found in many basal mathematics textbooks. Instruction included practice in the same problem-solving strategy used by the conceptual problem group. Evaluation of test scores indicated that the students in the both the word problem and contextualized problem groups did not improve significantly in computations skills. However, all groups did improve in both word problem and conceptual problem tasks. There was a significant effect for the contextualized problem group on the conceptual problem test.

As a final measure, an extended transfer task was completed twelve school days after the posttest was administered. The five students from the remedial math

contextualized problem group and five students from the remedial math word problem group who obtained the highest summed scores on the computation, word problem, and contextualized problem tests participated. The purpose of the task was to find out whether the students could use their skills to plan and build a skateboard ramp. The authors reported that students in both the contextualized problem and word problem groups were able to use what they learned in a subsequent activity to plan and build two skateboard ramps. It took the word problem group one class period to solve the ramp problem. The contextualized problem group did not solve it during the first class period because they could not work together and quarreled much of the time. They solved the problem on the second day within 5 minutes when they saw word problem students building the ramp. The success of both the word problem group and contextualized problem group results of this portion of the study seem to indicate that both strategy instruction and strategy instruction within context can help students to generalize math skills.

Recent research by Bottge, Reuda, Serlin, Hung and Kwon (2007) investigated if it was possible to shrink achievement differences between students with disabilities and average performing peers using enhanced anchored instruction math problems. Participants for the investigation included 128 seventh-grade math students from six middle school classrooms. One group consisted of students placed in inclusive classrooms settings with 13 students with learning disabilities and 13 students who were considered to be typical achievers. The other five groups included students who were considered to be typical achievers. All students qualifying for special education services were placed in the same class in order for the special

education teacher to provide additional support in an inclusion special education setting. Prior to instruction all six classes were administered a problem solving test designed to go with the two enhanced anchored instruction problems. The two tests assessed minimally overlapping sets of math concepts embedded in the two enhanced anchored instruction problems. These included constructed-response items aligned to NCTM (2000) standards recommended for students in grades 6 through 8. Sets of problems were weighted according to complexity and the contribution the skill(s) made in solving the overall problem. Instruction included one enhanced anchored instruction problem, *Kim Komet Challenge*, from *The New Adventures of Jasper Woodbury* (Learning Technology Center at Vanderbilt University, 1997). The *Kim Komet* unit was taught for 13 days in October and *Fraction of the Cost Challenge* taught for 11 days in March. Materials for *Kim Komet* included a video anchor that investigated pre-algebraic concepts of linear functions, line of best fit, variables, rate of change, and reliability and measurement error. After solving the problem in the video anchor students went on to a similar hands on task of building and testing their own car ramps. They created graphs to help predict where on the ramp to release their cars to successfully complete the stunts. The students completed both assessments a second time. The math teachers then taught units on the concepts related to geometry and proportional reasoning from the prescribed curriculum. The instruction was organized in ways similar to enhanced anchored instruction including reviewing previous work, explicitly teaching new concepts and solving related problems. Both assessments were administered for the third time. The second unit, *Fraction of the Cost*, was developed by the authors and included a video anchor. Instruction was

completed in a similar manner to the *Kim Komet* unit. After finishing the unit, students worked on a related problem called *Hovercraft Challenge*. The two unit assessments were then administered a final time. Direct observation, video and detailed daily lesson planning were developed to ensure fidelity of implementation. The overall effects of the two enhanced anchored instruction problems on math skills were compared for each of the six classes. Multiple comparison procedures tested differences on each measure by test and by disability status. For the *Fraction of the Cost* assessments, no differences were found between tests 2 and 3, but students scored higher on test 4 than in previous tests. Students in the pre-algebra group scored higher than those in the typical classes whose score was higher than those in the inclusive class. The researchers also looked at the differences in achievement between groups over the tests. On the *Kim Komet* test there were no differences in improvement over tests 1 and 2, but both the pre-algebra and inclusive classroom groups showed improvement for test wave 3. On the *Fraction of the Cost*, no differences in improvement were found between classes over the test. At the follow-up 14 weeks later students with learning disabilities demonstrated larger improvement than their typical classroom peers, although overall scores continued to be lower for the group with learning disabilities. These outcomes indicate that situated learning environments can assist students in gathering and retaining information and understanding appropriate applications as well.

The research on situated cognition continues to support the premise that students with learning disabilities understand content and concepts better when instruction is situated within a meaningful context. However, students still exhibit

difficulty in solving these problems. The research continues to show that the lack of problem solving strategies continues to hinder success on math word problems for students with learning disabilities. Further, the research supports the need for assisting students in developing strategies for organizing information in math word problems in meaningful ways (Fuchs, & Fuchs, 2005; Coleman, Buysse, and Neitzel, 2006; Fogen, Jiban, and Deno, 2007; Candace & Michael, 2007). There are also, limitations that will need to be addressed through further research. One important caveat is that math problems presented through anchored instruction are often at a high level of difficulty (Woodward, 2004). This may make these problems more difficult for students with learning disabilities to complete them independently. Bottge et al (2007) also cautions against overloading the working memory of students with disabilities with problems set at a high level of difficulty. In one investigation (Bottge, 1999) participants had greater success in successfully solving problems when a research based problem solving strategy developed by Montague (1997) was included in the procedures. An understanding of how to approach problem solving may therefore be a prerequisite skill for students attempting to solve authentic math problems. The use of mnemonic problem solving strategies may provide the tools for students with learning disabilities to effectively solve problems (Swanson, Carson, & Saschse-Lee, 1996; Swanson, O'Shaughnessy, McMahon, Hoskyn, & Sasche-Lee, 1998). The next section of this review presents research on a variety of problem solving strategies.

Using Graphic Organizers as a Problem Solving Tool

Additional research in the area of helping students with disabilities to successfully solve word problems has investigated the effects of graphic organizers as a problem-solving tool. A graphic organizer is a visual and graphic display that depicts the relationships between facts, terms, and or ideas within a learning task (Hall and Strangman, 2002). Graphic organizers have been used to assist students with learning disabilities to master difficult conceptual material in a variety of subject areas (Bender, 2007; Brunn, 2002; Hall, & Strangman, 2002; Braselton, S. & Decker, 1994). However, research in the area of graphic organizers and mathematics is somewhat limited. Further, the available research on the use of graphic organizers for solving math word problems has been intended for the use of classroom practitioners and in many of the peer-reviewed articles, the results were not analyzed in a statistical manner. Ives and Hoy (2003) have noted that although the use of graphic organizers for mathematics instruction has not been well researched, documented success in other areas such as reading and social studies lend support to the concept of using graphic organizers to assist students in math problem solving. This is particularly significant when it is considered that graphic organizers are successful in the areas of reading and language, which are an integral component of mathematic word problems.

Although available data is somewhat sparse in the area of mathematics, the existing research suggests that graphic organizers assist students with learning disabilities in solving math word problems (Braselton & Decker, 1994; van Garderen & Montague, 2003; Jitendra, Griffen, McGoey, Gardhill, Bhat, and Riley 1998,

Jitendra, Dipipi and Perron-Jones 2002; Xin, Jitendra and Deatline-Buchman, 2005).

This research is summarized in Table 3.

Van Garderen and Montague (2003) investigated the effects of visual-spatial representation of mathematical problems on the problem solving performance of students with learning disabilities. Participants in the study consisted of sixth graders with learning disabilities, average learners and gifted learners from four urban Florida schools. Students were assessed on measures of mathematical problem solving skills and their ability to demonstrate and use visual-spatial versus pictorial representations of data. Visual-spatial representation was defined as graphic representations that encode the algorithmic relationships described in the problem. Pictorial representations were defined as those that encoded people, places or things described in the problem but not the mathematical relationships or algorithms. The Mathematical Processing Test (Hegarty & Kozhenikov, 1999) was used to measure students' success problem solving. Test questions were administered verbally to individual students. Students were then verbally questioned as to how they approached each question. Scores were obtained for the total number of problems solved correctly, the number of times the student reported using a visual-spatial representation, and the number of times a student used a pictorial representation. Although the use of a pictorial representation did not result in improved problem solving, the use of visual-spatial organizers did positively correlate with problem solving success. In addition, it was noted that students who demonstrated strengths in math problem solving tended to use the more effective visual-spatial representations to organize their problems while the students with disabilities tended to use pictures

Table 3. Graphic Organizers as a Problem Solving Tool

Citation	N	Participants	Targeted Skills	Dependent Variable	Independent Variable	Research Design	Results Summary
Van Garderen and Montague (2003)	66	-6 th grade student with LD, average achievers, gifted	-completion of math problems	-math problem solving test score - visual-spatial representation use score -pictorial representation score -schematic representation score	-Oral presentation of mathematical processing instrument	-analysis of results using ANOVA -Pearson product-moment correlation for relationships between visual-spatial representation and mathematical problem solving performance	Successful students used more visual-spatial representations while unsuccessful ones used more representations that were pictorial. The use of visual-spatial organizers did positively correlate with problem solving success.
Braselton and Decker (2002)	2	-5 th grade math students	-application of a graphic organizer to math story problems	-successful completion of math story problem	-instruction in use of graphic organizer	--pretest posttest	After learning the graphic organizer, students showed improvement in problem solving compared to previous data.
Jitendra, Griffen, McGoey, Gardhill, Bhat and Riley (1998)	34	- elementary -25 w/mild disabilities -9 low performing -comparison group of 24 normally achieving	-use of schema for solving word problems	-word problem criterion pretest and posttest	-schema strategy training in problem schemata and problem solution	-AB design for pretest and posttest With a delayed posttest to measure maintenance	Both the normative and treatment group increased performance from the pretest to the posttest However, the schema group continued to show statistically significant improvement on the delayed posttest as compared to the control group.
Jitendra, Dipipi and Perron-Jones (2002)	4	-middle school student -poor math performance	-use of schema for solving word problems	-completion of word problems	-schema strategy training in problem schemata and problem solution	- multiple-probe-across-participants	- schema-based strategy was effective in substantially increasing the number of correctly solved multiplication and division word problems for all 4

that represented items described in the question but did not necessarily relate to the processes needed to solve the problems. This indicates that teaching the logic related graphic organizers to students with learning disabilities may improve their problem solving success.

Braselton and Decker (2002) utilized a graphic organizer to assist fifth grade students' with disabilities in reading and solving math word problems. The organizer consisted of a diamond shape visual organizer with five cue steps that students completed in order to solve the word problem. These steps were: restate the problem in own words, decide what information is necessary, plan for mathematical calculations, do calculations and review answer to see if it is reasonable. Students received instruction in the use of the graphic organizer including modeling by the investigator. They then practiced applying the graphic organizer with math word problems. Students worked math word problems using the graphic organizer independently. Researchers found that students' problem solving competence improved significantly when using the graphic organizer.

Graphic organizers come in a wide variety of forms and some research suggests that organizers in the form of "problem solving schema" will enhance middle school students' ability to solve word problems (Jitendra, Griffen, McGoe, Gardhill, Bhat & Riley, 1998; Jitendra, DiPipi & Perron-Jones, 2002; Xin, Jitendra & Deatline-Buchman, 2005). Schema based instruction is a strategy that emphasizes conceptual understanding through the teaching of specific knowledge organization and focuses on specific problem patterns or structures. These problem solving schema are then organized in a visual format. As part of the National Council of Teachers of

Mathematics' *Principles and Standards for School Mathematics* (2006), students should be expected to represent and analyze mathematical situations. Graphic organizers including schemas help students to achieve this goal. In one sense these schema formats may also be viewed as a form of universal design in that information is more accessible for students with reading or language difficulties including those with learning disabilities or students for whom English is a second language. Schemas include strategies that entail looking systematically for patterns within the word problem (Jitendra, Griffen, McGoey, Gardhill, Bhat & Riley, 1998; Jitendra, DiPipi & Perron-Jones, 2002; Xin, Jitendra & Deatline-Buchman, 2005).

In the initial research on the use of schema as a word problem solving strategy Jitendra, Griffen, McGoey, Gardhill, Bhat and Riley (1998) examined the differential effects of two instructional strategies: an explicit schema-based strategy and a traditional strategy, on the acquisition, maintenance, and generalization of mathematical word problem-solving skills. Thirty-four elementary-aged students with mild disabilities or who were at risk for mathematics failure were randomly assigned to each of the two treatment conditions either schema based or traditional instructional methods. Of the 34 students from Grades 2, 3, 4, and 5, 25 students were classified as having mild disabilities: learning disabilities, educably mentally retarded, or seriously emotionally disturbed. The remaining nine students included low-performing students who were not classified as being disabled but were experiencing difficulty in mathematics. In addition, a comparison group of 24 normally achieving third-grade students was also included in the study. The dependent measures included word problem-solving criterion pretest, posttest, and

delayed posttest of 15 problem-solving items for each instrument. As much of the research on math problem solving, these researchers chose to control for problem difficulty by using only one-step word problems in their research. The study consisted of two phases. In the first phase, the differential effects of a schema strategy and a traditional basal strategy on the acquisition of simple one-step word problems were assessed. Instruction in solving the word problems by using the schema strategy was taught in two discrete steps for each phase in this study. First, instruction entailed identifying the features of the semantic relations or problem schema in the problem and checking that the relevant elements of the chosen problem schema were present. Second, instruction emphasized designing a solution strategy or action schema for solving the problem and then selecting and executing the correct arithmetic operation. In the second phase, maintenance and generalization of the two instructional strategies were examined. Instruction for the traditional instruction condition was derived from the *Addison-Wesley Mathematics* (Eicholz, O'Daffer & Fleenor, 1985) basal mathematics program. Results indicated that both groups' performance increased from the pretest to the posttest. All students were able to maintain their use of word problem - solving skills and generalized the strategy to novel word problems. However, the differences between groups on the posttest, delayed posttest, and generalization test were statistically significant, favoring the group receiving schema based instruction. In addition, scores on the immediate posttest and delayed posttest for the schema group approached those of a normative sample of third graders. These data show that explicit instruction in a schema based strategy for solving word problems is a successful tool for students with learning disabilities.

Related research by Jitendra, Dipipi and Perron-Jones (2002) on schema based instruction investigated its effects on mathematical problem solving for four 8th grade students' from a suburban middle school, all of whom were diagnosed with learning disabilities and were performing poorly in mathematics. The study used a multiple-probe-across-participants design, which included baseline, treatment, generalization and maintenance phases to measure the effects of schema-based instruction on the success of word problem solving skills. The independent variable consisted of strategy training in problem schemata or conceptual understanding and problem solving or procedural understanding. The intervention consisted of scripted lessons with each instructional session lasting 35 to 40 minutes over an eight-week period. In this study, schema -training procedures were criterion based and required students to obtain 100% correct on two sessions prior to progressing to the next problem type. Instructional components included explicit strategy modeling, interactive discussion, guided practice, monitoring and corrective feedback, and independent practice. The dependent measures consisted of a series of tests constructed for the study made up of six one-step multiplication and division word problems involving two different problem types: vary and multiplicative comparison. For the vary problem type the size of groups were unknown and students were therefore required to employ the inverse operation and divide to find the solution. In multiplicative comparison problems, the referent was unknown so students employed multiplication of the given information to determine the correct solution. Results indicated that the schema-based strategy was effective in substantially increasing the number of correctly solved multiplication and division word problems for all four participants. Maintenance of

strategy effects was evident for ten weeks, followed by 5 ½ weeks, and finally 2 ½ weeks after the termination of instruction for three of the students (one student dropped out of the study). In addition, the effects of instruction generalized to novel word problems for all four participants. This study indicates that students with disabilities can be successful when given explicit instruction in a problem solving strategy such as the use of a schema.

Later research by Xin, Jitendra and Deatline-Buchman (2005) investigated the differential effects of two problem-solving instructional approaches, schema based instruction and traditional general strategy instruction, on mathematical word problem-solving performance with a group of middle school students. Participants were 22 students with learning problems, including 18 who were identified by the school as having a learning disability, one with severe emotional disorders, and three who were at risk for mathematics failure. All of the students attended a middle school in the northeastern United States. Two different instructional conditions were implemented, that of schema based instruction and more general strategy instruction. Instruction for the schema based instruction group occurred in two phases: problem schemata instruction and problem solving instruction. During problem schemata instruction, students learned to identify the problem type or structure and represent the problem using a schematic diagram. In the problem-solving instruction phase, problems with unknown information were presented. Strategy instruction for the general strategy instruction group was derived from that typically employed in commercial mathematics textbooks (e.g., Burton et al., 1998). The procedure used required students to (a) read to understand, (b) develop a plan, (c) solve, and (d) look

back. Students in both conditions received their assigned strategy instruction three to four times a week, each session lasting approximately an hour. The schema based instruction group received 12 sessions of instruction, with 4 sessions each on solving multiplicative compare and proportion problems and 4 sessions on solving mixed word problems that included both types. Students in the general strategy instruction group also received 12 sessions of instruction consisting of a list of steps, but they solved both types of problems in each session. Unlike the schema based instruction group, students in the general strategy instruction group did not receive instruction in recognizing the two different word problem types nor did they receive instruction in how to apply the strategy. Explicit use of the general strategy was not provided but rather the strategy was simply presented. Students in the two groups solved the same number and type of problems. Results indicated that the schema based instruction group significantly outperformed the general strategy instruction group on immediate and delayed posttests as well as the transfer test. This study illustrates the need for specific instruction in the problem solving strategy. Students who received explicit instruction in the schema based strategy were successful while those who were presented with the general learning strategy, but not specifically taught how to use it remained unsuccessful.

The research indicates students with disabilities do not independently develop problem solving strategies and it is therefore necessary that overt instruction in problem solving strategies be provided for students with learning disabilities to be successful. However, when students with learning disabilities are provided with instruction on using schema to solve math problems, their performance improves. In

each of these, students with learning disabilities were able to improve their ability to solve word problems with the use of an explicitly taught schema as a problem solving tool (Jitendra, Griffen, McGoey, Gardhill, Bhat & Riley, 1998; Jitendra, DiPipi & Perron-Jones, 2002; Xin, Jitendra & Deatline-Buchman, 2005).

Learning Strategies

Another body of research in assisting students with learning disabilities successfully solve word problem has focused on the use of strategy instruction as a means to address the deficits in independently developing strategies experienced by students with learning disabilities (Maccini & Hughes, 2000; Maccini & Ruhl, 2000). While graphic organizers tend to emphasize pictorial or visual-spatially dependent learning strengths, some researchers have suggested instructional techniques that include the use of linguistically based learning strategies as a successful problem solving tool for students with learning disabilities (Owen & Fuchs, 2002; Maccini & Hughes, 2000; Hohn & Frey, 2002; Montague & Bos, 2001). This is a logical outgrowth of research in a wide variety of subject areas, suggesting that students with learning disabilities benefit from learning strategies represented by acronyms that depict certain steps in problem solution (Boon, Fore, Ayres, Spencer, 2005; Welch, Van Laeys, Bender, Scott, 1996). However, only a limited number of studies investigated learning strategies for math problem solving among middle school students with learning disabilities and that research generally supports the use of learning strategies (Miller, and Hudson, 2007; Grobecker, 2000; Landi, 2001; Maccini, & Hughes, 2000; Harmon, & Morse, 1995; Hollingsworth, & Woodward, 1993; Harris, Graham, & Freeman, 1988). This research is summarized in Table 4.

Table 4. *Learning Strategies*

Citation	N	Participants	Targeted Skills	Dependent Variable(s)	Independent Variable(s)	Research Design	Results Summary
Owen & Fuchs (2002)	24	-Third grade students: 20 with LD, 1 with mild/mod MR, 2 SLP, 1 ADHD	Use of strategy for problem solving	-Scores on treatment measures for solving word problems	4 Conditions -control -acquisition (scripted lesson) -explicit problem solving strategy instruction at two levels for amount of time spent	ANOVA on improvement between pre-treatment and post-treatment measures	Groups receiving the highest level of instruction in problem solving strategy performed significantly better on both problem solving and transfer measures than did groups spending less or no time on strategy instruction. The control group showed no improvement on problem solving skills.
Maccini & Hughes (2000)	6	Students with LD in secondary school	Use of STAR strategy for problem solving	-Percentage correct on problem representation problem solution strategy use	-Lessons applying the STAR procedure to computation and problem solving involving integers	Multiple-probe across subjects	Participants learned to represent and solve addition, subtraction, multiplication, and division word problems involving integer numbers. Percentage of strategy-use across instructional phases increased. Improvements in searching the word problem, translating the word problem into an equation, identifying the correct operation(s), drawing a picture, writing an equation, and answering the problems.
Hohn & Frey (2002)	102 129	Third, fourth and fifth graders (for both investigations)	Use of SOLVED strategy for problem solving	-Scores on word problem quizzes	-Lessons applying the SOLVED procedure	Pre-test posttest design	Greater improvement was found for groups receiving instruction in the SOLVED strategy than for in the control group. Results were duplicated in the second investigation for third and fifth graders.
Montague & Bos (2001)	6	Students with LD from metro high school in SW.	Use of strategy for problem solving	Accurate completion of 2-step word problems Generalization was Accurate completion of 2-step word problems	Strategy instruction, acquisition and feedback for 8 step problem solving strategy.	Multiple Baseline	Five of six subjects made substantial progress in both speed and accuracy of problem completion and met criteria for mastery. The sixth also improved. Four of six reached generalization criteria.

Owen and Fuchs (2002) examined the effects of strategy instruction on mathematical problem solving over a 3-week period. Participants were 24 3rd-grade students: 20 with learning disabilities, one with mild/moderate mental retardation, two with speech language disorders, and one with attention-deficit/hyperactivity disorder. Teachers of these students were randomly assigned to four treatment conditions: (a) control, (b) acquisition, (c) low-dose acquisition or presentation of the strategy plus transfer, or (d) full dose acquisition explicit instruction of the strategy plus transfer. For treatment groups' b, c, and d, treatment consisted of explicit instruction in the use of the strategy for solving word problems including working examples and practice with a higher achieving peer. The acquisition condition consisted of four scripted lessons teaching a six-step method involving word problems involving finding halves of numbers. The six steps consisted of reading the problem, drawing a visual representation for numbers in the form of circles, drawing a rectangle that is split in half creating two boxes, adding each circle to a side of the rectangle by turns and crossing out the picture of the circle, comparing the circles in the boxes to make sure there was an equal amount and, counting the circles in one box and writing the answer. Treatment group c also received the lesson instruction on days 1 and 2. On days 3 and 4, students transferred the skill to other related problems. On the full dose acquisition plus transfer condition, students received the same 4 days of instruction and worksheets as the acquisition condition. They then received the two transfer lessons presented to the low dose group for a total of six lessons. The researchers used an analysis of variance on improvement between pre-treatment and post treatment measures in terms of number of problems solved correctly. A

statistically significant improvement in successful problem solving was found for full dose acquisition plus transfer group over the control group and the low-dose acquisition plus transfer groups. For amount of work completed, significant differences were found in the low-dose acquisition plus transfer groups and the full-dose acquisition plus transfer group over the control group. By contrast the control group failed to show improvement in problem solving skills. This study shows that explicit instruction in learning strategies yielded significant gains and that described levels of intense strategy instruction worked best. One caveat of this study is that it did not look at strategy instruction in isolation without the use of peer interaction. Thus, further research is indicated in considering strategy instruction separately. Finally, the type of strategy utilized was extremely concept specific and therefore not applicable to a wider range of math word problems.

Mancini and Hughes (2002) investigated the effects of the STAR instructional strategy within a graduated teaching sequence (i.e., concrete, semiconcrete, abstract) on the representation and solution of problem-solving skills encompassing integer numbers for secondary students with learning disabilities. STAR is an example of an empirically validated (Maccini & Hughes, 2000; Maccini & Ruhl, 2000) first-letter mnemonic learning strategy that can help students recall the sequential steps to help solve word problems. The steps for STAR include: **S**earch the word problem; **T**ranslate the problem; **A**nswer the problem; and **R**evue the solution. Six students with learning disabilities were selected from a secondary public school located in central Pennsylvania. The school served approximately 2,200 students in Grades 9 through 12, with 273 students receiving learning support services. For this study, a

multiple-probe design across subjects was used (Tawney & Gast, 1984), which was appropriate, as the study was a preliminary one on the application of instructional procedures to investigate individual performance across time. The instructional procedures used to teach STAR were adapted from the Strategic Math Series (Mercer & Miller, 1991). Treatment consisted of the algebra problem-solving strategy STAR. In the first phase of the intervention, concrete application, students were taught to represent math problems via manipulatives; in this experiment algebra tiles were used. The second step, "Translate the words into an equation in picture form," students were prompted to identify the operation(s) and represent the problem using concrete manipulatives. The third step, "Answer the problem," involved counting the remaining tiles after the operation was performed and the fourth step, "Review the solution," involved rereading the problem and checking the reasonableness of the answer. Students were required to obtain mastery of 80% or higher on two consecutive probes before advancing to the semiconcrete application phase. In the second phase of instruction, semiconcrete application, students move to a two-dimensional representation of the math problems. Instead of using manipulatives to represent the problems, students represent word problems using drawings of the algebra tiles. Then, in the third phase of instruction, abstract application, students were expected to represent and solve math problems using numerical symbols, answer the problem using a rule, and review the solution and check the reasonableness of their answers. Dependent measures included the percentage correct on problem representation, the percentage correct on problem solution and answer, and the percentage of strategy-use. To assess problem representation and problem

solution of integer numbers and related problem-solving tasks, instructional probes and generalization measures were scored using a holistic scoring guide. Points were awarded for correct or partially correct responses. Students were evaluated on their individual behaviors relative to the steps and sub-steps of the STAR strategy. All participants were assessed during baseline measures as well as after each instructional phase to determine changes in strategy-use over time. During baseline, a minimum of four probes was intermittently administered. All participants improved their percentage of strategy-use from baseline to instructional phases for all integer operations. Participants improved their percentage accuracy on problem representation from baseline to instructional phases in computation of integer numbers. Participants' mean percentage correct on maintenance measures given up to 10 weeks following the intervention was 75% for problem representation and 91% for problem solution. Results indicated that all participants learned to represent and solve addition word problems involving integer numbers and that 5 participants learned to solve subtraction, multiplication, and division word problems involving integer numbers. The 6th participant was absent frequently and therefore was unable to complete all of the objectives. Participants also demonstrated increases in their percentage of strategy-use across instructional phases. Categories of marked improvements included searching the word problem (i.e., reading the problem carefully), translating the word problem into an equation, identifying the correct operation or operations, drawing a picture of the problem, writing a correct equation, and answering the problem. On a social validation form, most participants indicated that they were interested in learning about algebra concepts and skills and that the

strategy helped them understand what it means to solve problems involving integer numbers, and they recommended its use with other students. In addition, most participants indicated they agreed or strongly agreed that the intervention was worth their time, that it helped them understand mathematics concepts, and that it helped them feel better about their introductory algebra skills. These results are similar to those found in the mathematics literature involving problems that students with learning disabilities experience with effective problem-solving strategies and self-monitoring (Montague & Bos, 1990). One limitation of the study was the multitreatment approach used. For example, although students memorized STAR and used structured worksheets listing the steps and sub steps, requiring a set criteria may be necessary to help students consistently remember the steps. Future studies should provide direct comparisons of instructional techniques to determine the most effective approaches to teaching algebra to students with learning disabilities. This study supports the need for further research and therefore validates the current study on learning strategies.

Hohn and Frey (2002) created a learning strategy called SOLVED in order to help elementary mathematics students remember and engage in metacognitive phases during mathematical problem solving. They described these phases in two steps. The first phase as problem representation, which they subdivided into two substages, problem translation in which information in the problem statement is interpreted and problem integration in which knowledge of problem types is used to form an integrated structure of the problem's relationships. They considered the next phase to be solution planning, in which the learner selects a solution procedure. Solution

execution follows, in which necessary computations are carried out. Solution monitoring, in which the problem solver reviews the computations to detect errors, completes their sequence. This study was completed in two separate experiments. The first experiment was designed to compare the SOLVED program to textbook based instruction. Participants in the experiment were 31 third-grade students, 37 fourth-grade students, and 35 fifth-grade students in two intact classes at each grade level. One class at each grade level was selected randomly to receive training in the SOLVED method; the other class served as a control. Groups were presumed to be relatively heterogeneous. The materials for this study consisted of two 4-problem quizzes presented prior to and after training and 12 sample problems used during training, at each grade level. The SOLVED method was then described and demonstrated for students. Instruction included a copy of the SOLVED checklist. After initial instruction students were expected to be able to describe the SOLVED process with relation to a specific math problem. Pre and post-test data was taken for each group of students. Results clearly indicated greater improvement for those in the SOLVED condition over time when compared with those in the control treatment for all three grades.

A second experiment was then implemented to analyze student use of the SOLVED technique and its relation to performance, and to determine whether performance levels would be maintained after a longer delay (Hohn & Frey, 2002). Participants in Experiment 2 were 38 third graders, 37 fourth graders, and 45 fifth graders in two different intact classes at each grade level from the same elementary school, as in Experiment 1. Testing materials consisted of three five-problem quizzes

presented immediately after each of three review lessons and a five-problem quiz administered 2 weeks after the final lesson. Four of the problem types were the same as in Experiment 1, and the problems used to compose these tests were drawn from those quiz items, as well as from sample problems. All students were taught three lessons, each reviewing the five grade-appropriate topics. Students had been exposed to these topics in work done earlier in the school year. Lessons were taught following the same direct instruction format used in Experiment 1; the SOLVED method was used in each lesson. Teachers in Experiment 2 participated in the same SOLVED training and feedback procedure as that employed in Experiment 1. After each lesson, the 5-item quiz was administered to students, who were reminded to show all their work. Two weeks after these lessons were concluded; the students completed an additional 5-item quiz covering the five topics addressed. The results of the second experiment indicate that there was steady improvement for third and fifth graders over trials and that processing gains continued 2 weeks later without prompting. For fourth graders, although improvement in accuracy and metacognitive problem solving over trials did not reach statistically significant levels, gains were observed in both areas. In addition gains were recorded for all groups whether disabled or not indicating that explicit instruction of problem solving strategies can benefit all students. This study lends support to efforts to use a more process-oriented approach as recommended by the National Council of Teachers of Mathematics (2001) for mathematics instruction and illustrates the need for providing students with appropriate skills for solving math problems.

In another study investigating leaning strategies as a problem solving tool, Montague and Bos (2001) worked with six adolescents with learning disabilities from a southern Arizona metropolitan school to evaluate the effectiveness of an eight step problem solving strategy on verbal math problem solving performance. Participants ranged in age from 15 to 19. All students had IQ scores in the average range. The study utilized a multiple baseline design including baseline, treatment, generalization, maintenance and retraining phases. Baseline data was taken on test scores and completion time for the pre-test. Ten two step problems were used for the dependent measure during baseline, treatment and maintenance. These were selected at random from a bank of 220 two-step for baseline and treatment. Three-step math problems from a bank of 50 were selected at random for generalization. All problems include a variety of combinations of the four basic math operations. The treatment phase began with strategy acquisition for the eight step strategy. This strategy contained the following steps: read problem aloud, paraphrase problem aloud, visualize, verbally state the problem, hypothesize, estimate, calculate and self-check. Note the relatively general nature of the several steps in this strategy; many learning strategies involve some general steps such as surveying, paraphrase, visualize” etc., and it is possible that a more specific strategy would enhance learning more so than this type of general, non-specific problem solving suggestion. Strategy acquisition was conducted over three 50-minute training sessions. The acquisition phase was divided into five steps: analysis of current learning habit, description of the new strategy, modeling of the new strategy, and student practice with classroom materials. Corrective feedback was provided throughout the acquisition phase. Students were required to reach 100

percent accuracy in verbalization of the strategy steps from memory. A practice session was completed before each test where students verbalized the strategy. A chart of the steps was provided at this time. Test sessions were then used to collect the dependent variable including items correct on each timed ten problem two-step math test and time to complete the test. Students were cued to use the strategy. On the following day a test of 10 three-step verbal math problems was administered to test for generalization of the strategy to more complex math problems. To measure maintenance of the strategy tests of 10 two-step math problems were administered at two week and three month intervals. Evaluation of the data revealed that five of the six subjects made substantial progress in both accuracy and speed after participating in the cognitive training strategy, and met the preset criteria for mastery. Although the last subject did not meet criteria there was significant increase in both accuracy and speed of problem completion. Four of the six subjects also reached the criteria set for generalization of the strategy to more difficult three-step problems. This study indicates that a specific learning strategy is a successful tool for students with learning disabilities even when the strategy itself involves general, rather non-specific steps toward problem solution.

Research supports the need for explicit instruction in specific problem solving strategies for students with learning disabilities(Owen & Fuchs, 2002; Maccini & Hughes, 2000; Hohn & Frey, 2002; Montague & Bos, 2001),. In each investigation, students who were explicitly taught a learning strategy for solving math word problems were able to significantly improve their problem solving performance. In addition, studies showed that students with learning disabilities generally benefit to a

greater degree than non-disabled peers who develop successful strategies without explicit instruction (Montague and Applegate, 2000; Parmar, Cawley & Frazita, 1996; Jimenez Gonzalez, Garcia, Espinel, 2002). However, while all strategy instruction seems to be effective, it is possible that more specific strategies generally increased problem solving ability.

Summary

As shown in this literature, researchers have noted that students with disabilities lack the decision making processes and analytic ability to solve word problems at the same level as their non-disabled peers. In addition, previous research indicates that students who are unable to accurately solve math word problems require explicit instruction in strategies for solving word problems to be successful (Bottge, Rueda, LaRoque, Serlin, R. and Kwon, 2007; Fuchs, Fuchs, Hamlett, & Appleton, 2002; Bottge, 1999). Recent research has shown that a wide variety of strategies seem to enhance students problem solving abilities, including situated learning environments, schema instruction, graphic organizers, and acronym based linguistic learning strategies. In addition the model of universal design supports the instruction in a wide variety of strategies that will allow students with differing strengths and abilities to access the curriculum (Fahsl, 2007; Fogen, Jiban, and Deno, 2007; Maccini, & Gagnon, 2006).

The availability of instruction in multiple strategies will improve student access to the curriculum (Wood, 2002; Hitchcock, 2001). Further, these studies show that the use of problem solving strategies is key in helping students to become successful and efficient problem solvers (Woodward & Montague, 2006; Montague,

2004; Peverly, 1991; Swanson, 1990; Brown & Kane, 1988). In many of the reviewed studies such as those involving situated cognition, effects were greatest when interventions were combined with instruction in specific problem solving strategies.

When solving word problems, students with learning disabilities often have difficulty understanding the main thoughts, remembering details from written passages, and making inferences (Woodward & Montague, 2006; Graves, 1986). Recent research has suggested that with explicit instruction in use of the necessary tools for problem solving these students can be successful in a problem solving environment (Jitendra, DiPipi and Perron-Jones, 2002). Strategy instruction such as schemas, which emphasize conceptual understanding, graphic organizers, which provide a visual format for organization of work, and learning strategies, which provide a format for students to organize, recall and solve problems, can assist students in becoming successful math problem solvers. In addition, strategy instruction can be used in a variety of context including testing situations and situated problem solving. Key components should include steps that specifically apply to word problem solving skills.

There are several limitations to the body of work. Although there is a growing body of research in the area of the use of learning strategies as applied specifically to solving word problems the research in this area is still somewhat limited. Further, the various strategies implemented may not go far enough in teaching students the specific strategy steps necessary to effectively attack word problems. Specifically, many of the strategies were somewhat generic in nature and did not specifically

address the key metacognitive components in solving word problems. Those that were more specific addressed only one exact type of math concept and were not generalizable to others.

Math teachers have been encouraged by the National Council of Teachers of Mathematics to adopt a broader view of math instruction which includes the inclusion of problem solving tasks (NTMC, 1989). The research clearly shows that not only do students with learning disabilities lack the skills and proficiency for problem solving employed by their non-disabled peers; they also lack the tools for developing these skills (Jitendra, DiPipi & Perron-Jones, 2002; Graves, 1986). The data that is currently available indicates that the area of explicit learning strategies deserves further attention by researchers. If students are to be successful problem solvers, explicit instruction in effective problem solving strategies must be implemented in the classroom (Montague, 2004; Owen & Fuchs, 2002; Hohn & Frey, 2002; Montague and Bos, 2001).

Purpose of This Research

The purpose of this study is to investigate the effectiveness of a specific learning strategy that has been explicitly taught in improving the ability of students with learning disabilities success in solving math word problems. Rather than a general set of strategy guidelines, the learning strategy developed for this study includes specific components that will help students to select key information from a word problem and organize that information into a meaningful and solvable format. The strategy steps are short and specific in order to facilitate its use. This strategy has been designed to apply to any math problem solving situation rather than specific

types of problems which will assist students across content areas. In addition, the strategy is one that if successful, students will be able to apply in classroom instructional settings and testing situations.

In current educational settings, students with disabilities are expected to perform at the same level as their non-disabled peers in testing situations, though they may be at a distinct disadvantage. This has served to limit their access to programs and opportunities available to non-disabled peers (Fuchs & Fuchs, 1999; Ward, 2000; McKeivitt & Elliott, 2003; Kameenui, Chard & Lloyd, 1997; Paul, Lavelly, Cranston-Gingras & Taylor, 2002). This study will therefore attempt to answer the questions will students with learning disabilities be able to acquire a sequential mnemonic strategy for problem solving when provided with specific training in that strategy and does explicit instruction in the use of a highly specific word problem solving strategy improve the accuracy of students with learning disabilities for problem solving? Finally, will students be able to maintain use of a sequential mnemonic strategy for solving novel math word problems over time?

CHAPTER 3

METHODS

Participants

The participants for this study included four middle school aged students who have primary special education eligibilities in the area of learning disabilities for processing of reading comprehension which affects their academic progress for mathematics in the area of comprehension and execution of word problems. All students participating in the study met the following selection criteria. Students were enrolled in a special education pullout class for mathematics in the eighth grade. Goals and objectives on Individual Education Plans (IEP) include improvement in solving math word problems. Permission for all students to participate in this investigation was obtained from the parent or legal guardian (see Appendix A).

The participants included three male students and one female student ranging in age from 13 years 7 months to 14 years 5 months. All students were enrolled in the general education setting for the majority of their day, but received special education services for both math and reading. One student was African-American, one Hispanic, and two were European-American.

Students were chosen to participate in this study based on difficulty with mathematical word problem solving. All of these students had IQ scores in the average range. All participants qualified for special education services for learning disabilities according to the state of Georgia eligibility requirements in the areas of basic reading, reading comprehension and math reasoning. The students were all placed in a special education math class because of difficulty in reading math

textbooks, instructions, directions and assignments including word problems and difficulty in thinking mathematically. In addition, two of the students were diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) and were taking medication during the course of the study. In addition to meeting the criteria for learning disabilities, students were also selected for participation in the study based on their performance on assessments measuring their ability to organize and solve word problems and failure to meet minimum requirements on the state sanctioned standardized test. None of the students had prior experience in using the learning strategy presented in this study.

Jorge. Jorge was a 14 year 5 month old male Hispanic student. Jorge was a very motivated student and reported that he enjoys school. His teachers describe him as a hard work and positive role model. Jorge was administered the Woodcock Johnson III Tests of Cognitive Abilities and Tests of Achievement in the fall of 2007. Assessments indicate that his cognitive abilities are in the low average range with his standard score falling in a range of 71 to 87. Subtests for Verbal Ability and Working Memory indicated that these were a relative strength for Jorge with standard scores of 67 to 82 and 70 to 86 respectively.

Achievement scores indicated relative weaknesses in Broad Reading, with standard score falling in the range of 69 to 76, and Broad Math falling in the range of 64 to 74. Although the discrepancies demonstrated in testing were smaller than for other students with disabilities, the placement committee agreed that based on English was a second language for Jorge and his demonstrated strengths for performance

skills in classroom settings supported his receiving services in the area of learning disabilities.

Anthony. Anthony was a 13 year 7 month old male African-American student. He was very excited about participating in the study. Anthony has experienced significant failure in mathematics. He had not passed state requirements in mathematics at any grade level. Anthony was administered the Woodcock Johnson III Tests of Cognitive Abilities and Tests of Achievement in the fall of 2007. Assessments indicate that his cognitive abilities are in the low average range with his standard score falling in a range of 77 to 91. Anthony's Verbal Ability is a relative strength with a standard score within the range of 80 to 94. Anthony demonstrates weaknesses in the area of Working Memory and Thinking Ability. His standard score for working memory fell in the 71 to 84 range. The Thinking Memory standard score representing Anthony's measure of thinking processes fell in the very low range of 64 to 74.

Achievement assessments for Anthony indicate that he has significant weaknesses in Broad Reading or the abilities to decode words, speed of reading, and comprehension of materials. His standard score fell in the 60 to 66 range. In addition, his Broad Math standard score fell in the 74 to 83 range. This score measures the ability to reason mathematically and to problem solve. According to the psychologist evaluation, poor Thinking Processes affect his achievement abilities in both reading and mathematics.

Anna. Anna was a 14 year 1 month old female European-American student. In addition to qualifying for services in the area of learning disabilities, she has also

been diagnosed with ADHD. Anna takes Aderall twice daily. Anna is an energetic student who participates in extracurricular activities. Anna was most recently evaluated in the fall of 2007 with the Woodcock Johnson III Tests of Cognitive Abilities and Tests of Achievement. Based on the cognitive assessment there is a 95% probability that Anna cognitive ability score (CIA) would fall in the range of 73 to 84.

Achievement measures indicated relative strengths in her speed of processing which was measured in the average range of 77 to 92. In addition, her verbal ability also fell in the average range of 75 to 91. Relative weaknesses were measured in Broad Reading including both phonemic awareness and comprehension with her score falling in the range of 62 to 73 and Broad Math with the score also falling in the 62 to 73 range. Reading comprehension is significantly weak. The psychologist reported her overall reading ability as negligible. Her standard score for this measure fell in the 41 to 55 range. Anna has not passed state required criterion assessments for reading or math despite accommodations including having material read aloud.

John. John was a 13 year 10 month old male European-American student. John was originally evaluated for services in pre-school for ADHD. Manifestations include tuning out and frequently losing his train of thought. He often has to begin tasks over because he has lost track of where he is in a given task. John currently takes *Adderall*. Concerns of 3rd grade teachers with regard to processing speeds and academic progress prompted additional testing for learning disabilities. John was most recently evaluated in the spring of 2007 with the Woodcock Johnson III Tests of Cognitive Abilities and Tests of Achievement. John's overall cognitive ability was measured in the range of 78 to 92.

Achievement assessment for John indicates a relative strength in the area of Verbal Ability. John also demonstrates a strength in classroom settings with tasks requiring an understanding of visual-spatial relationships such as geometry. Relative weaknesses were measured in both Broad Reading, with his standard score falling in the range of 54 to 65, and Broad Math falling in the range of 56 to 68. Although John is able to memorize sight words he is often unable to apply phonetic rules to decode unfamiliar words. In addition, poor reading skills affects his comprehension of word problems in math. John has not passed state assessments for either math or reading.

Setting

The study took place in a special education resource room in a middle school serving sixth, seventh and eighth grade students. The room was a full sized classroom and equivalent to all other classrooms in the building. A certified teacher and paraprofessional were present. To facilitate instruction in the proposed learning strategy a small table was separated from the rest of the classroom by a study carrel to eliminate distractions. Implementation of the strategy was completed at this same table.

Materials

Set of Word Problems: Two hundred math word problems of approximately the same length were used in the pretest, training materials and subsequent assessments. These were selected from grade level math materials and each consisted of two or three sentences. Problems were word to be at the second to third grade reading level. In cases where more than one operation was required problems were

broken down into parts requiring only one operation. Materials selected were those from *Prentice Hall* (2007) publishers of math texts.

Four main types of math problems have been described by Silbert et al. (1981). They are simple action problems and complex action problems both require the use of algorithms to solve. A third type of problem involves classification information is organized into specific data sets. Finally, comparison problems involve description of the relationship between data sets. The problems for this investigation consisted of simple action problems that include only one of the four whole number mathematical operations per problem. The simple action problems have been selected as the most appropriate for the students participating in this study based on testing data results for ability level. Additionally, research, reviewed previously documenting that students with learning disabilities have difficulty completing even this, the simplest type of problem involving one simple calculation (Baroody & Hume, 1991; Bottge, 1999; Parmar, Cawley & Frazita, 1996; Montague & Applegate, 2000; Jimenez Gonzalez & Garcia Espinel, 2002).

The reading level for problems was at the second and third grade reading levels. A sample consisting of 10% of the problems were selected and analyzed to determine that the reading level was appropriate and within the target range using the *MS Word Flesch-Kincaid Grade Level* formula readability level. Sample problems are presented in Appendix B. The pool of word problems were divided into 40 sets of four problems each. Individual sets included one of each of the four operations.

SCOPE: A Math Problem Solving Strategy: Students in this study were taught a learning strategy that will assist them in organizing, recalling and solving

word problems known as *SCOPE*. The *SCOPE* strategy was developed for this study. Each letter in the *SCOPE* strategy represented a step in the strategy that is an important component for word problem solving:

- *S* Survey the problem
- *C* Circle 2 numeric and 1 operational term necessary to solve problem
- *O* Organize the information into a solvable format by creating an algorithms
- *P* Perform the operation correctly
- *E* Exhibit correct final solution

The strategy offers a structured method to approach an unfamiliar word problem. The strategy also employs a word as a mnemonic that is easily remembered and meaningful. In real world situations to scope means to look at in a careful manner. Using a real word as the mnemonic for the strategy should enhance memorization of the strategy for students with disabilities (Manalo, Bunnell, and Stillman, 2002).

Performance of the learning strategy resulted in four specific observable behaviors by the student for each word problem completed accurately (steps 2, 3, 4 and 5 in the *SCOPE* procedure). Students were given a card containing the learning strategy for the students to review as they complete each problem (see Appendix C). Students also received verbal prompts as needed during the acquisition phase. If students did not exhibit competence in the use of the strategy by demonstrating its use for at least 75% of the problems, reteaching of the strategy was be provided.

Response Definitions and Data Collection

Below are descriptions of the response outputs for each step in the problem solving strategy. Students will receive points for responses using the scoring rubric.

1. The First step, Survey the problem, requires that the student read the problem. As this was not an observable or measurable behavior, no points were not awarded.
2. In the second step, Circle numeric and algorithmic terms, students received one point for each term correctly identified by circling the terms in the word problem. For each problem students were expected to identify a total of two numbers and one operation term representing the problem accurately, and thus students received a score ranging from 0 to 3 points on this step. No points were deducted or awarded for any information circled that did not relate to solving the problem.
3. For the third step, Organize the data, students received three points for putting the data into a solvable equation. Because organization of an algorithm is critical for problem solution, more points were awarded for this step than for merely identification of the numeric and operational terms in the problems. Students received either 0 or 3 points for this step. Points were awarded only if the format will result in the correct solution. No points were awarded for incorrect equations that would not indicate a correct solution.
4. The fourth step, *Performs the Calculations*, students were expected to perform the calculation indicated by the algorithm accurately. One point was awarded

for correct calculation. Zero points were awarded if the calculation was incorrect or if the selected algorithm did not result in a correct solution.

5. The final step, *Exhibit the Correct Solutions*, the student were required to indicate the correct solution by copying their final answer into the solution box. One point was awarded for showing the final answer. This step is often omitted by students with learning disabilities (Bottge, B. A., 2001; Van Garderen, D. & Montague, M., 2003; Wilson, C. L., & Sindelar, P. T., 1991; Yan, P. X., & Jitendra, A. K., 1999).

Experimental Design

A multiple probe across subjects design was used to evaluate the functional relationship between the dependent and independent variables (Albert & Tawney, 2006). A probe was defined as an intermittent assessment of the selected target behavior, in this case the use of a specific learning strategy to complete word problems, under nontreatment conditions. This type of design lends itself to small sample size and allows for evaluation across students. It is a true experimental design in that it allows for causal inference. A multiple probe across subjects design is practical for evaluating situations where an intervention would be likely to bring about permanent changes in the dependent variable. Experimental control can be demonstrated as long as the pretreated probe and true baseline data are constant and a consistent change is shown when the treatment is introduced.

A multiple probe across subjects design was also selected over an AB design because it will protect against the inability of AB - type designs to demonstrate indisputable control by the independent variable by showing the effects at different

times. It is unlikely that a confound could repeatedly coincide with the introduction of the experimental variable. The effects of a confounding variable therefore, were seen as a change in the behavior in each probe after the implementation of the intervention. In addition, the probe design avoids problems of extinction, fatigue and distraction that might occur in a multiple baseline design. It therefore, offers an efficient means of evaluating the effects of training on the sequential steps of the learning strategy.

Each student received individual instruction in the use of the strategy for 20 minutes per day. On the first day of instruction, students were provided with an explanation for the purpose of the strategy. Next, students were individually introduced to the learning strategy. Students were taught each step of the strategy in sequential order. Students then participate in guided practice for applying the strategy to example word problems. When students were able to complete problems without prompting, they were asked to complete problems independently. Feedback and correction in the use of the strategy was provided to students that experienced difficulty.

Dependent Variable

The dependent variable in this study was the number of math problems done correctly with each problem being worth a total of eight points for a maximum score of 32 points for the entire set. Students were presented with four word problems during each instructional session each day. All problems could be completed using a single algorithm. All four math operations were included in each set of problems in random order. A scoring rubric was used to score each problem based on the adherence to the learning strategy. The rubric is presented in Appendix D.

Procedures

Initial Probe: Initial baseline probes were completed for five days and were used to assess all students' abilities to independently solve word problems. Students completed four word problems for each set. All sets included one problem for each operation. Students were required to solve the problems independently; however problems were read aloud and students were allowed to use a calculator.

Intervention: To begin the intervention, the first participant was introduced to the SCOPE strategy in an instructional session lasting 20 minutes. This included providing an advance organizer of the strategy to help relate previously mastered information to the new lesson, an explanation of the new skill was presented; and a rationale for learning the new information. Verbal instruction included modeling to demonstrate the appropriate use of the strategy. This was a think aloud step similar to that used in both Maccini and Gangon's study (2006) and Montague and Applegate's study (2002).

A training checklist was used to ensure that the procedure used with each student was consistent (see Appendix E). The investigator went through the steps of the strategy using an example of the structured worksheet that the students were provided. Students were instructed to watch and listen as the investigator worked through the example. First, the student were taught to survey the problem as the first step represented by the *S* in *SCOPE*. The student practiced reading through the problem from beginning to end in a whisper. This also allowed them to have an overview of the question before attempting to solve it. The student practiced reading the problem independently. Because was not a measurable behavior, the second step

represented by the *C* in *SCOPE* was combined with the first. In this step, the investigator reviewed cue words used to determine mathematical procedures. Students have been previously taught these words as part of their math curriculum. The investigator also modeled how to collect the important information in the problem by thinking aloud and circling cue words. This included words which helped the student know which operations to use and how the information should be organized as well as numerical information. The investigator reviewed with the participants a list of words that relate to mathematical algorithms, modeling of the required behavior and guided practice with word problems. Feedback and reteaching was provided if the student demonstrated difficulty in completing this step.

The investigator then modeled how to organize the information into the solvable format of an equation. This is represented by the *O* in *SCOPE*. This included demonstrating the required behavior with thinking out loud and guided practice with word problems. Feedback and reteaching was provided if the student demonstrated difficulty in completing this step.

Next, the student was taught to perform the operations, represented by the *P* in *SCOPE*, to resolve the question being asked in the problem. Students were allowed to use a calculator or times table chart in order to remove the confounding variable of math facts memorization. Instruction consisted of reviewing the steps for solving an equation using opposite algorithms. This skill had been previously taught as part of the curriculum, but was not been applied to the solving of word problems.

Finally, for the last step represented by the *E* in *SCOPE* the student learned to show the final answer. Students were required to write their final answer in the space

provided. This is a step in problem solving that students with disabilities often omit and therefore fail to receive credit because they have not indicated what final solution they have obtained or incorrectly write the final solution. Redirection for this step consisted of verbal prompts to indicate the final solution.

Instructional Phases: For each step, students were expected to be able to repeat the mnemonic acronym and describe the steps with 100% accuracy. Instructional components include breaking the strategy down into individual parts and applying each one to a specific word problem. Next, students were given a card with the strategy including an example written on it to help prompt them as they work through a problem (Presented in Appendix C).

After practicing each step of the strategy with the investigator, the student then practiced applying the strategy independently on a daily basis. Daily practice consisted of verbal repetition of the strategy steps learned up to that point in the treatment followed by completion of four word problems. On the second and third day of intervention, these instructional procedures were repeated, as necessary, until the child can independently recall the SCOPE steps.

If students were unable to accurately state and describe the strategy, they were provided with retraining in the strategy. Students were then be presented with word problems in a written form down side of a page with work space provided on the remaining portion. After evaluating student work for each set of word problems, students received feedback on their application of the strategy through analysis of their work in individual conferences. This feedback was provided the following day before students attempt a new set of problems. Each problem was discussed and the

correct solution through application of the strategy will be explained and practiced. Students were asked to verbally describe their use of the strategy as each problem and solution is evaluated. When the first student showed three days of growth a second probe period of one day was conducted for all students. After the second probe period, students 1 and 2 received intervention independently.

To ensure that students actively participated in the intervention program they were provided with information on the value of this program to them in that it helped them to prepare to pass state required criterion referenced math tests which are in a word problem format. Students also charted their individual progress on a graph to provide incentive and feedback. Students selected reinforcements such as computer time as goals were achieved. In addition, verbal praise and encouragement was provided throughout the intervention. Students participated willingly and demonstrated investment in the study by following all directions and applying the SCOPE strategy to the word problems they were provided. In addition the students were heard to make positive statements including, “Oh, this is easy,” “Is it my turn yet”, and “My graph looks phat”.

Reliability Procedures

Interobserver Agreement. In order to document reliability in measurement of the dependent variable, another teacher from the students’ middle school scored all of the SCOPE word problem probe sheets while the investigator scored 25% of the same SCOPE word problems probe sheets for a previously completed pilot study. The investigator using the scoring procedures described above trained the additional teacher. The teacher did not have prior knowledge of the purpose or conditions of the

study. For the first three days of the intervention, the second observer scored all participating students' sheets. In addition, in subsequent probes both the initial observer and the second observer scored one of the completed word problem sheets for a student randomly selected from the group. To measure inter-observer agreement the number of items on which both observers agree was divided by the total number of points possible and multiplied by 100. Reliability of 100% was attained between the observers prior to initiating the current project.

Procedural Validity

An observer, a paraprofessional in the students' school, collected procedural validity data on the experimenter's implementation of the study's procedures. A written checklist (see Appendix E) was provided to this observer stating the instructional procedures used to train students on the scope strategy. The occurrence or non-occurrence of each step in the procedure was recorded. Nine individual steps were required to complete instruction in the strategy. The percent of completion of the steps was calculated by dividing the number of procedures actually occurring by the number of procedures expected to occur and multiplying by 100. The procedural reliability was calculated to be 100%.

Social Validity

Students were provided with the opportunity to offer input regarding the research via a Survey (see Appendix F). The survey was administered orally by the investigator and responses were recorded by the students who circled a yes or a no indicating whether or not they agreed with the given statement. The focus of the survey was on the students' satisfaction in using the learning strategy. Questions

included how helpful the students found the use of the learning strategy, the ease of learning, ease of use and whether they are likely to employ the strategy in the future. Students reported that they found the strategy easy to remember. They agreed that it helped them to organize the given problems and that they were able to use the steps. Students reported that they believed they would use the strategy in other math classes. They did not see the benefit for using the strategy in classes not specifically designated as a math class.

Pilot Study

In order to ensure feasibility of SCOPE procedures, a pilot study was completed with four students over a period of three days. SCOPE training sessions were conducted with the students as a group with the lead researcher doing the instruction and an assistant observing the training. The observer used the training checklist to determine that the procedures were followed as prescribed (Appendix E). All procedures were followed accurately on each day.

On the first day of instruction, students in the pilot study did not express a strong interest in completing the math problems and were prompted to stay on task several times. On the second day of instruction participants began to show an understanding of the strategy. One student said, “Oh, I get it. This will help me plug in my numbers!” Before initiation of the strategy this group of students often sought means to avoid math assignments. By the second day of instruction the group exhibited an unusual amount of enthusiasm for completing the required problems. All students then actively participated in the pilot study and completed the problems as required. Requests were made for more problems to complete. As a group, the

students showed improvement in the total number of problems attempted and the accuracy of completion.

Both the investigator and the observer independently completed scoring of the students' work using the Word Problem Scoring Rubric developed for this study (Appendix D). A comparison of students' scores indicated that scoring was consistent between both scorers with 100% reliability.

CHAPTER 4

RESULTS

The purpose of this chapter is to present the results of reliability and the effectiveness of the specific learning strategy that has been explicitly taught in improving the ability of each students' success in solving math word problems. Interpretations of the results of individual student performance are presented. A discussion and consideration of the limitations and implications of the findings are provided in the following chapter. The findings viewed with respect to the research questions: Will students with learning disabilities be able to acquire a sequential mnemonic strategy for problem solving when provided with specific training in that strategy? Will application of a sequential mnemonic strategy for problem solving lead to improved problem solving competency for students with learning disabilities? and Will students be able to maintain use of a sequential mnemonic strategy for solving novel math?

Reliability

Procedural reliability data were collected on both the dependent measure of student responses and the independent measure of the intervention, or procedural reliability. Inter-observer reliability data for the dependent variable was collected for all baseline assessments and for one fourth of all of the investigation probes. One student was selected randomly using simple random sampling for each probe. Inter-observer reliability was calculated at 100%. The researcher chose to measure reliability on 100% of the training sessions across all four participants because of the small sample size. Procedural reliability was calculated at 100% for each of the

participants during all training sessions. No anomalies were noted by the second observer during training of the learning strategy.

Sessions

As determined by a multiple-probe design, baseline data for the first participant Jorge was collected for the shortest period. Likewise, for the last participant, John, baseline was collected for the longest period and in maintenance for the shortest time period. Due to constraints of the academic school year, only two probes of maintenance data were collected for John over a period of three days. Jorge was in the intervention phase for seven days; both Anthony and Anna were in the intervention phase for eight days and John for five days. Table 5 presents the number of days each student spent in each condition.

Table 5: Number of days participants spent in each condition

Participants	Baseline	Intervention	Maintenance	Total Days
Jorge	5	12	29	41
Anthony	12	9	20	41
Anna	21	11	9	41
John	30	6	5	41

Effectiveness of the Intervention

Figures 1-5 present the percent correct for each of the word problems solved correctly. Instruction in the SCOPE learning strategy resulted in a significant and dramatic change in each student's ability to accurately solve given word problems. The increase in percent correct was maintained during the maintenance phase for each student. The effectiveness of the intervention was demonstrated through intersubject direct replication for the four participants.

Jorge. Jorge's data is represented in Figure 1. Jorge's mean percent correct during baseline was 12% over 5 sessions. The data trend was flat indicating stability in the data. Following the introduction of the intervention there was an immediate change in level indicating a positive effect of the intervention on problem solving skills. Jorge's mean percent correct during intervention increased to 82% with stability in level. Jorge met criterion, defined as 75% correct for three consecutive sessions. Although the data represented a slight downward trend for the third probe the score obtained was still above criteria. Between baseline and intervention there was 0% of overlap for data points. The lack of overlap indicates a positive change in performance.

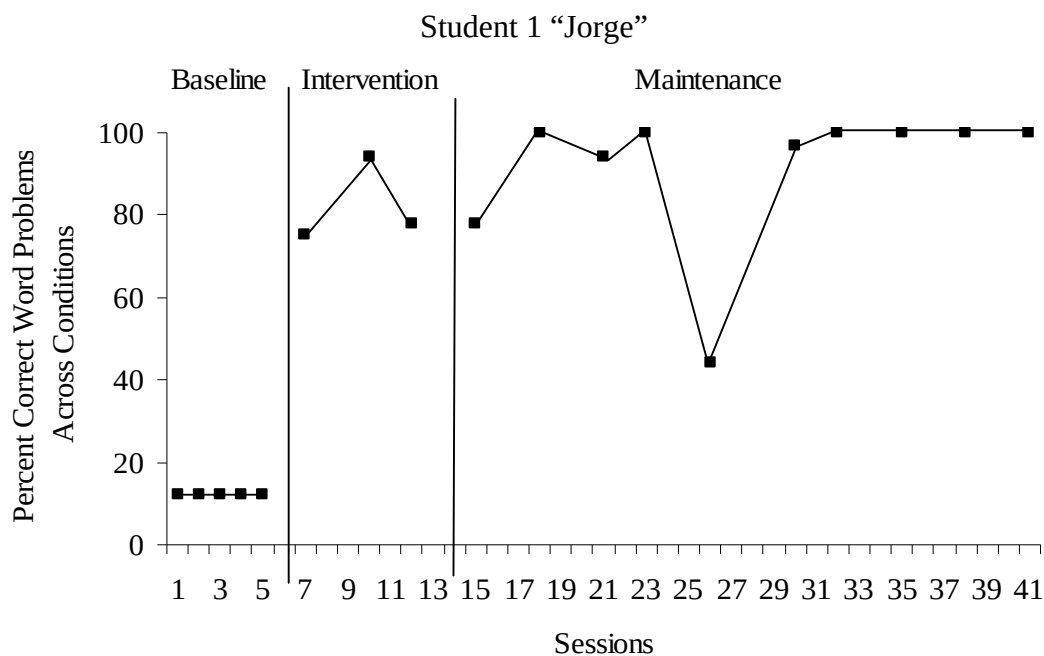


Figure 1

Jorge's mean percent correct for the maintenance phase was 91% over 10 probe sessions. There was an ascending trend in performance during maintenance indicating that Jorge continued to improve in the use of the strategy once reaching criteria. One probe score was much lower than others during maintenance. Jorge scored at 43% for that probe. He was provided with one reteaching session and subsequent probes indicated that he had mastered the learning strategy and that use of the strategy improved his performance for problems solving of word problems. Overall Jorge's scores were at or above those in the treatment phase indicating that the intervention was successful for this participant.

Anthony. Anthony's data are represented in Figure 2. Anthony's mean percent correct during baseline was 5% over 10 sessions including. Anthony's data represented a slight downward trend, which justifies initiation of the intervention if the anticipated result will increase the desired behavior. During intervention Anthony's mean percent correct increased to 94%. There was a slight downward trend; however even at the lowest point Anthony's percent correct was 88%. There was a 0% overlap between baseline and intervention. As with Jorge, the intervention had a positive effect on Anthony's performance. Anthony met criterion during the intervention for three consecutive probes.

Anthony's mean percent correct increased during maintenance to 98% over the maintenance probes. Anthony's performance did not decline over time when presented with similar word problems. Percent overlap between maintenance and intervention was 100%. Although Anthony exhibited a slight decline during the intervention phase he self-corrected by asking specific questions related to the

strategy. The intervention was effective for Anthony in increasing the percent of correct solving of word problems.

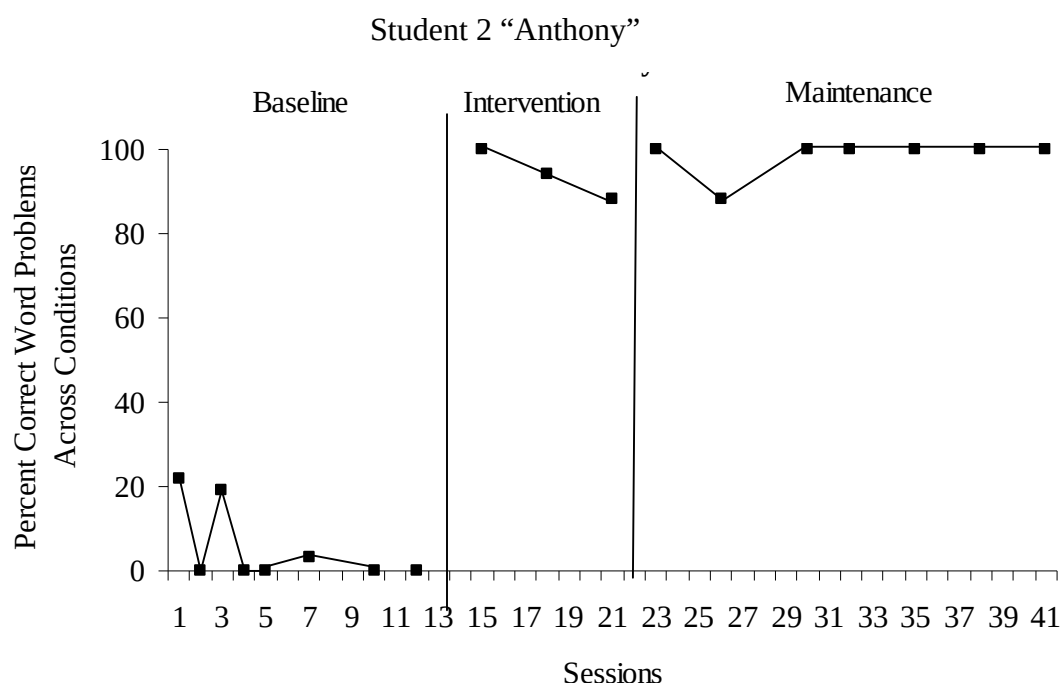


Figure 2

Anna. Figure 3 presents Anna’s data. During baseline, Anna’s mean percent correct was 2% correct over 11 baseline sessions. Anna’s baseline data remained consistently low. Anna’s data remained flat throughout baseline warranting introduction of the intervention. Upon initiation of the intervention, Anna’s scores immediately improved. Anna reached criterion for all three intervention probes. She reported that she was very motivated to do well with the instruction provided to her. Her mean percent correct during intervention was 98% over three intervention probes.

Anna continued to exhibit success during the maintenance phase. She demonstrated accuracy in problem solving using the learning strategy by scoring 99% correct for word problems over six maintenance probes. There was 84% overlap

between the intervention and maintenance phases. The intervention had a positive effect on Anna's ability to organize and solve word problems.

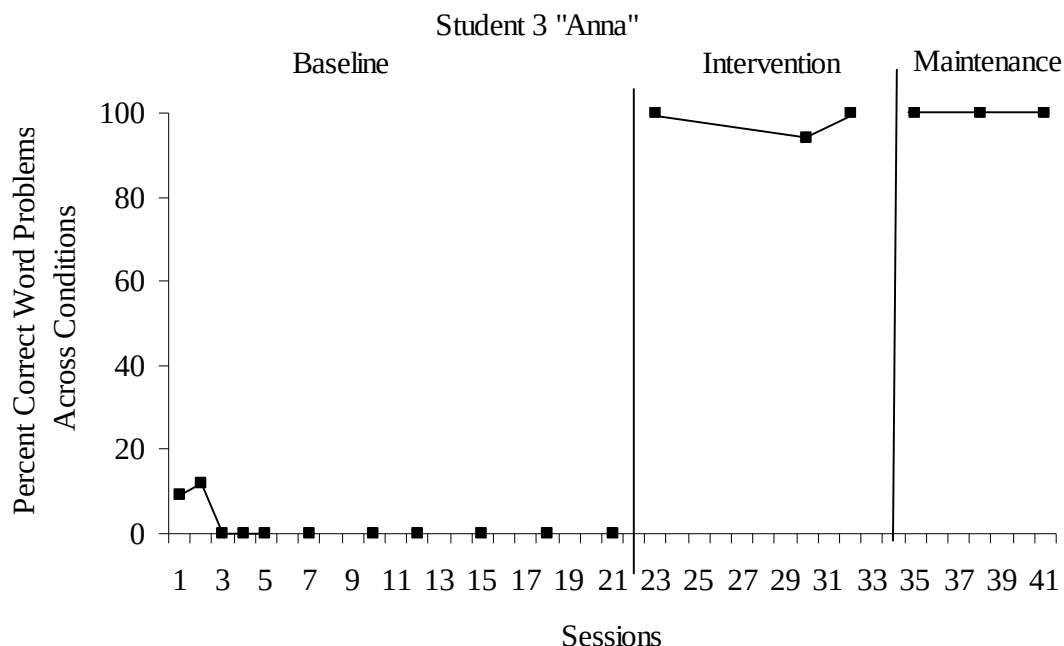


Figure 3

John. John was the final participant for the study. His data is represented in Figure 4. John's mean percent correct during baseline was 9% over 14 trials. As with the other participants, John's data was relatively flat during baseline. The data indicated stability for his achievement level. There was an immediate change in level from baseline to intervention. John's mean percent correct during intervention increased to 100%. There was a 0% overlap in the data between baseline and intervention. John demonstrated immediate progress when provided instruction in the intervention. Only two probe sessions were completed with John because of time constraints and his quick demonstration of understanding.

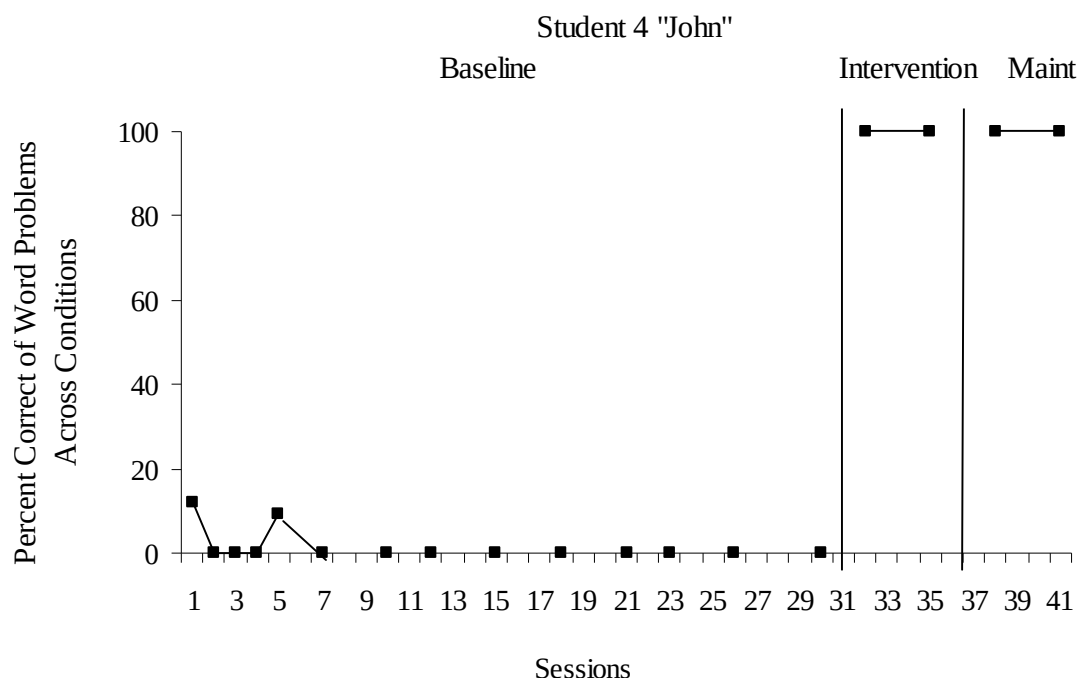


Figure 4

In the maintenance probes, John's mean percent correct was 100% over two sessions. John participated in maintenance for the shortest duration of all the participants with two scores in this condition as well. The trend during maintenance was consistently high. There was 100% overlap in the data between the intervention and maintenance probes. The intervention was effective for John in raising his word problem solving scores.

Summary Across Students

The concurrence for all four participants is represented in Figure 5. The intervention resulted in improvement in both level and mean percent correct for all four participants. The average mean score rose from only 3% correct for word problem solving during baseline to 93% during intervention. This increase in percent correct for word problem solving scores indicated that the intervention was effective

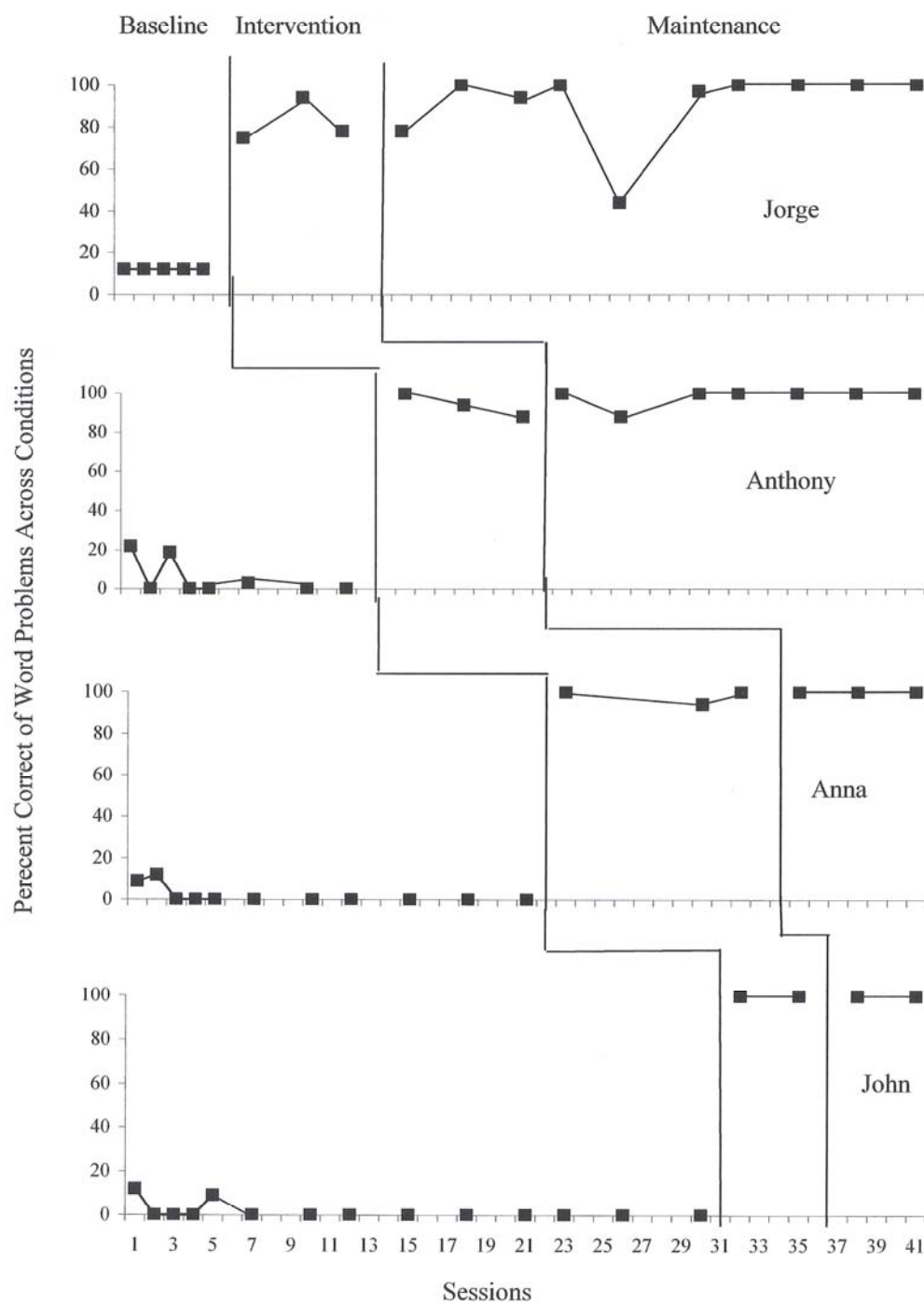


Figure 5.

in assisting student to organize and solve word problems. For all four students there was a rising trend during the intervention phase. The positive trend indicated improvement in performance over time. Direct replication of the effectiveness of the intervention was demonstrated across all four participants. Repetition of the intervention across students provides limited external validity within the population of students participating in the study. Maintenance mean scores averaged 97%. This mean is higher than the baseline mean representing an improvement in the participants' problem solving scores that was maintained over time. Maintenance scores did not decline over time indicating a that students were able to continue to remember and correctly apply the strategy. However, the relatively short period for the study would indicate the need to measure continued success over time.

In response to the research question, application of a sequential mnemonic strategy for problem solving did increase the percentage of correct responses to given word problems for students with learning disabilities. Additionally, the students evidenced their ability to acquire the mnemonic through their accurate completion of the scope worksheet, which required them to demonstrate the use of the mnemonic. Finally, three of the students demonstrated maintenance in the use of the strategy over time by maintaining the acquired skills. The fourth student did maintain effective use of the strategy as well; however, the maintenance condition for this student was too short to draw a solid conclusion. Overall, the results of the investigation support the use of mnemonic learning strategies for students with learning disabilities.

Social Validity

Following data collection at the end of the study, participants were asked to complete a student survey to relate their experience with the intervention. The protocol is presented in Appendix F. The survey was read aloud to the group of students. They were then required to respond either yes or no to the prompts on individual response sheets. The surveys were completed by students anonymously to ensure answers that responses represented their actual beliefs. Responses are presented in Table 6.

Table 6: Participants Responses to Student Survey

Question	Yes Response	No Response
Did you think the SCOPE strategy was easy to remember?	4	0
Did the SCOPE strategy help you organize math problems?	4	0
Were you able to use the steps?	4	0
Would you use SCOPE in other math classes	4	0
Would you use SCOPE for math in non-math classes?	1	3

Overall, the participants responded favorably to the intervention. The students reported that they felt that the learning strategy was easy to remember. They believed that the survey helped them to organize math problems. Students also thought that they were able to use or apply the steps. They felt that they would be able to make use of the strategy in other math classes. In question five, three of the four participants agreed that they did not think they would use the strategy in a non-math class settings. The age and educational experience of the participants may have influenced their

response to the final question in that they may not have been able to think of examples where math skills might be used in non-math settings. The overall favorable responses of the participants further support the effectiveness of the intervention.

CHAPTER 5

DISCUSSION, LIMITATIONS, AND IMPLICATIONS

The purpose of this study was to evaluate the effectiveness of an intervention designed to increase the percent correct of word problem solving for math word problems for eighth-grade math students with learning disabilities. The research inquiry sought to answer the questions: Will students with learning disabilities be able to acquire a sequential mnemonic strategy for problem solving when provided with specific training in that strategy? Will application of a sequential mnemonic strategy for problem solving lead to improved problem solving competency for students with learning disabilities? and Will students be able to maintain use of a sequential mnemonic strategy for solving novel math word problems over time? The intervention was designed to promote students' ability to learn and apply a learning strategy so that they could discern the important information contained in word problems, organize the information into an understandable and solvable format so that an accurate solution could be obtained. The results indicated that the strategy was effective in increasing the percent of correct responses for solving math word problems for all four participants. Additionally, all of the students responded favorably to the intervention. A student survey completed by the participants indicated that they had responded favorably to the intervention and understood the requirements. This chapter provides a discussion of the results of both the intervention and the student survey with regard to relevant research and theory, identifies the limitation of the study, and presents both instructional and research implications.

Discussion

The results of this study supported the initial hypothesis in that intervention resulted in an increase in percent correct for solving word problems for middle grades students with learning disabilities. Baseline data on all four students indicated that they lacked an understanding of how to approach and solve math word problems despite accommodations such as having material read aloud and the use of a calculator. The mean percent correct during baseline was well below criteria for all students. While criteria was set at 75 %, the group baseline mean was calculated at only 3% with a range of 9%.

There was a rising trend in the data for all four participants during the intervention. The immediate increase in correct responses when the intervention was implemented support the premise that students with disabilities experience failure because they lack effective strategies for problem solving (Fogen, Jiban, Deno, 2007; Maccini & Hughes, 2000; Maccini & Ruhl, 2000). All four participants reached criterion during intervention. This suggests that the intervention was effective in teaching students to solve math word problems through the use of a mnemonic learning strategy.

All of the students demonstrated positive behaviors during the study. Each one completed the word problem sheets as required. None of the students offered arguments or complaints during the intervention. Additionally, John demonstrated interest in the intervention by asking when his turn to learn the strategy would be on numerous occasions. Anthony also demonstrated interest during baseline by asking questions that related to how he should appropriately solve the word problems. All of

the students practiced the steps as required and completed the assignments given to them.

The maintenance data indicated that students with learning disabilities are able to apply strategies to problem solving tasks when a strategy has been explicitly taught. All of the students continued to improve during maintenance, which indicates that continued practice in using the strategy was beneficial for success in using it. One student did demonstrate a weakness during maintenance for the 13th probe. Jorge exhibited a significant drop in percent of correct responses to 48%. This was well below criteria. Jorge received reteaching in the strategy from the investigator using the same procedure as initial instruction. His success rate improved on subsequent probes demonstrating success in the use of the strategy. Jorge's difficulty occurred late in the maintenance phase. Other participants were not in the maintenance phase as long as Jorge. His difficulty indicates that periodic review of strategies may be necessary for full acquisition. Opportunities for review and guided practice are supported in the literature as sound teaching practices (Fuchs, & Fuchs, 2005; Coleman, Buysse, and Neitzel, 2006; Fogen, Jiban, Deno, 2007; Candace and Michael, 2007).

Examination of students' work indicated that prior to intervention they either did not apply any strategy at all or simply selected numbers from the given problem and added them together. This strategy frequently accounted for the correct responses during baseline on addition problems. Since each problem set contained one addition problem participants were able to demonstrate one correct response per sheet. This strategy was particularly evident for Jorge who was highly motivated to perform well

in class. Students also frequently left problems blank rather than risk making a mistake. The participants' lack of strategies for approaching the problems supports findings in the literature (Fahsl, 2007; Fogen, Jiban, and Deno, 2007; Maccini, & Gagnon, 2006; Jimenez, Gonzalez, & Garcia, 2002).

The observed behavior of the participants reflects the findings of many researchers who report that students with learning disabilities often struggle with how to approach math problems, make effective decisions, and carry out a chosen plan (Maccini & Hughes, 2000; Maccini & Ruhl, 2000). The current research illustrated many researchers concerns that students with disabilities lack appropriate skills for solving problems. Therefore, providing instruction in structured strategies that students may apply to solve problems are essential to increase student success.

Information collected in the student survey indicated that the participants understood the value of a learning strategy in helping them to improve their performance. All four of the students reported that when given a strategy that was easily remembered they found they were able to organize the problems more effectively. As reported by Jitendra, DiPipi and Perron-Jones (2002) research has suggested that with explicit instruction in use of the necessary tools for problem solving these students can be successful in a problem solving environment. Responses to the student survey reflected this belief. Students reported that they were able to use the steps in the strategy to solve word problems. The increase in students' accuracy for solving the problems indicated that they were correct in their assessment. Participants also agreed that they would continue to utilize the strategy in subsequent math classes.

Overall, the students responded favorably to the intervention. On several occasions, students inquired if they got to “work on their problem solving today” and wanted to know whose turn it was to learn the strategy. Upon learning the strategy, all students demonstrated an interest in applying it to the math problems. Anthony was witnessed using the strategy for an assignment not related to the intervention. Students also appeared to enjoy graphing their progress. Upon completion of baseline and the beginning of the acquisition phase, students were allowed to use the computer to graph their progress. All of the students wanted print outs of their graphs showing the improvement they had made. They did receive copies at the end of the intervention. They were observed comparing data from the graphs and commenting on how each participant had improved. Student created graphs were not part of the intervention and therefore not included, however, the graphs did appear to represent a strong motivation for participation.

Results in Relation to Research and Theory

This study both supports and extends the literature in the area of problem solving for students with learning disabilities. The initial abilities of students to independently approach and solve a math word problem were explored in this study. The low mean scores obtained during baseline for all students despite receiving standard accommodations such as the use of a calculator and having material read aloud demonstrates their lack of problem solving skills. Even students, such as John, who were in baseline for a longer period than earlier participants failed to independently develop a strategy over time. In fact, as time progressed for John without his receiving instruction in the intervention he spent more time on a single

problem and completed fewer of them. Despite spending more time on a single problem, his performance on even a single item did not improve. All of the participants' baseline performance supports evidence that students with learning disabilities lack the ability to independently create and use effective problem solving strategies (Fogen, Jiban, Deno, 2007; Maccini & Hughes, 2000; Maccini & Ruhl, 2000). As a result, students with learning disabilities are falling increasingly behind in the acquisition of math skills (Maccini and Gagnon, 2006; Thurlow, Albus, Spicuzza, & Thompson, 1998; Thurlow, Moen, & Wiley, 2005).

Much of the research points to the need for a strategy that students can independently apply to solving math word problems (Candace and Michael, 2007; Fogen, Jiban, Deno, 2007; Coleman, Buysse, and Neitzel, 2006). The specific, unambiguous nature of the intervention made it possible for the students to acquire the strategy quickly. This provided participants with more immediate reinforcement for their effort. For students who have often experienced failure, having effective tools allows them to experience success.

The success of the participants in the intervention supports the findings of Jitendra, DiPipi and Perron-Jones (2002) that given explicit strategy instruction students with learning disabilities can apply those strategies and become successful problem solvers. The participants were able to exhibit immediate improvement in accuracy for problem solving when explicitly taught a strategy. The Office of Educational Research and Improvement (OERI, 2004) supports the need for this type instruction. In a report submitted to the United States Department of Education, OERI

called for effective instruction for students with special needs that provides specific instruction on strategies for problem solving.

The results of this investigation support those of Van Garderen (2007), Monatgue and Bos (2001), and Maccini and Hughes (2002) as well as Fuchs, Fuchs, Hamlett, and Appleton (2002), and all of whom have used strategy instruction to enhance math performance. Similarly, Bottge, Rueda, LaRoque, Serlin, and Kwon (2007) included a learning strategy in their work with situated cognition and found that the addition of this component to earlier research methodology improved student performance as well. Clearly, the inclusion of learning strategies in math instruction is warranted.

Limitations

There were several limitations to this study. Because of the small number and the limited variability of the participants, generalization is likely to be limited. The lack of generalizability and therefore reduced external validity is a limitation that is inherent in single-subject research methodology. It may be difficult to determine if the intervention would be effective for students who do not match the specific profiles of the participants in this study.

A related limitation inherent in the single-subject design is the need for one-on-one presentation of the intervention. A significant time constraint is presented by the need to provide one-on-one instruction for 20 minutes per class period. In addition, the individual instructional relationship is not necessarily equivalent to that of whole group instruction. It therefore cannot be assumed that the same type of

outcome can be expected when whole group instruction is presented rather than individual instruction.

Finally, as the researcher was also the classroom teacher logistical problems were inherent in the research. As a full time classroom teacher, the researcher was required to balance the needs of the research investigation with those of regular classroom responsibilities. Researchers may feel concern that the integrity of treatment implementation is compromised by such realities of the classroom (Gresham, Macmillan, Beebe-Frankenberger & Bocian, 2000). This in turn reduces the external validity of the study. Also, as the classroom teacher the researcher is part of the environment. Therefore, changes created by the researcher such as differences in routine or teaching style may affect the outcome of the research (Creswell, Hanson, Clark Plano, & Morales, 2007; Cochran-Smith, & Lytle, 1990). There is evidence to suggest that the relationship between the teacher and student affect the outcomes of instruction (Sterling, 1998; Hiebert, 1999). As the classroom teacher, it is impossible to remove this relationship, which may prove to be a confounding variable.

Despite these limitations, this study demonstrated that an intervention utilizing a mnemonic based learning strategy increased the percent of correct responses for solving math word problems by middle grades students with learning disabilities. Single-subject research methodology was successfully employed to examine the variability of the participants' responses to the intervention. The current research suggests several new areas of research and provides an instructional strategy that may be useful for teachers of students with learning disabilities. The research also supports

the current need for research-based interventions to be implemented in classroom instruction.

Implications

This dissertation offers implications for both instruction and future research. With regard to instruction, the current literature suggests that students struggling with math problem solving skills benefit from explicitly taught learning strategies that aid the learner in organizing and solving given problems. Students with learning disabilities often exhibit difficulty in independently developing and applying strategies for problem solving. Instruction designed to provide students with the necessary tools or strategies appear to address this demonstrated need by students with learning disabilities. As established by this dissertation, such an intervention can be both effective for and perceived as useful by its recipients.

All of the participants demonstrated improved performance after receiving instruction in the learning strategy. Future use of this study should incorporate an additional phase to measure the ability of students to generalize use of the strategy. All of the participants' reported that they believed the intervention was helpful for them in the context given. It would be useful for researchers to measure the whether the effects continued into other classes or context.

Further research is indicated. Because of the nature of the single-subject design methodology with the small sample size, additional replications are necessary to support the generalization of findings across different settings, students and researchers. Replications are also necessary to determine if the intervention will be effective with participants in different age groups, with different ability levels or in

alternative settings such as inclusive classrooms. Implementing the intervention with average achieving students would allow for comparison of progress with students with learning disabilities. Such comparisons could inform modifications to the current procedure to make it more effective. Further, it would also be beneficial to measure the effectiveness of the intervention using whole group setting methodology, which more accurately represents actual classroom conditions.

An additional research implication arises from the type of problem employed in this investigation. Students were successful with the single operation problems measured in this study. The next step would be to apply this strategy to more complex problems. If students can be taught to apply this strategy with more complex problems, it would prove more useful. Further, longitudinal studies to measure whether the strategy could be carried over into other content areas such as science would be useful. This was a usage that, based on the students' survey responses, the participants did not envision. Because math is in and of itself a tool, a learning strategy for math problem solving might prove effective in other conditions such as the use of formulas in science class. Investigations exploring these and similar questions would advance both research and practice.

Conclusion

The underlying hypothesis of this research has been that students with disabilities do not independently develop effective problem solving strategies as compared to general education peers (Jitendra, DiPipi & Perron-Jones, 2002; Parmar, Cawley & Frazita, 1996; Montague & Applegate, 2000; Gonzalez & Espinel, 2002; Graves, 1986). At the same time, math educators have been encouraged by the

National Council of Teachers of Mathematics to adopt a broader view of math instruction which includes the inclusion of problem solving tasks (NTMC, 2006). This emphasis is also reflected in current educational legislation including the reauthorization of Individuals with Disabilities Education Act (IDEA, 1997) and No Child Left Behind (NCLB, 2001). Students with disabilities are at a distinct disadvantage in educational settings. They require research proven instructional strategies that facilitate learning to solve math word problems, specifically in situations in which they are not responding to traditional instruction (Maccini, and Gagnon, 2006; Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005; Kovalski, and Prasse, 2004). The literature reviewed provides a basis for research in improving instruction in problem solving for mathematics. Much of the research points to the need for a strategy that is general enough for students to apply to any problem involving mathematical algorithms, and broad enough to be applicable to a wide variety of examples (Fuchs, & Fuchs, 2005; Coleman, Buysse, and Neitzel, 2006; Fogen, Jiban, Deno, 2007; Candace and Michael, 2007). The literature supports the suggestions that instruction in a specific problem solving strategy will improve success in problem solving (Montague, 2004; Owen & Fuchs, 2002; Hohn & Frey, 2002; Montague and Bos, 2001). Therefore, students are to be successful problem solvers, explicit instruction in effective problem solving strategies must be implemented in the classroom (Montague, 2004; Owen & Fuchs, 2002; Hohn & Frey, 2002; Montague and Bos, 2001).

This research analyzed a set of data consisting of problem solving competence through the application of a sequential mnemonic problem solving strategy. The

results of this study indicated that when provided explicit instruction in a mnemonic problem solving strategy students are able to acquire the strategy, apply it to given word problems and arrive at correct solutions. This research will contribute to a growing body of research supporting the use of specific language based problem solving strategies for improving the success of students with disabilities problem solving skills.

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Appendix A
PARENTAL CONSENT FORM

To whom it may concern:

I agree to allow my child, _____, to take part in a research study titled, “Improving math problem solving strategies of middle school students”. The research will be conducted by Jana Nylund under the supervision of Dr. Cecil Fore from the Department of Communication Sciences and Special Education at the University of Georgia. I do not have to allow my child to be in this study if I do not want to. My child may refuse to participate or stop taking part at any time without giving any reason, and without penalty. My child’s grades will not be affected if they choose to participate or not. I may ask to have the information related to my child returned to me, removed from the research records, or destroyed.

The following points have been explained to me:

- The reason for the research is to teach students a problem solving strategy that may assist them in successfully solving math word problems as required by state and federal guidelines.
- The procedure will consist of teaching students a specific learning strategy for solving math word problems in the classroom setting. Students will receive instruction from the classroom teacher in a five-step strategy known as SCOPE, which was developed for this study. This will include one on one instruction with in the current class setting in the steps of the strategy and how to apply them to a given word problem. Students will be provided with the opportunity to practice the strategy and to receive additional instruction in its use if necessary. After evaluating student work for each set of word problems, students will receive feedback on their application of the strategy through analysis of their work in individual conferences. This project will take place for approximately 20 minutes per day over approximately five weeks.
- Students will be provided with information on the value of this program to them in that it will help to prepare them to pass state required criterion referenced math tests, which are in a word problem format. Students will also chart their individual progress on a graph to provide incentive and feedback. Students will be allowed to select reinforcements such as computer time for participation and as goals are met. In addition, verbal praise and encouragement will be provided through the study.
- No immediate psychological, social, legal, economic or physical discomfort, stress or harm is expected for the participants. Any individually identifiable information collected about my child will be held confidential unless otherwise required by law. My child’s identity will be coded with a pseudonym, and all data will be kept in a secured location. If I do not want my child to take part then he/she will be allowed to study as usual.
- The investigator will answer any questions about the research, now or during the course of the project. Jana Nylund may be reached at (706) 743-8146. Dr. Cecil Fore may be reached at (706) 542-4603.

- I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

Jana Nylund, Investigator

Telephone: 706-743-8146

Email: jnylund@oglethorpe.k12.ga.us

Signature

Date

Name of Parent or Guardian

Signature

Date

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding my child's rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia, 30602-7411: Telephone (706) 542-3199; E-mail Address IRB@uga.edu

Appendix B

EXAMPLE OF SCOPE WORD PROBLEM PAGE

EXAMPLE OF SCOPE WORD PROBLEM PAGE

Use the SCOPE strategy to solve the following word problems.

S	C	O	P	E
Tyler shot 4 rolls of film on his vacation to the Grand Canyon. Each roll has 24 pictures. How many pictures did he take?				
Will received \$80 for graduation from his grandfather. His uncle gave him another \$25. How much money was he given in all?				
Mercury's daytime temperature is 750°F while the nighttime temperature falls to -300°F . What is the difference between the daytime and nighttime temperatures?				
A new bullet train in Europe traveled the 450 miles from Paris to Berlin in 3 hours. How fast was the train moving?				

Appendix C

LEARNING STRATEGY EXAMPLE PROMPT

Learning Strategy Example Prompt

There are nine shelves and each shelf holds fourteen books, how many books are there on all of the shelves?

Strategy Prompts

- S** Survey the word problem
Read the word problem quietly to yourself and
- C** Collect the important information
Write the information needed to solve the problem
- 9 shelves
14 books
how many on all
- O** Organize the information into a solvable equation and
- $9 \times 14 = b$
- P** Perform the operation
- $$\begin{array}{r} 13 \\ 14 \\ \times 9 \\ \hline 126 \end{array}$$
- E** Exhibit the correct final solution
- Reread the problem.
Does the answer make sense?
- My answer is: 126 books

Appendix D

WORD PROBLEM SCORING RUBRIC

Word Problem Scoring Rubric

S	C	O	P	E	
Surveys the problem	Collect numeric and mathematic terms necessary to solve problem	Organize data by creating diagram, model or equation	Perform calculation correctly	Exhibit correct final solution	Total Possible Points Per Problem
Not Observable Behavior	0 1 2 3	0 3	0 1	0 1	8
	0 1 2 3	0 3	0 1	0 1	8
	0 1 2 3	0 3	0 1	0 1	8
	0 1 2 3	0 3	0 1	0 1	8
					32

Appendix E

SCOPE PROCEDURAL TRAINING CHECKLIST

SCOPE Procedural Training Checklist

Student _____ Observer _____ Date _____

Score 1 if the behavior is observed as described in the procedural protocol.

Score 0 if the behavior is not observed or does not comply with the procedural protocol.

_____ 1. Provided an Advance Organizer

2 . Provided Teacher Modeling of the Strategy Steps

The teacher first thinks aloud while modeling the use of the strategy with the target problems.

_____ **S:** The first step in the SCOPE strategy is for me to survey the word problem.

_____ **C:** The second step is to collect the data.

_____ **O:** My next step is to organize the problem into an equation that I can solve.

_____ **P:** Then I need to perform the operation. I will actually do the math

_____ **E:** Finally, I need to exhibit my final answer.

_____ 3. Provided guided practice monitoring progress

_____ 4. Provide Independent Student Practice

_____ 5. Provided Feedback and Correction

_____ Total(of 9)

_____ % Adherence to procedural protocol

Appendix F

SOCIAL VALIDITY STUDENT SURVEY

SOCIAL VALIDITY STUDENT SURVEY

Did you think the SCOPE strategy was easy to remember?	Yes	No
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Did the SCOPE strategy help you organize math problems?	Yes	No
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Were you able to use the steps?	Yes	No
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Would you use SCOPE in other math classes?	Yes	No
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Would you use SCOPE for math in non-math classes?	Yes	No
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