

EFFECTS OF THE SOLVE STRATEGY ON THE MATHEMATICAL PROBLEM
SOLVING SKILLS OF SECONDARY STUDENTS WITH LEARNING
DISABILITIES

by

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ABSTRACT

SHAQWANA MARIE FREEMAN. Effects of the SOLVE strategy on the mathematical problem solving skills of secondary students with learning disabilities. (Under the direction of DR. CHRISTOPHER O'BRIEN)

Students with learning disabilities are most typically characterized as struggling readers (i.e., 80-90% of students are identified on the basis of reading failure; LD OnLine, 2008 Lerner, 1989; Lyon, Fletcher, Shaywitz, Torgesen, Wood, et al., 2001); however, as many as 50% of students with learning disabilities have IEP goals in the area of mathematics suggesting that general curricula in mathematics present a relevant barrier to the success of this population (Geary, 1999). Given that expectations in the era of the Common Core State Standards promote higher achievement in mathematics, specifically Algebraic thinking (CCSS, 2012), secondary curriculum in the area of Algebra presents a hurdle for students with a specific learning disability to keep pace with peers and graduate on time.

This study investigated the effects of the SOLVE Strategy on the mathematical problem solving skills of secondary students with disabilities. A multiple probe across participants design was employed to determine the impact of the independent variable (i.e., instruction in the SOLVE Strategy) on the primary dependent variables (i.e., strategy use, correct response). The intervention was implemented with six 8th grade students with specific learning disabilities. Results indicated a functional relation between SOLVE Strategy usage and improved problem solving performance for all six target students. Additionally, all participants were able to generalize the SOLVE Strategy to other mathematic topics and concepts, and the teacher and students felt the intervention

was socially acceptable. Finally, limitations of the study, suggestions for future research, and implications for practice are provided.

DEDICATION

I would like to dedicate this dissertation to my son, Sa'Vion. I love you so much, and everything that I do is for you. You have truly been my inspiration and without you I wouldn't be where I am. I would also like to dedicate this dissertation to my mom and dad (Elizabeth and Alvin). Thank you for believing in me and providing me with the love and support I needed to make it to this point in my life. I can never repay you for all that you have done and are doing for me, but know that I am very grateful. I love both of you! To my husband Chris, thank you for encouraging me, and putting up with the emotional roller coaster throughout this process. Whenever I was faced with a challenge I could always count on you to give me a pep talk and end with "Go Get 'Em Tiger"! Thank you and I love you!

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION	1
Delimitations	16
Definition of Terms	18
CHAPTER 2: REVIEW OF THE LITERATURE	20
Characteristics of Students with Learning Disabilities	21
Learning Strategy Instruction	40
The Need for Explicit Instruction	48
Mathematical Problem Solving Intervention Strategies for Secondary Students with Learning Disabilities	57
Mnemonic Strategy Instruction	67
CHAPTER 3: METHODS	83
Participants	83
Setting	84
Dependent Variable	86
Data Analysis Procedures	87
Data Collection and Procedures	89
Independent Variable Data (Instruction in the SOLVE Strategy)	89
Instruments and Measures	92
CHAPTER 4: RESULTS	95
Interrater Reliability	95
Treatment Integrity	96
Dependent Variables	96

Social Validity	108
CHAPTER 5: DISCUSSION	113
Effects of Intervention on Dependent Variables	114
Discussion of Social Validity Findings	117
Limitations and Recommendations for Future Research	118
Implications for Practice	121
REFERENCES	125
APPENDIX A: STRATEGY USE SCORING GUIDELINES	142
APPENDIX B: COMPUTATION SCORING GUIDELINES	143
APPENDIX C: STRATEGY KNOWLEDGE TEST	144
APPENDIX D: STEPS FOR THE SOLVE STRATEGY AND HELPFUL HINTS CUE CARD	145
APPENDIX E: LEARNING CONTRACT	146
APPENDIX F: SAMPLE PROBE COMPLETED	147
APPENDIX G: PROGRESS CHARTS	150
APPENDIX H: SCRIPTED LESSON PLAN	153
APPENDIX I: SOCIAL VALIDITY QUESTIONNAIRES	172
APPENDIX J: LETTERS OF CONSENT AND ASSENT	174
APPENDIX K: LETTER OF SUPPORT	181

CHAPTER 1: INTRODUCTION

Inadequate progress in mathematics made by secondary students with learning disabilities in the United States (U.S.) has been a concern for practitioners, researchers, administrators, parents, and policymakers for years. Math difficulties usually begin in elementary grades and persist through secondary schooling with students with disabilities performing several grade levels behind their non-disabled peers (Cawley, Parmer, Yan, & Miller, 1998; Miller & Mercer, 1997). On a national assessment of mathematical proficiency (i.e., National Assessment of Educational Progress; NAEP) Lee, Grigg, and Dion (2007) reported that only 32% of students with disabilities who were included in testing in Grade 8 were performing at or above proficiency level.

According to the Thirtieth Annual Report to Congress on the Implementation of the Individuals with Disabilities Act (U.S. Department of Education, 2008), from 2000 through 2006, the percentage of students ages 6 through 21 served under *IDEA*, Part B, educated in general education classes for most of the school day (i.e., 80% or more of the day) increased from 46.5 percent to 53.7 percent). Prior to 2001 (i.e., 1997 through 2000), the percentage had remained relatively unchanged. Earlier research by Greenstein and Strains (1977) found that mathematics abilities for students with learning disabilities plateau at the fourth grade level and students do not achieve higher level problem solving skills beyond that level. A few years later, Warner, Alley, Schumaker, Deshler, and Clark

(1980) found that adolescents with learning disabilities reached a mathematics plateau after seventh grade. Students in the latter study made on average one year growth in mathematics from Grade 7 to Grade 12 (i.e., the mean math score in 12th grade was only a 5th grade level).

With that being said, in 2007 the U. S. public schools educated more than 6 million students with learning disabilities, approximately 9% of all students (Swanson, 2008). Swanson also noted that close to one-third of these students are between the ages of 14 and 17 years old. Unfortunately, of the 6 million students with learning disabilities, more than 50% were likely to drop out of high school without receiving a diploma (Wagner, 2004). For all youth, including those with disabilities, graduating from high school is necessary and critical for all young adults (Swanson, 2008).

Prior studies (e.g., Blackorby & Wagner, 1996; Lichtenstein, 1993; Wagner, 1991) have documented that students in special education drop out of school at a much higher rate than students in general education. While high-stakes testing had significant consequences for all student, this was especially true for students with disabilities who experienced academic failure most of their academic career. The pressure to pass these state tests and earn a high school diploma caused many of them to drop out of school (Thurlow & Johnson, 2000).

While there may be a number of contributing factors to high dropout rates another notable factor is the unsuccessful completion of Algebra I (Reys & Reys, 2011). The increase in high school exit exams has influenced and increased policies of alternative diplomas or certificates of completion (Dorn, 2003; Thurlow & Thompson, 2000). Johnson and Thurlow (2003) reported on 15 different types of certificates and diplomas

in the United States in 2002. The purpose of this was so that states could offer some type of certificate for students with disabilities when they exited high school while still upholding the standards related to earning a standard high school diploma (Thurlow & Johnson, 2000). Algebra I has become a part of graduation requirements in many states and serves as a gateway course for higher level mathematics and science courses. Higher level mathematics requires all students to be proficient problem solvers, but as stated previously students with learning disabilities struggle with mathematical problem solving.

Not surprisingly, Blackorby and Wagner (1996) found that only 12% of students with disabilities take advanced mathematics classes in high school (e.g., algebra, geometry, trigonometry). Success in high school algebra is important to success in postsecondary education and well paying jobs. For example, Algebra is a gateway course for higher level mathematics and science courses. With that being said, students with learning disabilities have difficulty meeting content standards and passing state assessments (Thurlow, Albus, Spicuzza, & Thompson, 1998; Thurlow, Moen, & Wiley, 2005). This calls into question the two federal mandates directly affecting special education: the Elementary and Secondary Education Act (ESEA, 2010) and the Individuals with Disability Education Improvement Act (IDEA) of 2004.

The Elementary and Secondary Education Act measures all students by the same standards, whereas IDEA focuses more on the individual student. The ESEA measures every student on proficiency in math and reading instead of on individual improvement. The Individuals with Disability Education Improvement Act calls for individualized curriculum and assessments that determine student success based on growth and

improvement each year. The Individuals with Disabilities Education Act was reauthorized in 2004 with the goal of preparing students for further education, employment and independent living (20 U.S.C. 1400 [d] [1] [A]).

In March, 2010, The Obama administration released recommendations for the reauthorization of the Elementary and Secondary Education Act (ESEA) in a document titled —*Blueprint for Reform* (<http://www2.ed.gov/policy/elsec/leg/blueprint/index.html>). The blueprint lays the foundation for states to adopt academic standards that prepare students to succeed in postsecondary education and the workplace. The blueprint challenges the nation to embrace education standards that would put America on a pathway to global leadership. Additionally, the blueprint asserts that every student should graduate from high school ready for college and a career having meaningful opportunities to choose from upon graduation from high school. The College and Career Ready Standards outlined in the blueprint have become known as the Common Core State Standards (CCSS). These standards are intended to define the knowledge and skills students should have within their K-12 education careers so that they will graduate high school ready to succeed in entry-level, credit-bearing academic college courses (CCSSI, 2010). To date, 45 states, 3 territories, and the District of Columbia have fully adopted the CCSS, one state has provisionally adopted the standards, and one state has adopted the ELA standards only (Boyer, Phillips, Jones, & Witzel, 2011).

The mathematics high school CCSS sets a rigorous definition of college and career readiness, by helping students develop a depth of understanding and ability to apply mathematics to novel situations, as college students and employees regularly do (CCSS, 2010). The standards stress conceptual understanding to make sure students

learn the critical information needed to succeed at higher levels. The high school standards also emphasize *mathematical modeling*, the use of mathematics and statistics to analyze empirical situations, understand them better, and improve decisions.

Mathematical modeling is similar to problem solving in that students are required to link classroom mathematics and statistics to everyday life, work, and decision-making. The high school standards call on students to *practice applying mathematical ways of thinking to real world issues and challenges* preparing students to think and reason mathematically (CCSS, 2010).

Ongoing reform efforts, including the CCSS and the standards documents of the National Council of Teachers of Mathematics (NCTM), call for robust mathematics curricula, more innovative instructional approaches, and greater access to higher-level mathematics for students traditionally steered in other directions (NCTM, 2000). Additionally, the NCTM guidelines are what guided the creation of the mathematics CCSS to promote application and problem solving skills beyond the basic knowledge level of mathematics. In the NCTM's latest standards document (2000), problem solving is strongly endorsed:

Successful problem solving requires knowledge of mathematical content, knowledge of problem-solving strategies, effective self-monitoring, and a productive disposition to pose and solve problems. Teaching problem solving requires even more of teachers, since they must be able to foster such knowledge and attitudes in their students (p. 341).

It is emphasized that instructional programs from Prekindergarten through Grade 12 enable all students to (a) build new mathematical knowledge through problem

solving, (b) solve problems that arise in mathematics and in other contexts, (c) apply and adapt a variety of appropriate strategies to solve problems, and (d) monitor and reflect on the process of mathematical problem solving (NCTM, 2000). This emphasis goes along with the emphasis of the previous standards (NCTM, 1980; NCTM, 1989). Faced with the challenge to help all students succeed with the complexities of algebra and problem solving, instructional leaders are encouraged to turn to research literature for teaching methods that enhance student achievement in algebra.

Looking more closely at problem solving, the conceptual definition of problem solving in mathematics is complex. Possibly the most significant reason for this is because no formal conceptual definition has ever been agreed upon by experts in the field of mathematics education. Grunnetti and Jaquet (2005) even suggested that a common definition of mathematical problem solving could not be provided. One term that is often associated with mathematical problem solving is novelty. Historically, this notion was first put forth in 1925 (Kohler, 1925). However, Polya is often credited with the use of novelty as a component of his definition. For example, Polya (1945 & 1962) described mathematical problem solving as finding a way around a difficulty, around an obstacle, and finding a solution to a problem that is unknown. Lester and Kehle (2003) suggested that reasoning and/or higher order thinking must occur during mathematical problem solving.

Students with high incidence disabilities at the secondary level are commonly included in content-area classrooms, such as mathematics, English, science, and social studies. Largely, ability to succeed in these core content classrooms determines the student's long-term potential for success in school. Unfortunately, by high school,

students with learning disabilities are failing in the secondary mathematics curriculum. It has been found that students at the secondary level have not mastered basic skills (Algozzine, O'Shea, Crews, & Stoddard, 1987; Cawley, Baker-Kroczyński, & Urban, 1992), struggle with reasoning algebraically (Maccini, McNaughton, & Ruhl, 1999), and experience difficulty with problem solving (Hutchinson, 1993; Montague, Bos, & Doucette, 1991).

It is evident through research that students with learning disabilities at the secondary level exhibit memory deficits (Bryant, Bryant, & Hammill, 2000; Bryant, Hartman, & Kim, 2003; Ginsburg, 1997; Cooney & Swanson, 1987) which potentially contributes to their academic failure. In a study on mathematics difficulties for students with learning disabilities in Grades 2 through 12, Bryant, Bryant, and Hammill (2000) identified 29 mathematics behaviors associated with difficulties in mathematics. The top ranked issue that teachers identified as being problematic for students with learning disabilities as well as students who are low performing in mathematics was solving word problems. Given the mathematics difficulties demonstrated by students with learning disabilities, prevention and intervention are critical components to include as part of instructional delivery (Fuchs & Fuchs, 2001).

Other examples of effective strategies for improving mathematical performance of students with learning disabilities include the following: (a) schema-based instruction (e.g., Jitendra, Hoff, & Beck, 1999; Xin, 2008), (b) peer-mediated instruction (e.g., Fuchs, Fuchs, Hamlett, et al. 1997; Fuchs, Fuchs, Mathes, & Martinez, 2002), (c) mnemonic instruction (e.g., Maccini & Hughes, 2000; Test & Ellis, 2005), and (d) concrete-representational-abstract sequence (e.g., Witzel, 2005). More recently, the

Center on Instruction conducted a meta-analysis in which they examined studies on teaching mathematics to students with learning disabilities (Gersten, et al., 2008). Based on the findings from the meta-analysis seven effective instruction practices were identified: (a) teach students using explicit instruction on a regular basis (i.e., clear modeling, think aloud specific steps, provide immediate corrective feedback to students); (b) teach students using multiple instructional examples; (c) have students verbalize decisions and solutions to a math problem; (d) teach students to visually represent the information in the math problem (e.g., drawing, graphic representations); (e) teach students to solve problems using multiple/heuristic strategies (i.e., a generic approach for solving a problem); (f) provide ongoing formative assessment data and feedback to teachers; and (g) provide peer-assisted instruction to students.

Research conducted by Jones et al. (1997) identified six contributing factors that may hinder the effectiveness of instruction for secondary students with learning disabilities: (a) prior achievement by the student, (b) perceptions of self-efficacy by the student, (c) content of instruction, (d) management of instruction, (e) evaluation of instruction, and (f) the educator's beliefs about effective instruction. Additionally, Miller and Mercer (1997) identified attributes of learning disabilities, information processing factors, characteristics in the areas of language, cognition, meta-cognition, and social and emotional behavior as contributing factors that also affect the mathematical performance of students with learning disabilities. Looking at meta-cognition specifically, students with learning disabilities have difficulty assessing their ability to solve problems, identify and select appropriate strategies, organize information, monitor problem solving

processes, evaluate problems for accuracy, and generalize strategies to appropriate situations (Miller & Mercer, 1997).

Progress has been made in improving problem solving skills for youth with disabilities; however, there are still deficits between general population peers and students with learning disabilities in mathematic performance. One option that has been demonstrated through research to be particularly effective for students with learning disabilities in mathematics is the use of explicit instruction (e.g., Carnine, Jones, & Dixon, 1994; Carnine & Stein, 1981; Charles, 1980; Gleason, Carnine, & Boriero, 1990; Hollingsworth & Woodward, 1993; Leinhardt, 1987; Mastropieri, Scruggs, & Butcher, 1997; NMAP, 2008; Resnick, Cauzinile-Marmeche, & Mathieu, 1987). Explicit instruction involves the teacher following a sequence of events, generally stating the objective, reviewing skills necessary for new information, presenting new information, questioning students, providing group instruction and independent practice, assessing performance, and giving more practice (Swanson, 2001). Thus classroom instruction must reflect principles of explicit instruction to meet the unique learning needs of students with learning disabilities as recommended by the Center on Instruction (Jayanthi, Gersten, & Baker, 2008) and the National Mathematics Advisory Panel (2008).

Research conducted by the University of Kansas Center for Research on Learning indicates that students should be taught skill-specific learning strategies using principles of explicit instruction. Learning strategies are tools students utilize to approach learning and use information to help them understand information and solve problems (Schumaker & Deshler, 1992). Learning strategy instruction focuses on making the students more

active learners by teaching them how to learn and use what they have learned to solve problems and be successful. Strategy instruction supplies struggling students with the same tools and techniques that efficient learners use to help them understand and learn new material or skills (Luke, 2006). With guidance and ample opportunities for practice, struggling students learn to link new information with previously taught information in meaningful ways, thus making it easier for them to recall the new information or skill at a later time, regardless of the situation or setting (Luke, 2006). Certain learning strategies tend to be task-specific, meaning that they are useful when learning or performing certain tasks which are known as cognitive strategies. Examples include note taking, asking questions, or filling out a chart; however, it has also been found that metacognitive awareness (Campione, Brown, & Connell, 1988) is an essential element in how good learners approach tasks. Metacognitive awareness is the learner's awareness of the learning process and what it takes to achieve desired results in a specific learning task (Luke, 2006). We know now, for example, that the most effective strategy interventions combine the use of cognitive and metacognitive strategies. Research has demonstrated that consistent, intensive, explicit instruction and support are key components for instructional success (e.g., Mercer, Lane, Jordan, Allsopp, & Eilsele, 1996; Scheuermann, Deshler, & Schumaker, 2009; Swanson & Deshler, 2003).

According to Swanson (1999) the most effective form of teaching students with learning disabilities is to combine components of direct instruction (e.g., teacher-directed lecture, discussion, and learning from books) with components of strategy instruction (e.g., teaching ways to learn such as memorization techniques and study skills). Swanson (1999) identified the main instructional components of this combined model as: (a)

sequencing (e.g., breaking down the task, providing step-by-step prompts); (b) drill-repetition-practice (e.g., daily testing, repeated practice, sequenced review); (c) segmentation (e.g., breaking down skills into parts and then synthesizing the parts into a whole); (d) directed questioning and responses (e.g., teacher asks process or content questions of students); (e) control of task difficulty; (f) use of technology (e.g., computers, presentation media); (g) teacher-modeled problem solving; (i) small-group instruction; and (j) strategy cues (e.g., reminders to use strategies, think-aloud models).

Reviews of interventions for students with learning disabilities by Swanson (1999) and Forness, Kavale, Blum, and Lloyd (1997) indicated that the use of strategy instruction using mnemonic strategies has helped students with disabilities significantly improve their academic achievement. Research across varying content areas has demonstrated that mnemonic strategy instruction can be effective for students with learning disabilities (e.g., Manalo, Bunnell, & Stillman, 2000; Pressley, Levin, & Delaney, 1982). However, limited research has been conducted in the area of secondary mathematics.

Due to the limited number of studies on mnemonic strategy instruction conducted in mathematics, little is known about its effectiveness for students with learning disabilities at the secondary level. There has been one mnemonic problem solving strategy (i.e., STAR) researched that has empirical data to support its effectiveness at increasing the mathematical problem solving skills of students with learning disabilities at the secondary level.

First, Maccini and Ruhl (2000) conducted a study to determine the effects of the STAR strategy on problem solving skills of students with learning disabilities. Results of

this study indicated that students improved their ability to represent and solve word problems involving subtraction of integers, and students maintained treatment effects over varying time intervals. Several limitations of this study were identified. First, the study was conducted at the end of the school year causing a threat to the internal validity of the study. Next, there were no cue cards or worksheets to help the students memorize the steps of the STAR strategy. Lastly, students' performance on generalization measures was below average making it necessary to use more complex problems and vary the story lines of the word problems.

Second, Maccini and Hughes (2000) investigated the effects of the STAR strategy within a graduated teaching sequence (i.e., concrete, semi-concrete, abstract) on the representation and solution of problem-solving skills of six secondary students with learning disabilities using a multiple probe across participants design. Although students demonstrated improvement in problem solving skills some students did not remember all of the steps of the STAR strategy, making it necessary to set mastery criteria for learning the steps of the strategy before continuing with the study.

Additionally, various research studies have investigated the effects of training students with memory problems both with and without disabilities to use mnemonic strategies independently (e.g., Cassel & Reid, 1996; Fulk, Mastropieri, & Scruggs, 1992; King-Sears, Mercer, & Sindelar, 1992; Scruggs & Mastropieri, 1992). Scruggs, Mastropieri, Berkely, and Marshak (2010) referred to mnemonic strategies as an "evidence-based practice and practice-based evidence." Despite the title of the article, it is not evident that the researchers applied all of the standards or quality indicators set forth by Horner et al. (2005) needed to contribute support for an evidence-based practice.

Also, the content areas that the researchers examined for the use of mnemonic strategies were limited to elementary: life science, social studies, reading, and vocabulary; and secondary: social studies, anatomy, and SAT vocabulary.

Significance of the Study

To respond to the increased number of students with disabilities (e.g., learning disabilities) who are being educated in secondary general education mathematics courses, more research is needed to determine effective strategies for increasing student academic performance. Teaching problem solving skills to students, as emphasized by the Common Core State Standards (CCSS, 2010) and NCTM (2000), is one way to improve students' mathematical performance. To assist students with problem solving the Center on Instruction recommended that students be taught to solve mathematical problems using heuristic strategies (Jayanthi et al., 2008). The heuristic approach offers students an opportunity to talk themselves through problems and reflect on their attempts to solve problems. Additionally, memory of factual information is essential for success in school, particularly at the secondary level; however, there is limited research in mathematics about the effectiveness of mnemonic strategy instruction compared to other content areas (Scruggs, Mastropieri, Berkeley, & Marshak, 2010). The proposed study addresses the mathematical needs of students with learning disabilities by providing them with a heuristic mnemonic mathematical problem solving strategy (i.e., SOLVE) that was empirically tested to determine its effectiveness at increasing problem solving skills. More specifically, this research combines strategy instruction and explicit instruction as recommended by Swanson (1999) to teach the SOLVE Strategy.

Because the previous review by Scruggs, Mastropieri, Berkely, and Marshak (2010) did not address mathematics, additional studies are needed to determine if mnemonic strategy instruction can be considered an evidence based practice in mathematics as well. There are a number of mathematical mnemonic problem solving strategies (e.g., FAST DRAW, SOLVE, RIDGES) that are being used by secondary teachers across the country, but these strategies lack empirical research to support their use and effectiveness. For example, the National Training Network has published curricula (e.g., *Algebraic Thinking*) that are being implemented across the U.S. by districts and individual schools with the SOLVE Strategy as one of its major components, yet there have been no empirical studies conducted to validate its effectiveness. The SOLVE Strategy shows promise in that it follows a similar problem solving process as some of the other mathematical mnemonic strategies; however, the SOLVE Strategy is more broad and can possibly be generalized to multiple concepts and topics. Therefore, this study was an adapted implementation of the instructional process for the SOLVE Strategy combining explicit instruction and incorporating an established approach to eight systematic stages of instruction (i.e., pretest, describe, model, verbal practice, controlled practice, advanced practice, posttest, generalization; Schumaker & Deshler, 1992) to determine if the strategy is effective at increasing mathematical reasoning and problem solving.

Purpose

The purpose of this study was to examine the effectiveness of explicit instruction in the SOLVE Strategy on the mathematical problem solving skills of students at the secondary level who have been identified as having a specific learning disability. As

noted previously, explicit-intensive instruction refers to the established approach of the eight stages of instruction consistent to learning strategy instruction research conducted by the University of Kansas Center for Research on Learning (Lenz & Deshler, 2004). Specifically, I assessed (a) student knowledge of the strategy, (b) student use of the strategy while completing mathematical word problems, (c) correct response for each word problem, and (d) student scores on a standardized measure of mathematical problem solving. The study attempted to answer these research questions:

1. What are the effects of the SOLVE Strategy on the mathematical problem solving skills of secondary students with learning disabilities?
2. To what extent does training in the SOLVE Strategy increase accuracy on grade level mathematical word problems?
3. To what extent does training in the SOLVE Strategy increase standardized mathematical reasoning scores?
4. What are teachers opinions about using the SOLVE Strategy within their instruction?
5. What are student perceptions of using the SOLVE Strategy in their everyday mathematics classes?

It was believed that with the implementation of the SOLVE Strategy students' problem solving skills would increase, thus improving academic performance of students with learning disabilities. Additionally, with high-stakes testing being a considerable factor in education today the SOLVE Strategy may offer a way to improve standardized scores of students with learning disabilities in mathematics. Measuring student's performance on standardized mathematical assessments before and after intervention

allowed me to demonstrate whether or not student performance changed after the intervention was in place. When examining strategies that can be used to help increase academic achievement in the classroom it was imperative to take into consideration the amount of time it would take to successfully teach the strategy to students during normal classroom instructional time.

The independent variable was explicit instruction of the SOLVE Strategy. Students with learning disabilities at the secondary level were participants in this study. Students were taught to apply the SOLVE Strategy to one-step mathematical word problems.

The primary dependent variable was the percentage of correct responses by the student on the five question probe test. The secondary dependent variable was the percentage of strategy use for each probe question. These two variables were measured by the researcher after each session using pre-established answer keys. The third dependent variable was student problem solving scores on a standardized mathematical assessment. This was measured using subtests of the Woodcock Johnson III.

Delimitations

It is important to note the delimitations of this investigation that may influence the results of this study. For instance, the study was conducted at a private school in a large metropolitan area. All students who attend this school have been identified as having a learning disability or attention deficit hyperactivity disorder. The students come from average to upper socioeconomic backgrounds, the class sizes are smaller than traditional high schools, and the school was equipped with recourses that may not be available in traditional schools.

Summary

In summary, research is needed to examine effective mathematical strategies for secondary students with disabilities. The intent of this study was to add to the literature by providing students with an effective empirically based strategy for solving mathematical word problems. Chapter 2 provides a review of related literature of importance to this study. The methodology used to conduct the study can be found in Chapter 3. The results of the study are presented in Chapter 4. Lastly, in Chapter 5 a discussion, including implications of this study, limitations, and suggestions for future research are presented.

Definition of Terms

The terms used throughout this study with their definitions are presented in this section. Terms listed in this section are critical for understanding implementation procedures and results of this study.

Explicit Instruction—instruction in which the teacher follows a sequence of events; generally stating the objective, reviewing skills necessary for new information, presenting new information, modeling procedures for students, questioning students, providing group instruction and independent practice, assessing performance, and giving more practice (Swanson, 2001).

Heuristic Strategy—a method or strategy that exemplifies a generic approach for solving a problem (Jayanthi et. al., 2008).

Learning Disability—a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia (IDEA, 2004).

Learning Strategy—a tool a person uses to approach learning and using information (KUCRL, 2009).

Learning Strategy Instruction—instruction that focuses on making students more active learners by teaching them how to learn and how to use what they have learned to be successful (KUCRL, 2009).

Mnemonic Strategy Instruction—instruction in which a memory enhancing instructional strategy is used with students with and without disabilities to assist them with remembering important information by linking new information that is taught to information that they already know.

National Council of Teachers of Mathematics Standards—a set of standards set forth by the National Council of Teachers of Mathematics (NCTM) intended to drive all mathematic education.

CHAPTER 2: REVIEW OF THE LITERATURE

Contemporary schools face an increasingly daunting task of addressing incredible learner diversity, more rigorous standards for teaching in the content areas, and the continuation of high-stakes accountability for the success in teaching learners with all levels of academic need or readiness (Reys & Reys, 2011; Thurlow & Johnson, 2000). Caught in the middle of this notably challenging context are students with specific learning disability who are typically included in general education settings, fully participating in the general curriculum, and held accountable to the same rigorous standards in inclusive settings (U.S. Department of Education, 2008). Although, students with learning disabilities are most typically characterized as struggling learners (i.e., 80-90% of students are identified on the basis of reading failure; LD OnLine, 2008 Lerner, 1989; Lyon, Fletcher, Shaywitz, Torgesen, Wood, et al., 200), as many as 50% of students with learning disabilities have IEP goals in the area of mathematics suggesting that general curricula in mathematics present a relevant barrier to the success of this population (Geary, 1999).

Given that expectations in the era of the Common Core State Standards promote higher achievement in mathematics, specifically Algebraic thinking (CCSS, 2012), secondary curriculum in the area of Algebra presents a hurdle for students with a specific learning disability to keep pace with peers and graduate on time. In this chapter, I reviewed the literature related to a few notable themes:

- The core characteristics of adolescents with specific learning disability that present difficulty in secondary schools
- Why students with specific learning disability experience difficulty with grade level performance in mathematics
- The expectations of math performance in secondary schools
- What works for teaching students with learning disabilities? What works for teaching mathematics to students with learning disabilities?
- Need for further research on use of mnemonic-based problem solving strategies using the explicit-intensive instruction model (i.e., involving the 8 stages of instruction established by the University of Kansas Center for Research on Learning).

Characteristics of Students with Learning Disabilities

What is a Learning Disability?

Although Samuel Kirk is credited with coining the term “learning disability” in 1963 from a speech that he gave to the group that would later become known as the Association for Children with Learning Disabilities, it was actually first used by Kirk and Bateman in a 1962 article featured in *Exceptional Children*. Even though the term was used previously, it wasn’t until 1977 that “specific learning disability” was operationally defined with diagnostic and exclusion criteria in federal legislation. Although defining a learning disability continues to be problematic (Kavale & Forness, 2000; Keogh, 1988; Mather & Roberts, 1994), the most favorable and widely used definition comes from the Individuals with Disabilities Education Act.

The term “specific learning disability” means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such term does not include a learning problem that is primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage (20 U.S.C. §1401 [30]).

The classic sign of a learning disability has been a distinct and unexplained gap between an individual’s level of expected achievement and his/her actual performance level. Learning disabilities can affect and present itself differently at various stages of development. Additionally, learning disabilities can range from mild to severe and it is not uncommon for individuals to have a learning disability in more than one area (NCLD, 2012). Three areas most affected by learning disabilities are reading (e.g., dyslexia), writing (e.g., dysgraphia), and mathematics (e.g., dyscalculia).

Dyslexia. According to the International Dyslexia Association, dyslexia is a specific learning disability that is neurological in origin; “It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities” (Lyon, Shaywitz, & Shaywitz, 2003, p. 2). Students with dyslexia typically experience difficulties with other language skills such as spelling, writing, and pronouncing words. Of the students who are found eligible for special education services

approximately 85% of them have a primary learning disability in reading and language processing (Lyon et al., 2003). The International Dyslexia Association also suggested that dyslexia runs in families. For example, parents with dyslexia were very likely to have children who were dyslexic as well. For some, dyslexia is identified at an early stage in life, but for others dyslexia goes unidentified until they get older.

Dysgraphia. The *Diagnostic and Statistical Manual of Mental Disorders (DSM)* identifies Dysgraphia as a “Disorder of Written Expression” as “writing skills (that) ...are substantially below those expected given the person's ...age, measured intelligence, and age-appropriate education (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000).” Dysgraphia can make the act of writing very difficult for students. It can also lead to other problems such as spelling, poor handwriting, and putting thoughts on paper. Characteristics of individuals with dysgraphia can include: trouble organizing letters, numbers, and words on a line or page.

Dyscalculia. The *DSM-IV* identifies Dyscalculia as “difficulties in production or comprehension of quantities, numerical symbols, or basic arithmetic operations that are not consistent with the person's chronological age, educational opportunities, or intellectual abilities (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000).” Different subtypes of mathematical disability may occur. For example, neuropsychologists often differentiate between *acalculia* and *dyscalculia* (Keller & Sutton, 1991). *Acalculia* refers to a condition in individuals who once mastered mathematical ability but subsequently lost it (e.g., as a result of brain injury), and *dyscalculia* (or developmental dyscalculia) refers primarily to a failure to develop mathematical competence (Keller & Sutton, 1991). Because math disabilities vary so

much, the effect they have on an individual varies just as much. For instance, a student who has difficulty processing language will face different challenges in math than a person who has difficulty with visual-spatial relationships. Although researchers and practitioners may intend to address the same construct when referring to math disabilities; there is much variability in the characteristics of both the actual and intended groups of students described across studies and settings (Landerl, Bevan, & Butterworth, 2004; Mazzocco, 2005). There is even variation in the terms used to define study participants and, thus, the populations that participants represent (e.g., Geary, 1993, 2004; Hanich, Jordan, Kaplan, & Dick, 2001; Mazzocco & Myers, 2003; Russell & Ginsburg, 1984; Shalev & Gross-Tsur, 2001). Further, learning disabilities in mathematics can arise at nearly any stage of a child's development (Misunderstood Minds, 2012).

Prevalence and Characteristics of Specific Learning Disabilities.

The number of students identified as having a specific learning disability (SLD) and receiving special education services has more than doubled since the original passage of The Individuals with Disabilities Education Act in 1975. Since the existence of the SLD category, approximately half of all students determined eligible for special education are found eligible under this category (Zirkel, 2006). According to the United States Department of Education (2006) 2.9 million children in the US have been diagnosed with having a specific learning disability and receive special education services. This represents over 5.5% of the total school-age population, and approximately one-half of all children receiving special education services. With that being said, identification and treatment of children with SLD have been and continue to be areas of interest and concern (NASP, 2007).

Because the diagnosis of learning disabilities is not a clear, objective medical condition and involves the use of psychometric evaluation, the field of special education has struggled with developing consensus around an operational definition of learning disabilities, which has left room for ambiguous and biased decisions with regard to diagnosis (Artiles, Kozleshi, Trent, Osher, & Ortiz, 2010). The years of emphasis on the student who should truly be “in” special education detracts from the critical question of what can be done to improve instruction for students who demonstrate a profile of academic weakness in a particular area.

Thus, more needs to be done to prevent academic failure of students in content area classes. Placement in special education may not be the answer based on current research and poor post-school outcomes of students with disabilities (Artiles, et al., 2010; Blackorby & Wagner, 1996; Blackorby, et al., 2005). There has been some improvement from the minority groups of students; however, the achievement gap between students with and without disabilities still remains (Wagner, Newman, Cameto, Levine, & Garza, 2006). With these findings there has been a national response to the over identification of students with learning disabilities.

A national response to this has been the implementation of Response to Intervention (RTI) as an alternative to traditional approaches. RTI, in essence, is a framework or process of systematically evaluating students’ needs and then aligning intervention to instruction that is designed to prevent academic and behavior difficulties for students (Vaughn, Wanzek, & Fletcher, 2007). The National Center on Response to Intervention (2010) gave this definition

Response to intervention integrates assessment and intervention within a multi-level prevention system to maximize student achievement and to reduce behavioral problems. With RTI, schools use data to identify students at risk for poor learning outcomes, monitor student progress, provide evidence-based interventions and adjust the intensity and nature of those interventions depending on a student's responsiveness, and identify students with learning disabilities or other disabilities.

No matter what definition one chooses to use, when implemented correctly RTI can serve as a powerful preventative tool that aids "at-risk" students from being referred for special education services without proper interventions. Two advantages to using RTI for specific learning disability identification is that there would be a strong focus on providing effective instruction and improving all students' outcomes, and decision-making is supported by continuous progress monitoring closely aligned with desired instructional outcomes (Fuchs & Mellard, 2007). With RTI now being implemented at the secondary level it is important to examine factors that influence the acquisition of skills and concepts by students in addition to the interventions and supports that respond challenges students experience.

Why do Students with Specific Learning Disability Experience Difficulty in Secondary Mathematics?

Some of the typical characteristics associated with students with learning disabilities have a direct impact on their ability to understand and complete word problems (Steel & Steele, 2003). According to Brodesky, Parker, Murray, and Katzman

(2002) there are eight areas that have been identified that may influence mathematic disabilities. The following section reviewed each of these areas.

Language. Morin and Franks (2010) explored why students have difficulty learning mathematics from a language-processing perspective. The authors suggested that “understanding of the spoken and printed word is complicated by the complex, syntax structure, and semantic variation inherent in the words used to convey meaning (Morin & Franks, 2010).” Therefore, teachers should be conscious of the language and terminology they use in their instruction.

As part of the Communications Standard (NCTM, 2000), students need to describe strategies, explain their reasoning, justify solutions, and make persuasive arguments, both orally and in writing. They need to learn mathematical vocabulary and use it to express mathematical ideas with precision and clarity. In class and small group discussions, students need to build on the thinking of their classmates and ask questions to help them understand and clarify another person's strategies (Brodesky et al., 2002). If a student has a deficit in language they may have difficulty understanding a) long or complex sentence structures and figures of speech, b) retrieving vocabulary words, c) orally presented tasks, and d) responses to teacher-directed questions (Walcot-Gayda, 2004). Additionally, solving algebraic word problems may pose as a problem to students who have difficulty with language because the students may have trouble understanding the facts and words that are used. A problem may also occur in understanding and using some of the terminology found in mathematics textbook (Steele & Steele, 2003).

Maccini and Ruhl (2000) pointed out that teachers assume students know basic facts and vocabulary which often lead to academic failure for students with learning

disabilities. Students can be able to verbal state a definition without actually understanding the concept and how it relates to problem solving.

Visual-spatial processing. The representation of mathematical ideas is another one of the ten standards in the Principles and Standards for School Mathematics (NCTM, 2000). Students create and use representations to solve problems and to explore and communicate mathematical concepts in all the strands. For example, in the number and operation strand, students use different visual representations for percents including (a) number lines, (b) fraction circles and bars, (c) base ten blocks, and (d) hundred-grids. In algebra, students extend visual patterns in order to determine a rule, analyze graphical representations of functions, and create mathematical models (Brodesky et al., 2002). Deficits in visual-spatial processing make interpreting what is seen difficult for students with learning disabilities (Steel & Steel, 2010).

Attention. At the secondary level there is an increase of complex math content. With this increase there is also an increase in the demand for students' attention over longer time spans. In a typical mathematics class students would have to listen to directions and explanations, participate in class discussions, and work effectively by themselves. Completing multi-step investigations and long-term projects, paying attention to details, and completing tests and assessments, often within a limited time frame, are other obstacles that students with attention deficits face (Brodesky, et al, 2002).

Psycho-social. Psycho-social skills are heavily related to the communication processing strand from the NCTM Standards and Principals (NCTM, 2000). Communication of mathematical ideas is something that students need to be able to do at

the secondary level. Students work together in pairs or small groups to carry out mathematical investigations and then share their findings in a whole class discussion. Students need to be able to give and receive constructive feedback to help them or their peers improve a problem solution. Confidence is needed by students to try new mathematical investigations and persist through frustrations(s) that may arise when solving problems. All of these types of tasks involve psycho-social skills. Students who have deficits in psycho-social skills may misread social cues and thus cause tensions when they are working with peers. Making inappropriate comments and disrupting class discussions are just two examples of behaviors that students with psycho-social deficits may exhibit (Brodesky et al., 2002).

Fine-motor skills. Fine-motor skill is the coordination of small muscle movements which occur in body parts, such as the fingers and hands, usually in coordination with the eye (Brodesky et al, 2002). Fine-motor skills are needed in mathematics to carry out tasks such as (a) performing calculations, (b) writing explanations, (c) making tables and graphs, (d) using manipulatives, (e) drawing representations, (f) cutting out shapes, and (g) building scale models. Fine-motor skill deficits can also manifest when students are aligning numbers, plotting points on graphs, and drawing straight lines. These students tend to work slowly and their final products may be illegible or lack the necessary precision (Brodesky).

Organization. The Principles and Standards for School Mathematics (NCTM, 2000) emphasize the integral role of problem solving in mathematical learning. The Problem Solving standard states that "students should have frequent opportunities to formulate, grapple with and solve complex problems that require a significant amount of

effort." (NCTM, 2000) Solving these complex problems involves several organizational demands: (a) figuring out how to get started; (b) carrying out a sequence of steps; (c) keeping track of the information from prior steps; (d) monitoring one's progress and adjusting the strategies accordingly; and (e) presenting solutions in an organized manner. Students must also organize their time to insure that they do not rush through tasks and make careless errors or spend an excessive amount of time and not complete the task (Brodesky et al., 2002). With that being said, cognitive processing plays a major role in student's ability to be effective problem solvers.

Cognitive processing. One of the goals of standards-based mathematics is for students to have and build a deep understanding of mathematical concepts (Brodesky et al., 2002). Understanding concepts involves making connections between ideas, facts, and skills and the metacognitive process of reflecting upon and refining that understanding. As students begin to explore the secondary mathematics curricula they use more symbolic representations than in the elementary grades. Consequently, students who tend to think concretely may need additional support to help them make the transition from concrete to abstract representations (Brodesky et al., 2002; Steele & Steel, 2003). Johnson, Humphrey, Mellard, Woods, and Swanson (2010) wrote that arithmetical learning difficulties can be associated with cognitive deficits (e.g., Bull & Johnston, 1997; Geary & Brown, 1991; Geary, Brown, & Samanayake, 1991; Hitch & McAuley, 1991; Rourke & Findlayson, 1978; Rourke & Strang, 1978; Siegel & Ryan, 1989; Temple, 1991).

According to Goldman and Hasselbring (1997) research in cognitive science points to the distinctions among three basic types of mathematical knowledge:

declarative, procedural, and conceptual. The authors point out that each type is critical to developing mathematical literacy consistent with the NCTM Standards and New Standards. Declarative knowledge is facts about mathematics which can be conceptualized as a network of relationships containing basic problems and their answers. The facts stored in this network have different strengths that determine how long it takes to retrieve an answer. The stronger the relationship in this network, the more quickly and effortlessly students can retrieve the information. Procedural knowledge is the rules, algorithms, or procedures used to solve mathematical problems. It is represented as step-by-step instructions in how to complete tasks, and the steps are to be executed in a predetermined linear sequence. Lastly, conceptual knowledge was defined as connected information that make up a whole where the relationships that connect the information together is just as important as the whole that they create. This particular mathematical knowledge type focuses on understanding rather than computational steps (Goldman & Hasselbring). Since mathematical literacy involves more than fluent retrieval of basic math facts students will have to know the relationship between declarative, procedural, and conceptual knowledge in order to solve problems.

According to Hieber and Carpenter (1992) the importance of metacognition to mathematical problem solving has been well documented. Montague, Bos, and Doucette (1991) suggested that errors in problem solving may be the result of students with learning disabilities inability to monitor their problem solving performance. For example, Montague and Applegate (1993) found that as task difficulty increased gifted students verbalized more metacognitive strategies compared to students with learning disabilities. As the task difficulty increased for students with learning disabilities they “shut down”

indicating cognitive overload (Montague et al.). As Montague and Bos (1990) pointed out successful problem solvers monitor their thinking and strategy use. Johnson, Humphrey, Mellard, Wods, and Swanson (2010) conducted a meta-analysis on the cognitive processing deficits of students with specific learning disabilities. One of the major findings from this analysis was that students with math disabilities have average intelligence, but struggle with executive functioning, processing speed, and short-term memory.

Johnson et al. (2010) conducted a meta-analysis to determine if differences in cognitive processes between students with learning disabilities and their nondisabled peers were of sufficient magnitude to justify inclusion of such measures in the specific learning disabilities assessment batteries. A total of 177 studies were reviewed and 32 were included in the analysis. Results indicated a moderate to large difference in the cognitive processing abilities of students with a specific learning disability compared to their nondisabled peers. Based on these findings, including cognitive processes related to the suspected area of disability in the explanatory component of a specific learning disability diagnostic process is supported. Despite research support that students with learning disabilities have cognitive processing deficits when compared to their nondisabled peers (Berninger, 2006; Semrud-Clikeman, 2005; Swanson, 2009) cognitive processes are not routinely assessed as part of the specific learning disabilities identification process (Johnson et al., 2010). Additionally, key cognitive areas identified as areas to focus more on included working memory, processing speed, executive function, and receptive and expressive language (Johnson et al.).

Memory deficits. Both short- and long-term memory play vital roles in learning mathematics (Brodesky et al., 2002). Students rely on memory to perform (a) calculations and procedures, (b) identify geometric figures, and (c) create graphs that have all of the necessary parts. A common characteristic of students with long-term memory deficits is the inability to easily store and retrieve information, such as number facts or the steps of algorithms. Making connections between what is currently being taught and what was learned previously is important in mathematics. Having deficits with long-term memory can impede students' ability to make these connections.

Additionally, short-term or working memory can serve as barriers for students with mathematic disabilities. Students use their working memory to keep track of several pieces of information for a brief time, such as keeping track of calculations when solving multi-step problems or performing mental calculations (Bodesky et al., 2002). Having deficits in either long- or short-term memory can pose a number of problems for students with learning disabilities. According to Steele and Steel (2003) students with learning disabilities with memory deficits have difficulty remembering all the steps in complex problems, recalling formulas, remembering the rules for order of operations, calculating with integers, and solving quadratic equations.

Ashcraft, Donley, Halas, and Vakali (1992) suggested that the executive is responsible for initiating and directing processing, comprehension, and retrieval from long-term memory. Baddeley (1996) described the various executive functions. The first executive function was the ability to organize performance on two or more separate tasks. The second executive function was the ability to switch retrieval strategies (e.g., multiplying and adding in a multidigit multiplication problem). The third executive

function was attending selectively to different inputs (i.e., attention is spent on selected parts of a problem at different times). The fourth executive function was activating and manipulating information in long-term memory. All of Baddeley's components of the central executive seem likely to be involved in arithmetical calculation which may help to explain why students with learning disabilities struggle with calculation tasks. The suppression of irrelevant information has also been characterized as being a part of executive functioning. Previous studies (e.g., Passolunghi, Cordnoldi & De Liberto, 1999; Passolunghi & Siegel, 2004; Passolunghi & Siegel, 2001; Russell & Ginsburg, 1984) have suggested that students with math disabilities have a difficult time suppressing irrelevant information.

Learning disability and secondary mathematics. Cawley, Parmer, Yan, and Miller (1998) noted not only that math difficulties usually began in elementary grades, but also persisted through secondary schooling with students with disabilities performing several grade levels behind their non-disabled peers. Consequently, problem-solving skills have increasing importance due to technology demands (e.g., calculators, computers, and software programs) that require advanced levels of mathematics proficiency (Little, 2009).

There have been a number of nationwide mathematics reforms of the last several decades (e.g., National Education Association, 1894; NCME, 1923; NCTM, 1989). In 1894, the National Education Association suggested that the mathematics curriculum at the secondary level be standardized. From this movement algebra-geometry-algebra became the secondary mathematics course sequence, which continues to be the course sequence that is followed in most high schools today. Next, the Commission on the

Reorganization of Secondary Education (1918) issued *Cardinal Principles of Secondary Education* which did not have a strong focus on mathematics, but instead focused on everyday life skills that would assist students with becoming successful citizens. In 1923, the National Committee on Mathematical Requirements called for more unification, and proposed the concept of function as a central unifier of algebra and geometry. During this time the number of students attending secondary schools increased concurrent to an increasingly diverse student population (Reys & Reys, 2011).

As noted previously, the mathematical focus in earlier years was on solving problems in everyday life. This changed in 1957 when the Soviet Union beat the United States into space with the launching of Sputnik. “New math” or “modern math” that emphasized guided discovery of mathematical structures, patterns, and relationships became the focus (Miller & Mercer, 1997; UICSM, 1957). This “new math” only lasted about 20 years once it was discovered that students were unable to perform basic math operations (Miller & Mercer, 1997; Reys & Reys, 2011). Subsequently, the National Council of Teachers of Mathematics (NCTM; 1980) called for an increased focus on problem solving. This, along with the National Commission on Excellence in Education (1983) and the National Research Council (1989) led to high schools requiring more years of mathematics to graduate from high school. In 1989, NCTM developed standards that went back to focusing on discovery learning via constructivism for teaching mathematics (Miller & Mercer, 1997). Likewise, the NCTM Principles and Standards of 2000 outlined content and processes by grade level for mathematics with problem solving being one of the five process standards.

More recently, the Obama administration has advocated for education standards designed to make all high school graduates “college- and career-ready.” To achieve this goal the National Governors’ Association and the Council of Chief State School Officers (NGA/CCSSO) have developed the “common core” standards. To date, more than 47 states have adopted the *Common Core State Standards for Mathematics* since its release in 2010. In the Obama Blueprint document the common core standards require greater rigor and higher expectations as compared to the previously lower and inconsistently required standards such as those of the 1970s (Mathis, 2010). Since the common core standards are fairly new, little to no research is available on the impact of common national standards in the US.

High stakes testing. The most significant educational challenge facing American society in the 21st century is the gap in academic achievement on standardized tests among subgroups in schools including students with disabilities and students from low income communities (Kim & Sunderman, 2005). The No Child Left Behind Act of 2001 (NCLB; 2002) was one of the first national policies that addressed the need for closing “the achievement gap”. This act placed stringent requirements on “all schools” and “all students” to make adequate yearly progress (AYP) on academic standards in reading and mathematics by the 2013-2014 school year (Kim & Sunderman, 2005). State-level National Assessment of Education Progress (NEAP) scores have served as a common measure across states. From these data studies have revealed that determinations of “proficient” in making AYP had little correlation to relative NEAP performance (Bandeira de Mello, Blankenship, & McLaughlin, 2009). Under the accountability system introduced by the NCLB Act of 2001, it has been found that many states have lowered

their standards in an effort to make AYP. When the NAEP scale equivalent scores of each state's standards from 2005 to 2007 were compared, researchers documented that in states with a significant change in their NAEP scale equivalent scores, standards for that state had become easier. For example, of the Grade 8 mathematics scores in 12 states with a significant change in their NAEP scale equivalent, 9 had significantly decreased their expectations (Bandeira de Mello et al., 2009). These results were used to help justify the current administrations push for common "college- and career-ready" standards.

Since NCLB, students with disabilities, including those with learning disabilities, are required to participate in these statewide assessments. The Individuals with Disabilities Education Improvement Act (IDEIA; 2004) mandates that students with disabilities are included in all general State and district-wide assessments with appropriate accommodations as indicated on their Individualized Education Programs (IEP). Students with learning disabilities are now involved in high stake testing which inadequately measure their academic performance (Sireci, Li, & Scarpati, 2003). Students' performance in the US on standardized tests has become a major concern. One indication of this widespread challenge in mathematics is the estimate that 40 – 60% of students nationwide are failing Algebra I (Berg, 2009).

Algebra I serves as a "stepping-stone" for continued study of mathematics and is no longer an elective course in high school, but a required mathematics course for all high school students (Reys & Reys, 2011). Currently, Algebra I is required in most states for graduation for all students regardless of if they are going to go on to college or not. It is symbolic to a gate that everyone has to pass through in order to graduate from high school and to advance to high level mathematics and science classes (Chazan, 1996).

Throughout history it has been suggested that one possible way to increase performance in mathematics for students with learning disabilities is to teach problem solving skills (Carnine, 1991; CCSS, 2010; NCTM, 2000 Parmar & Cawley, 1997; and Xin & Jitendra, 1999). For example, the 2000 *Principles and Standards* developed by the NCTM states that problem solving should be taught from prekindergarten through grade 12. Instructional programs should enable all students to (a) build new mathematical knowledge through problem solving, (b) solve problems that arise in mathematics and in other contexts, (c) apply and adapt a variety of appropriate strategies to solve problems, and (d) monitor and reflect on the process of mathematical problem solving. It is also suggested that students should be taught how to use diagrams, look for patterns, trying special values or cases as problem solving strategies to solve mathematical problems.

Students who struggle with mathematics do not lack intelligence or motivation; instead, they lack the perceptual and associative processing tools that allow individuals to process numbers and mathematics (Berg, 2009). The lack of these processing tools, sensory-cognitive development, limit students' memory, challenging them to learn, retain, and apply math facts, recall formulas, and remember sequences and structure of multi-step problem solving.

Summary

When examining the areas that affect mathematics specifically we know that (a) language, (b) visual-spatial processing, (c) attention, (d) psycho-social skills, (e) fine-motor skills, (f) organization, (g) cognitive processing, and (h) memory deficits can all impede students with learning disabilities from being successful in mathematics (Brodskey et al, 2002). According to Johnson et al. (2010) deficits in verbal working

memory, visual working memory (Hitch & McAuley, 1991), processing speed (Bull & Johnston, 1997; Swanson & Jerman, 2006), attention (Fuchs, Compton, Fuchs, Paulsen, Bryant, & Hamlett, 2005), and executive function (Geary, 2004) have been demonstrated to differentiate between average achievers and students with math disabilities. These deficits manifest in difficulties with math fact fluency (Geary, Brown, & Samaranayake, 1991), problem solving (Geary), and number sense. Because learning disabilities can arise at any stage of development it is imperative that we identify strategies adolescents can use to help them be successful in content area classes.

It is evident that implementing RTI requires purposeful planning, and continuous evaluation. Prior research has shown that adolescents with learning disabilities reach a mathematics plateau after seventh grade making only one year's growth during Grades 7 through 12 (Warner, Alley, Schumaker, Deshler, & Clark, 1980).

Historically, despite all of the remediation in most secondary programs for students with learning disabilities, the academic performance gap persists (Deshler, Schumaker, Alley, Warner, & Clark, 1982). Alley, Deshler, and Warner (1970) found that 85% of adolescent students with learning disabilities demonstrated deficits in test-taking and study skills. Likewise, Carlson and Alley (1981) found that high school students with learning disabilities performed significantly below their nondisabled peers in note taking, monitoring writing errors, test taking, and listening comprehension. Because adolescents with learning disabilities are above a fourth grade level, Deshler et al. (1982) suggested that students can be supported in the general education curriculum by teaching them specific learning strategies.

There is a great need for intervention research for adolescents with learning disabilities. Most of the professional literature relating to learning disabilities has focused on younger students, hence the nationwide shift to RTI. However, Deshler (2005) made the argument that in spite of existing effective interventions for students, the chance of any of them being implemented with fidelity at a large-scale was remote. Additionally, the need for effective intervention strategies for older students is just as great as effective interventions for younger students because as students get older and start to mature they are faced with more and more challenges making it imperative to develop interventions that address multiple aspects of the learning disabilities across varying age groups and academic setting demands (Deshler, 2005).

Learning Strategy Instruction

One way to assist students with learning disabilities with the shift to more content-focused classes is to provide them with effective and efficient learning strategies. Simply put, a learning strategy is an individual's approach to completing a task. More specifically, a learning strategy is an individual's way of organizing and using a particular set of skills to learn content or complete tasks more effectively and efficiently both in and out of school (Schumaker & Deshler, 1992).

Research from the University of Kansas Center for Research on Learning

An ample amount of the research conducted on the explicit teaching of learning strategies to adolescents with learning disabilities has come from The University of Kansas, Center for Research on Learning (KU CRL). This research suggests the use of learning strategies as a way to improve student performance in inclusive settings or on grade appropriate tasks. Additionally, the *Learning Strategies Curriculum* was developed

over approximately the last 30 years of research. It is composed of three academic areas: (a) acquiring information, (b) storing information, and (c) expressing knowledge (KUCR, 2012).

Acquiring information. The Word Identification Strategy—a strategy for decoding complex words (Lenz, Schumaker, Deshler, & Beals, 1984), the Paraphrasing Strategy—a strategy to translate main ideas and details of a passage into one’s own words (Schumaker, Denton, & Deshler, 1984), and the Word Mapping Strategy—a strategy used to predict the meaning of words (Harris, Schumaker, & Deshler, 2008) are all a part of the information acquisition strand.

Lenz, Schumaker, Deshler, and Beals (1984) conducted a study to examine the effects of the word identification strategy on the reading abilities of adolescents with learning disabilities. Twelve students were selected for participation in the study, and were assessed based on five measures (i.e., 3 oral reading measures, 2 reading comprehension measures). The word identification strategy is a systematic process in which multisyllabic words can be recognized in reading assignments in content area classes (e.g., social studies, science). Students were trained in a general problem-solving strategy in which specific substrategies were applied for the quick identification of difficult words. Training was provided by the student’s teachers using the eight-step instructional sequence created by Deshler, Alley, Warner, and Schumaker (1981) to promote strategy acquisition and generalization. The eight steps included: (1) pretest and obtain commitment to learn, (2) describe the strategy, (3) model the strategy, (4) verbal rehearsal of strategy steps, (5) controlled practice and feedback, (6) grade-appropriate practice and feedback, (7) posttest and obtain comment to generalize, and (8)

generalization. Using a multiple-baseline across participants design, students were placed in three groups of three and received approximately 20 to 25 minutes of instruction in the intervention per day for a 6-week period. Results indicated that the strategy was effective in reducing common oral reading errors (e.g., mispronunciations, substitutions). Students were also able to maintain their performance up to five weeks after intervention.

Researchers pointed out that the strategy was taught as a problem solving process rather than as a decoding process, and the eight stages of instruction were used to insure student understanding, memory, and mastery of the strategy.

Schumaker, Denton, and Deshler (1984) created a paraphrasing strategy to increase adolescents with learning disabilities ability to recall information from text. The mnemonic “RAP” was created to help students remember the steps of the strategy: (a) Read a paragraph; (b) Ask myself, “What was the main idea and two details?” and (c) Put it into my own words. The RAP strategy is based on sound theory utilizing paraphrasing to help improve memory of main ideas and details in text. Initial pilot data for the RAP strategy were promising in that students who were taught to use the RAP strategy increased their recall of text from 48% to 84%.

Although there was no empirical study conducted Harris, Schumaker, and Deshler (2008) created the Word Mapping Strategy to help adolescents predict the meaning of words. There is an instructor’s manual that follows the eight stages of instruction outlined by Deshler, Alley, Warner, and Schumaker (1981).

Storing information. The information storage area includes strategies such as the FIRST-letter Mnemonic Strategy and the Paired Associates Strategy. The FIRST-letter Mnemonic Strategy enables students to scan textbooks to create lists of critical

information and devise first letter mnemonics to remember the material (Nagel, Schumaker, & Deshler, 1986). More specifically, the strategy includes strategies for reviewing written information, finding important information through the use of "clues" (e.g., bold-faced headings), creating lists of related information, creating memory devices to enhance recall of the items in the lists, and memorizing those lists in preparation for a test.

The Paired Associates Strategy enables students to pair pieces of new information with existing knowledge by using a visual device (Bulgren, Hock, Schumaker, & Deshler, 1995). Students learn pairs of informational items, such as names and events, places and events, or names and accomplishments. From these pairs students identify pairs of items, create mnemonic devices, create study cards, and use the study cards to learn the information. Twelve high school students with learning disabilities were instructed in the strategy to identify and remember pairs of small groups of information using a multiple baseline across participants design. Results indicated that before students learned the Paired Associates Strategy, they only answered on average eight percent of test questions correctly related to paired information when the paired information was identified for them. After intervention students answered correctly an average of 85 percent of the questions about paired information that was identified for them. When given reading passages to study on their own, they answered an average of 22 percent of test questions correctly before instruction in the strategy versus answering 76 percent correctly after mastering the strategy. Results also revealed student improvement in test performance and creation of study cards. Students had distinct preferences among mnemonic devices and adapted strategies based on previous experience.

Expressing knowledge. Lastly, the expression and demonstration of understanding academic area includes strategies such as the Sentence Writing and Test Taking Strategies. The Sentence Writing Strategy was designed to teach students how to write simple, compound, complex, and compound-complex sentences (Schumaker & Sheldon, 1985). The Test Taking Strategy was used by students to focus attention on critical aspects of test items, systematically answer questions, and improve test performance (Hughes & Schumaker, 1991). The *Test-Taking Strategy* is designed to be used while taking classroom tests. Students allocate time and priority to each section of the test, carefully read and focuses on important elements in the test instructions, recall information by accessing mnemonic devices, systematically and quickly progress through a test, make well-informed guesses, check their work, and take control of the testing situation.

Schumaker and Sheldon (1985) developed a sentence-writing strategy that has been used successfully to help students with learning disabilities understand sentences better. The acronym PENS helps students remember the steps in writing a sentence: Pick a sentence type and formula, Explore words to fit the formula, Note the words, Search for verbs and subjects, and check. The Sentence Writing Strategy teaches students to recognize and write 14 sentence patterns with four types of sentences: simple, compound, complex, and compound-complex.

When examining the aforementioned research there was a consistent theme across the methods used to deliver the intervention to students. With that being said, an instructional sequence has been validated by the educators at the University of Kansas, Center for Research on Learning following these teacher-directed steps: (a) pretest, (b)

describe, (c) model, (d) verbal practice, (e) controlled practice, (f) grade-appropriate practice, (g) posttest, (h) generalization (Schumaker & Deshler, 1992). Schumaker and Deshler (1992) discuss some of the key features surrounding the research conducted on learning strategy interventions for adolescents with LD, including the stages of the research, research standards, the curriculum, and the instructional methodology.

First, the teacher assesses the current level of student performance using a strategy pretest and students commit to learning a new strategy. Second, the teacher describes the features of the strategy as well as when, where, why, and how to use the strategy. Next, the teacher models how to use the strategy by "thinking aloud" as the strategy is applied to content material. During the verbal practice stage, students memorize the steps of the strategy and other essential requirements. Afterwards, controlled practice activities are used to enable students to become proficient strategy users with ability level materials. One critical component at this stage for students is for teachers to provide specific feedback on student performance. Next, students use the strategy with grade-appropriate or increasingly more difficult materials. Finally, students are given a posttest followed by the teacher facilitating student generalization of the strategy through use in other academic and nonacademic settings. Each of the learning strategies has multiple parts that students remember with the aid of a mnemonic. These strategies are typically learned in small groups, sometimes in a resource room, through short, intensive lessons over several weeks. All in all, in order to effectively design mathematics instruction it is imperative to examine where the focus of mathematics instruction has been and where it is going.

Selected Research in Learning Strategies from Various Sources

In addition to the research conducted at the KU CRL, other researchers in the area of learning strategies have also found positive results. According to Maccini, McNaughton, and Ruhl (1999) teacher's delivery of instructional strategies was shown to be more effective than some of the more student-centered (i.e., discovery) approaches. Modeling, guided practice, and corrective feedback on responses to practice problems were also recommended as ways to increase student academic performance.

For example, Graham, Harris, and colleagues (e.g., Graham, Harris, MacArthur, & Schwartz, 1991) have validated strategies for improving the quality of student compositions, planning processes, and revisions using the PLAN and WRITE strategies. In another line of research, Palincsar and Brown (e.g., Palincsar & Brown, 1986) successfully tested and replicated reciprocal teaching, a strategy to improve student reading performance. Scruggs and Mastropieri (e.g., Scruggs & Mastropieri, 1992) have validated several approaches to teach students how to construct and use mnemonic strategies (i.e., keyword strategy, pegword strategy, first). The DRAW strategies tested by Miller and Mercer (e.g., Miller & Mercer, 1991; 1993), which resulted in improved student performance in math calculations as well as in solving word problems, are discussed further later in this chapter.

Writing. Graham, Harris, MacArthur, and Schwartz, (1991) reviewed their research program in written language, including examinations of what and how students with LD write. Based on their research, students' writing difficulties stem from problems with basic text production skills, limited knowledge about writing, and difficulties with planning and revising text. In their previous studies, the researchers evaluated the

effectiveness of instructional procedures for addressing strategy instruction, procedural facilitation, word processing, basic skills instruction, and the process approach to writing.

Mnemonic strategies. According to Mastropieri and Scruggs (1998) students with learning disabilities and other special needs may be at particular risk for failure in school due to memory deficits. In order to promote academic success in school, Mastropieri and Scruggs (1998) recommend that teachers teach students *how* to remember as well as *what* to remember. According to Mastropieri and Scruggs teaching students how and what to remember can be done by a variety of strategies, but they found that the most powerful strategies have been the keyword method, the pegword method, and letter strategies. Additionally, systematic instruction using mnemonic strategies can be important in helping to determine school success for students with learning disabilities and memory deficits.

Summary

Most favorable learning outcomes for students occur when their skills and abilities closely match the demands of the curriculum and instruction within the classroom. Therefore, it is important that to match quality classroom instruction to meet the needs of the students. When there is a mismatch between the curriculum and instruction within the classroom, student outcomes and learning may suffer (Mellard, 2003). One way to assist students with learning disabilities with the shift to more content focused classes is to provide them with effective and efficient learning strategies.

According to Schumaker et al. (2002) much of the instruction that takes place in general and special education class settings does not adhere to validated instructional practices. A fair amount of the special education literature in mathematics has suggested

that instruction be explicit and systematic (e.g., Fuchs & Fuchs, 2003; Gersten, Baker, Pugach, Scanlon, & Chard, 2001; Swanson & Hoskyn, 1998). Secondary grades show a departure from the skills emphasis of elementary grades to a more specific content emphasis. Students are faced with greater demands to read information from textbooks, take notes from lectures, work independently, and express understanding in written compositions and on paper and pencil tests (Deshler & Schumaker, 1986).

The Need for Explicit Instruction

In a 1999 meta-analysis, Swanson found two major intervention practices that produced large outcomes for students with specific learning disability. One was direct/explicit instruction; the other learning strategy instruction. Archer and Hughes (2011) described explicit instruction as “a series of supports in which students are guided through the learning process with clear statements about the purpose and rationale for learning the new skill, clear explanations and demonstrations of the instructional target, and supported practice with feedback until independent mastery has been achieved” (p. 1).

From the Swanson (1999) analysis it was found that teachers who were applying those kinds of intervention (e.g., direct/explicit instruction): (a) broke learning into small steps; (b) administered probes; (c) supplied regular quality feedback; (d) used diagrams, graphics and pictures to add to what they were saying in words; (e) provided ample independent intensive practice; (f) modeled instructional practices that they wanted students to follow; (g) provided prompts of strategies to use; and (h) engaged students in process type questions like “How is that strategy working? Where else might you apply it?”

Research in General Education

In 1968, the U.S. Office of Education initiated a comprehensive program called Project Follow-Through for economically disadvantaged students in elementary grades in 180 communities. Although not its original purpose, Project Follow-Through focused on identifying effective approaches for teaching economically disadvantaged students. The study was conducted over multiple years with the first cohort of students entering Kindergarten in 1968 and included tens of thousands of students across the country ending in 1981 (Meyer, Gersten, Gutkin, 1983). The effectiveness of 12 programs was examined and categorized based on the description and primary instructional emphasis provided by the program developers. Programs were categorized as (a) basic-skills, (b) cognitive-conceptual, and (c) affective–cognitive models. Students were administered a variety of measures that focused on the acquisition of basic skills, problem-solving abilities, or self-concept. From this study Watkins (n.d.) reported that in terms of measures of basic academic skill improvement, The Direct Instruction model had unequivocally higher average effect on scores in the basic skills domain (as well as the other domains) than did any other model. Project Follow-Through has been used in support of explicit instruction approach (Archer & Hughes, 2011). Similarly, Direct Instruction and explicit instruction are based on principles such as (a) increasing on-task behaviors, high levels of success, and content coverage (Meyer & Hughes, 2011). According to Stein, Carnine, and Dixon (1998) the major difference between Direct Instruction and explicit instruction is Direct Instruction’s emphasis on curriculum design; every other component overlaps (Stein, Carnine, & Dixon, 1998).

Pursuing this further, Brophy and Good (1986) conducted a review of the literature conducted in general education classrooms from 1973 through 1983 in which the link between teacher behavior and student achievement was investigated. Results indicated that in most instances, students of the teachers who were using explicit instruction techniques had higher achievement scores than students in control classes. Another finding was that students learn more efficiently when their teachers first structure new information for them and help them link it to prior knowledge, and then monitor their performance and provide corrective feedback during drill, practice, or application activities. It is believed that explicit instruction can be applied to any body of knowledge or set of skills that has been sufficiently well organized and analyzed so that it can be presented (i.e., explained, modeled) systematically and then practiced or applied during activities that call for student performance that can be evaluated for quality and given corrective feedback (Brophy & Good, 1986).

Additionally, Gage and Needles (1989) reviewed a model of good strategy use. One important finding was that good strategy users know many strategies and a lot of information about when and where to use them. For example they are reflective and have low anxiety, and possess beliefs that they can do well by using the right approaches. While strategy use is very important the challenging part is finding the most effective instructional approaches to teach the strategies to students. Gage and Needles (1989) also suggested that strategies are best learned when the teacher is interactive, with teacher-provided responsive feedback. Reciprocal teaching and direct explanation were preferred teaching techniques suggested by the authors. Both of these teaching approaches involve (a) extensive explanation of the strategies to students, (b) explicit and extensive modeling

of strategic techniques, and (c) practice with extensive teacher diagnoses followed by remedial instruction that is individually tailored to students.

Additionally, the National Mathematics Advisory Panel (2008) recommended that students be taught mathematics using explicit instruction. Explicit instruction with students who have learning disabilities was shown to consistently positively affect performance with word problems and computation. The Panel defined explicit instruction as the teacher providing clear models for solving a problem type using an array of examples, that students receive extensive practice in use of newly learned strategies and skills, that students are provided with opportunities to think aloud (i.e., talk through the decisions they make and the steps they take), and that students are provided with extensive feedback. While the Panel did not endorse all mathematics instruction be taught using explicit instruction, it was recommended that struggling students receive some explicit mathematics instruction regularly.

Research in Special Education

Swanson and colleagues (Swanson, 1999; Swanson & Hoskyn, 1998) reviewed all the intervention research published since 1963 when the field of learning disabilities first began. From these reviews three critical instruction components were identified that improved student outcomes: (a) control of task difficulty (i.e., sequencing examples and problems to maintain high levels of student success, (b) small interactive group instruction with six or fewer students, and (c) directed response questioning (i.e., students generate questions while reading or working on a scientific or mathematical problem).

Christenson et al. (1989) summarized findings of their research on instruction for students with mild learning disabilities which identified five factors that reinforced the

need for well-organized and explicit methodologies for teaching academic content: (a) clear expectations about what is to be learned, (b) clarity of presentation, (c) multiple opportunities for student responses, (d) active teacher monitoring of these responses, and (e) frequent teacher evaluation and feedback.

Additionally, Vaughn, Gersten, and Chard (2000) summarized findings of several research syntheses that were federally funded through the Office of Special Education Programs. Intervention research reviewed focused on a variety of topics, including instruction in written expression and reading comprehension, as well as grouping practices for students with learning disabilities. In the area of writing instruction, the authors analyzed 13 studies (all of which resulted in large effect sizes) and identified best practices in teaching expressive writing skills to these students. These practices included (a) explicit teaching of essential steps in the writing process, including models and prompts; (b) explicit instruction in teaching writing conventions across multiple genres (e.g., persuasive essays, compare-and-contrast essays); and (c) guided feedback to students from teacher and/or peer feedback about the quality of their writing attempts. Additionally, Vaughn et al. (2000) synthesized the results of two meta-analyses on reading comprehension research (Gersten et al., 1998; Mastropieri, Scruggs, Bakken, & Whedon, 1996). From this it was concluded that instruction in reading comprehension should provide students with multiple opportunities to practice the strategy with feedback before they are expected to use the strategy on their own. The last area investigated by Vaughn and colleagues dealt with the effects of instructional grouping arrangements (e.g., whole-group, small-group, pairs) on student achievement. Elbaum et al. (2000) conducted a meta-analysis of 19 studies that examined grouping methods and included

students with disabilities. The highest effect sizes were associated with small-group instruction.

According to Kroesbergen and Van Luit (2003) Direct Instruction is most effective for teaching basic or isolated skills. Based on their meta-analysis of over 50 studies of students with math disabilities, explicit methods of teaching were more effective than less direct instructional methods such as discovery learning. A series of meta-analyses of intervention research, Lee Swanson (i.e., Swanson & Hoskyn, 1998; Swanson, 1999, 2001) has identified instructional components that predict positive learning outcomes for students with learning disabilities. Based on these analysis 180 published intervention studies were reviewed. Swanson (2001) identified 12 criteria associated with direct instruction. He suggested that when any four of these indicators are present, direct instruction is occurring: (a) breaking down a task into small steps, (b) administering probes, (c) administering feedback repeatedly, (d) providing a pictorial or diagram presentation, (e) allowing independent practice and individually paced instruction, (f) breaking the instruction down into simpler phases, (g) instructing in a small group, (h) teacher modeling a skill, (i) providing set materials at a rapid pace, (j) providing individual child instruction, (k) teacher asking questions, and (l) teacher presenting the new (novel) materials (Swanson, 2001, p. 4).

Explicit instruction and mathematics. The Center on Instruction conducted a meta-analysis on mathematical interventions as instructional practices and activities that attempted to enhance the mathematics achievement of students with learning disabilities (Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2008). Forty-four studies with randomized control trials or high quality quasi-experimental designs were included in the

meta-analysis. Based on the findings of the meta-analysis seven effective instructional practices were identified for teaching mathematics to students with learning disabilities. First, it was recommended that students with learning disabilities should be taught mathematics using explicit instruction on a regular basis. This could be done by the teacher (a) clearly modeling the solution specific to the problem, (b) thinking aloud the specific steps during modeling, (c) present multiple examples of the problem and applying the solution to the problem, and (d) providing immediate corrective feedback to the students on their performance. Their second recommendation was to teach students using multiple instructional examples. For example, teachers should select a range of examples of a problem type so that students are exposed to as many of the different possible variations. It was also suggested that multiple examples be presented in a specified sequence such as concrete to abstract, easy to hard, and simple to complex. Third, it was recommended to have students verbalize, or think aloud, their decisions and solutions to a math problem. Verbalizing steps in problem solving may help to address students' impulsivity (i.e., solving problems by randomly combining numbers rather than implementing a solution strategy step-by-step) thus facilitating students' self-regulation during problem solving. Next, students should be taught to visually represent the information in the math problem. It was suggested that visuals are more effective when combined with explicit instruction. Additionally, teachers should conduct or be provided data from ongoing formative assessments that evaluate students' progress and use this data to drive their instruction. Finally, students should be taught to solve problems using multiple heuristic strategies. A heuristic strategy is a method or strategy that exemplifies a generic approach for solving a problem (i.e., a strategy that can applied to broad

mathematical contexts). The Center on Instruction (2008) identified four intervention studies in the area of heuristic strategy instruction.

Research on heuristic strategy instruction. Hutchinson (1993) conducted a study with 20 students with learning disabilities to teach them three types of algebraic word problems involving different story lines and different structures. The researchers employed both a multiple baseline across participants and a two group experimental design. Students were assigned to either strategy instruction or typical classroom instruction, and were provided self-questions on cue cards, structured worksheets, teacher modeling of the strategy, prompts, corrective feedback, and reinforcement. Students were not taught to use self-questioning prompts for a specific problem type; instead the prompts in the guide can be applied to any problem type. Results indicated that students in the strategy instruction group performed significantly better than students in the control group on posttest measures. Furthermore, students that received strategy instruction improved problem solving performance and maintained their performance for six weeks.

Van Luit and Naglieri (1999) investigated the utility of a Mathematics Strategy Training for Educational Remediation (MASTER) program, (Van Luit, Kaskens, & Van der Krol, 1993). This program (i.e., MASTER) is based on the assumption that strategy instruction within the context of mathematics can help special children improve their performance in math. The effectiveness of the program was investigated with 84 students with poor mathematics skills, (i.e., learning disabilities; $n = 42$, and mild levels of mental retardation; $n = 42$) using a pre- and posttest design. The teacher modeled several strategies for solving computational problems. Each student was allowed to choose a

strategy to help them complete the problem, but the teacher assisted the students in discussion and reflection about their choices. Results indicated that the use of the self-instruction program resulted in significant improvement over the general instruction program.

Woodard, Monroe, and Baxter (2001) reports the findings from a larger, yearlong case study, focusing on ways to improve problem solving through classwide performance assessment tasks and ad hoc tutoring for 182 students with learning disabilities. During the ad hoc tutoring phase students suggested a strategy for solving the problem, and the tutor probed the other students to see if they agreed and encouraged different individuals to work the next step in the problem. Specifically, the tutor's roles were to: (a) help students understand the problem and what it was asking; (b) clarify students' ongoing interpretation of the problem; (c) remind students of relevant components of the problem that had been previously discussed; and (d) offer explicit suggestions when students became stuck on a problem. The researchers employed a group design using pre/posttest measures. Results from this study indicate that the combined focus on problem solving in the ad hoc tutoring sessions and the classwide practice on performance assessment tasks led to positive gains for students with learning disabilities over time. This approach contrasted sharply with traditional strategy approaches to math problem solving in that it didn't focus on memorizing specific steps when solving traditional word problems.

Next, Woodard (2006) conducted a study in which 58 students in Grade 4 were taught multiple fact strategies based on a review of the intervention literature on developing automaticity in math facts. The two approaches (i.e., strategy use and timed practice drills) were combined and compared to timed practice drills only to determine

which method would be most effective for learning multiplication facts using a group design. Daily lessons consisted of the introduction of new strategies or review of old strategies, but students were not required to memorize strategies. They did have to discuss the strategy and contrast it with previously taught strategies. Results indicated that both approaches were effective in helping students achieve automaticity in multiplication facts; however, students in the integrated approach generally performed better on posttest and maintenance test measures that assessed the application of facts to extended facts and approximation tasks.

Summary

While there is extensive overlap between direct and explicit instruction, Stien et al. (1998) identified the major difference between the two as curriculum design. From all of the research reviewed explicit instruction was a key element in helping students succeed in strategy instruction. In 2008, the National Mathematics Advisory Panel and the Center on Instruction reported explicit instruction as consistently showing positive effects on math performance of students with mathematical difficulties, in both computation and problem solving. Additionally the Center on Instruction recommended that students be taught multiple heuristic strategies when solving problems. From the research and national reports it can be concluded that explicit instruction plays a major role in the success of students in mathematics as well as other content areas.

Mathematical Problem Solving Intervention Strategies for Secondary Students with Learning Disabilities

In order to increase the mathematical performance of students with learning disabilities, it is important to examine intervention strategies that have been effective in

teaching problem solving skills. A number of reviews of the literature revealed intervention strategies found to be effective for students at the secondary level with learning disabilities (e.g., Mastropieri, Scruggs, and Shiah, 1991; Maccini and Hughes, 1997; Xin and Jitendra, 1999).

First, Nuzum (1983) conducted a study using a single subject design (i.e., multiple probe across participants) that examined the effect of an instructional model on the word problem solving performance of four secondary students with learning disabilities. The model included six instructional phases with each phase beginning with clear instructions and cue cards. As the instructional phases progressed students no longer used cue cards. The types of word problems included addition, subtraction, and two-step problems requiring addition and subtraction. Results indicated that the number of problems solved correctly by students increased when intervention phases progressed. Additionally, students performed well on the posttest measure.

Next, Marzola (1985) replicated the work of Nuzum (1983) extending it by implementing a group design with sixty fifth- and sixth-grade students who were diagnosed with learning disabilities. The experimental group was taught strategies for solving word problems, whereas the control group practiced word problems without any instruction. All of the strategies were organized and sequenced based on five objectives, (a) identify the questions, labels, and the necessary information; (b) determine the correct operation in addition or subtraction word problems; (c) recognize and eliminate extraneous information; (d) decide if the problem was a one- or two-step problem and then solve it; and (e) check their work. Students were instructed in each of these five objectives after the demonstrated mastery of the previous objective. Results indicated that

students in the experimental group outperformed student in the control group who did not receive instruction in problem solving. Two-step problems and problems with extraneous information were the two areas that students performed significantly better on.

Montague and Bos (1986) conducted a similar study to the two previous studies in that the researchers examined the effects of an eight-step cognitive strategy on students' generalization to three-step problems was examined. Students ranged in age from 15-19 and participants consisted of five males and one female. The eight steps included (a) read the problem aloud, (b) paraphrase, (c) visualize, (d) state the problem, (e) hypothesize, (f) estimate, (g) calculate, and (h) self-check. Results indicated five of the six students improved after cognitive strategy training. Additionally, four students successfully generalized the strategy to three-step problems. Upon error analysis results revealed that students mostly made computation and operation errors on the tests after the strategy training which suggest that cognitive strategy training may provide students a general approach for solving word problems, but does not ensure correct computation of answers to the word problems.

Bennett (1980) conducted a study that examined the effects of pre- and post-organizers on 21 secondary students with learning disabilities scores on word problems with different levels of syntactic and computational complexity using a group design. During the pre-organizer phase students were taught four steps to solve word problems (a) read problem, (b) underline numbers, (c) re-read problem, and (d) decide on the operation sign and problem type. During the post-organizer phase students followed the following five steps (a) read problem, (b) check operation, (c) check math statement, (d) check calculations, and (e) write labels. During the last phase of intervention students no

longer used the cue cards, and post-test scores improved on one-step problems with lower levels of syntactic complexity.

Montague (1992) conducted a study with six secondary students with learning disabilities using strategy training to improve students' problem solving performance in mathematics. Strategy instruction for these students consisted of two instructional phases where teachers instructed student on (a) cognitive (seven problem solving strategies) or (b) metacognitive strategies (self-awareness and regulation of the strategies). Students then had to memorize the strategies through self-instructions, monitoring, and questioning. If student were assigned to the cognitive strategy group during the first instructional phase, then during the second instructional phase they would receive instruction in metacognitive strategies on the treatment they missed during the first instructional phase. A quasi-experimental, control group time-series design was used. Results indicated that students' problem solving performance increased more once they had a combination of cognitive and metacognitive strategies than either of the strategies in isolation; however, students did not generalize strategy use to their regular classroom and did not maintain their performance over time making it necessary to conduct booster sessions.

Montague, Applegate, and Marquard (1993) conducted a study with secondary mathematics students in which 72 students were randomly assigned to three treatment conditions (i.e., cognitive, metacognitive, or a combination of both strategies together) for 7 days, followed by 5 days of intervention treatment phase on the treatment missed during the first phase. A group design was employed, and results of this study was similar to the results from Montague (1992) in that students' increased their performance in each

treatment phase, but students showed the most improvement in the combination phase. Generalization in this study was not investigated, but it was noted that students needed booster sessions to help them maintain their skills over time.

Bottge (1999) conducted a study to determine if secondary students with learning disabilities could transfer skills gained from video-based problem solving to an authentic task. Using a pretest-posttest design 66 students were assigned to 2 treatment groups (i.e., remedial and prealgebra classes; contextualized instruction with the use of videodiscs) and 2 control groups (i.e., remedial and prealgebra classes; word problem instruction). Results indicated that students in the contextualized problems condition performed better on contextualized problem tasks and transfer tasks.

Jitendra, Hoff, and Beck (1999) conducted a study to examine the effects of schema-based strategy instruction on the mathematical problem solving skills of four secondary students with learning disabilities on one- and two-step addition and subtraction word problems. A multiple probe across participants and behaviors design was employed to determine whether the two instructional phases of schemata instruction (i.e., problem schema instruction using story situations, problem schema instruction using word problems with unknown quantities) increased student's scores on word problem tests, maintenance, near and far generalization measures, and strategy usage and questionnaire. Results indicated participants improved performance from baseline across all treatment phases. While generalization scores varied, students were able to maintain performance up to four weeks following intervention.

Manalo, Bunnell, and Stillman (2000) conducted two studies that examined the effectiveness of process mnemonics on the mathematics computation performance of

eighth-grade students with learning disabilities. Twenty-nine students with learning disabilities were assigned to process mnemonic instruction, demonstration-imitation instruction, or one of two control conditions (i.e., study skills or no instruction). In the process mnemonic instruction group students were given a mnemonic to assist them with recalling the process involved with adding, subtracting, multiplying, and dividing numbers with and without decimals. Instruction for the group of students assigned to the demonstration-imitation instruction group included the teacher modeling the process for students and then having students practice across similar problems. Students in the control group received no instruction. Results indicated significant improvements from pre- to posttest in both the process mnemonic and demonstration-imitation groups ($d = 2.88$ for both). It was also found that the group of students who received process mnemonic instruction maintained a higher mean performance six weeks following intervention than students who received demonstration-imitation instruction (87% vs. 61% respectively). In a second experiment 28 students were assigned to treatment conditions similar to the previous experiment except instruction was delivered by two instructors instead of the researcher and there was only one control group (i.e., no instruction). Similar to previous findings students in both treatment conditions outperformed students in the control group, and students in the process mnemonic group had higher maintenance measure scores than students in the demonstration-imitation group (82% vs. 56% respectively).

Naglieri and Johnson (2000) investigated the effects of cognitive planning strategy on the mathematics performance of students who were poor planners. Cognitive strategy intervention included three 10 minute phases (i.e., worksheet completion,

teacher-facilitated discussion of effective strategies, worksheet completion). Nineteen students with learning disabilities were assigned to either the experimental group or one of four comparison groups (i.e., students with weaknesses with attention, successive, simultaneous, or no weaknesses). Three students identified as having low planning scores from the Cognitive Assessment System (CAS) (Naglieri & Das, 1997) measure demonstrated the greatest change from baseline to intervention compared to students assigned to other groups. Effects of the intervention were not measured over time.

Building upon previous studies (i.e., Bottge, 1999; Bottge & Hasselbring, 1993), Bottge, Heinrichs, Chan, and Sterlin (2001) also investigated the effects of contextualized instruction with the use of videodiscs to solve word problems using a pretest-posttest design. Seventy-five students, including 16 with learning disabilities, were assigned to treatment or control groups. Results indicated all groups made gains from pretest to posttest on problem-solving measures regardless of which condition (i.e., treatment or control) they were assigned to. The only measure students in the treatment group performed better on was computations where students in the prealgebra classes outperformed students in the remedial math classes.

Joseph and Hunter (2001) investigated the effects of a cognitive assessment instrument to identify students' use of cognitive planning strategies. Using a multiple baseline across participants design, three students with learning disabilities were taught a cue card strategy for solving fraction problems. Results indicated that while all of the students improved from baseline conditions, only two of the students (i.e., average and above-average planner) were able to maintain high scores on maintenance probes. It was suggested by the authors that students with learning disabilities be taught specific

strategies for planning problem-solving tasks, as well as self-regulatory strategies for completing those tasks.

Jitendra, DiPipi, and Perron-Jones (2002) conducted a study to examine the effects of schema-based strategy instruction on the mathematical problem solving skills of four secondary students with learning disabilities on multiplication and division word problems. A multiple probe across participants design involving explicit instruction was used to teach students to (a) recognize and represent or map the different types of word problems onto diagrams and (b) map salient features of the word problems onto a diagram and then translate the information into an equation and solve for the unknown. Students reached improved from baseline meeting criterion by 12 sessions and maintaining their performance up to 10 weeks following intervention. Additionally, students were able to generalize their strategies to other word problems.

Bottge, Heinrichs, Mehta, and Watson (2002) conducted a study to determine the effectiveness of anchored instruction on problem solving skills of secondary students. Of the 42 participants, 6 were identified as have a specific learning disability, and all participants were assigned to treatment (i.e., enhanced anchored instruction) or control (i.e., traditional problem instruction) groups. Results indicated significant differences at posttest favoring contextualized instruction on the contextualized instruction test and transfer test only. Furthermore, additional analyses of the performance of students with disabilities indicated that only modest gains were made among those students.

Along those same lines, Bottge, Heinrichs, Chan, Mehta, and Watson (2003) conducted a study using a repeated measures design to examine the math performance of low-and average-achieving students across baseline, anchored instruction, and instruction

with applied problems. A total of 37 secondary students, including 4 identified as having a specific learning disabilities. Results of the study indicated that students performed better during the anchored instruction phase compared to baseline. Of the four students with learning disabilities three maintained low performance throughout all conditions of the study with them exhibiting specific difficulties performing computation and procedural tasks.

Cass, Cates, Smith, & Jackson (2003) conducted a study using geoboards to teach problem solving skills. A multiple baseline across participants and behaviors was used to evaluate the effects of teaching students to solve area and perimeter problems using geoboards and then paper and pencil without geoboards. Results indicated all students reached criterion level of 80% correct on problems solving activities for 3 consecutive days. Students were also able to maintain 90% accuracy on maintenance measures as well as generalization measures.

Next, Xin, Jitendra, and Deatline-Buchman (2005) investigated the effects of mathematical word problem solving instruction on 22 secondary students with mathematics difficulty. A pretest-posttest design was used to explore the effects of schema-based instruction and general strategy instruction on student's performance on compare and proportional multiplication and division word problems. Results indicated that students in both conditions made significant gains. However, students who received schema-based instruction preformed significantly higher than students in the general strategy instruction group on posttest, maintenance measures, follow-up tests, and generalization measure.

Finally, Jitendra et al. (2009) conducted a study to evaluate the effectiveness of schema-based instruction (SBI) on student's acquisition of ratio and proportion word problem solving ability. Researchers used a pretest-intervention-posttest-retention design in which six teachers and 148 students participated with 10% of the students receiving special education services. Results indicated that SBI had statistically significant effects on increasing student's ability to correctly solve word problems involving ratios and proportions. Another important finding was that the use of SBI also improved the problem solving skills of the students over an extended period of time (i.e., four months after the study). This study shows promise that secondary students with diverse needs can benefit from SBI instruction that emphasizes the mathematical structure of word problems.

Summary

While progress has been made in improving problem solving skills for youth with disabilities, there are still deficits between general population peers and students with disabilities in mathematic performance. Research has shown that students who have sufficient problem solving skills have improved mathematical performance (e.g., Cass, et al., 2003; Jitendra, et al., 2002; Xin, et al., 2005). The new Common Core State Standards ask that students "understand solving equations as a process of reasoning" and say explicitly what needs to be taught about this process. With more attention focused on mathematical reasoning and the application of mathematical skills to word problems, it is important to teach students strategies that address their cognitive processing and memory deficits. One possible solution would be to teach students mathematical mnemonic strategies to address these memory deficits.

Mnemonic Strategy Instruction

Scruggs, Mastropieri, Berkeley, and Graetz (2010) conducted a meta-analysis that examined the effects of special education interventions on learning for secondary students with disabilities. A total of 70 experimental or quasi-experimental studies published from 1984 to 2006 with more than 2,400 students were included in the analysis. As demonstrated previously by Scruggs and Mastropieri (2000) mnemonic instruction produced very high mean effects for students with disabilities ($M = 1.47$).

A mnemonic strategy has been defined as “a specific reconstruction of target content intended to tie new information more closely to the learner’s existing knowledge base and, therefore, facilitate retrieval” (Scruggs & Mastropieri, 1990, pp. 271-272). Simply put, mnemonics strategies are enhancements used to aid in improving memory. Research by Mastropieri and Scruggs (1998) suggests that the way we learn new information when we first study facilitates memory better as oppose to using memory techniques to retrieve the information.

Numerous research studies have investigated the effects of training students with disabilities with memory problems to use mnemonic strategies independently (e.g., Cassel & Reid, 1996; Condos, Marshall, & Miller, 1986; Fulk, Mastropieri, & Scruggs, 1992; King-Sears, Maccini & Hughes, 2000; Maccini & Ruhl, 2000; Mastropieri, Scruggs, Mercer, & Sindelar, 1992; Levin, Gaffney, & McLoone, 1985; McLoone, Scruggs, Mastropieri, & Zucker, 1986; Scruggs & Mastropieri, 1992). Studies from the 1980’s (e.g., Mastropieri et al., 1985; McLoone et al., 1986) successfully trained students with disabilities to use the mnemonic strategies to improve their memory, and to generalize the procedures for learning new vocabulary words to other areas where they

had to learn and memorize vocabulary words. More recent studies trained students with disabilities to use the strategies across different content areas, including science and social studies (Fulk et al., 1992; King-Sears et al., 1992; Scruggs & Mastropieri, 1992). In their review of research on mnemonic instruction, Scruggs, Mastropieri, Berkely, and Marshak (2010) referred to mnemonic strategies as an evidence-based practice and practice-based evidence. Despite the title of the article, it is not evident that the researchers applied the all of the standards or quality indicators set forth by Horner et al. (2005) needed to contribute support for as evidence-based practice. Also, the content areas that the researchers examined for the use of mnemonic strategies were limited to elementary: life science, social students, reading, and vocabulary; and secondary: social studies, anatomy, and SAT vocabulary. All of the studies included demonstrated some positive benefits for training students to use mnemonic strategies independently; however there is no support of mnemonic strategy use in elementary or secondary mathematics.

Types of Mnemonic Strategies

There are three types of mnemonic strategies that appear most consistently in the literature: (a) the keyword strategy, (b) the pegword strategy, and (c) the letter strategy. First, the keyword strategy is based on linking new information to keywords that students have already encoded to memory. The keyword method is used by taking the new word needed to be learned and creating a keyword that is concrete (i.e., easy to picture), already familiar to the learner, and acoustically similar to the new vocabulary word (DLD & DR, 2001). The keyword is then linked to the definition of the new vocabulary word in an interactive picture which shows the keyword and the definition “doing something together.” For example, when teaching this strategy one might teach the new vocabulary

word by first identifying a keyword that sounds similar to the word being taught and easily represented by a picture or drawing. Next, a picture is created that connects the word to be learned with its definition. According to Scruggs and Mastropieri (1994), the keyword strategy is most effective when the information to be learned is new to students.

Second, the pegword strategy is used when numbered or ordered information needs to be remembered. Pegwords are short words that sound like numbers and are easy to picture. Each number (e.g., 1-10) is assigned a short word(s); based on these words pictures are created so that students are able to remember important ordered information (see Mastropieri & Scruggs, 1991 for examples). Research has shown that this strategy and strategies similar to it are very effective, and that when color is added and appropriately used, memorization is easier (Scruggs, Mastropieri, Levin, & Gaffney, 1985). The pegword strategy supports recall of numerically-ordered information by pairing easily pictured and acoustically similar substitutes for numbers and concepts. This makes the order of concepts easier to remember.

Finally, the letter strategy, which involves using letter prompts to remember lists of things, is the most familiar to both students and teachers. Of all the mnemonic strategies, the letter strategy has been researched the most (e.g., Maccini & Hughes, 2000; Scruggs & Mastropieri, 1992; Test & Ellis, 2005). As an example, in elementary grades students remember the acronym HOMES to recall the names of the Great Lakes (i.e., Huron, Ontario, Michigan, Erie, and Superior). Not all first letters of terms create words. To memorize the names of the planets in their order from the sun (if Pluto were still included), the letters would be M-V-E-M-J-S-U-N-P. There is not a word from which these letters can be created. Consequently, an acrostic can be created, in which the

first letters are reconstructed to represent the words in a sentence. The sentence for remembering the planets that has been widely used was "My very educated mother just sent us nine pizzas" (Mastropieri & Scruggs, 1994, p. 271). Additionally, PEMDAS in mathematics is used to represent the order of operations (i.e., parenthesis, exponents, multiplication and division, and addition and subtraction). The acrostic widely associated with this is mnemonic was created based on these letters, "Please Excuse My Dear Aunt Sally." As with any strategy, providing structured instruction on strategy use and providing students with ample opportunities to practice is important.

Mnemonic Strategies and Students with Learning Disabilities

Mnemonic instruction has been well researched and validated for students with high incidence disabilities, particularly students with learning disabilities (e.g., Maccini & Hughes, 2000; Manalo, Bunnell, & Stillman, 2000; Pressley, Levin, & Delaney, 1982; Veit, Scruggs, & Mastropieri, 1986). Reviews of interventions for students with learning disabilities by Swanson (1999) and Forness, Kavale, Blum, and Lloyd (1997) indicated that the use of strategy instruction using mnemonic strategies have helped students with disabilities significantly improve their academic achievement. Specifically, Swanson (1999) found that strategy instruction using mnemonics produced larger effect sizes than strategies that did not use such procedures. It was also found that even though students without disabilities academically outperformed students with disabilities on different tasks, when strategy instruction was used the effect sizes were significantly smaller.

Mnemonics in content area classes. According to Scruggs et al. (2010) from the early 1980s to the present, researchers have conducted more than 40 experiments, including more than 2,000 participants with high incidence disabilities. Based on this,

mnemonic strategies have been found to be very effective for students with mild disabilities at the elementary and secondary levels, for a wide range of content areas.

English. Mastropieri, Scruggs, Levin, Gaffney, and McLoone, (1985) conducted a study to determine the effects of a pictorial mnemonic strategy and principles of direct instruction on adolescents with learning disabilities ability to learn the definitions of 14 vocabulary words. Using stratified random assignment 16 students were assigned to the mnemonic picture condition, and the other 16 students were assigned to the direct instruction condition. Results from experiment 1 indicated that the mean recall of mnemonic-picture subjects (79.5%) was statistically higher than that of direct-instruction subjects (31.2%), $t(30) = 7.12, p < .001$. In the second experiment 30 students were randomly assigned to similar treatment groups as in the first experiment (i.e., mnemonic imagery, direct instruction). Aligned with the findings from the first experiment, students in the mnemonic group (mean recall of words, 69.3%) statistically outperformed student in the direct instruction group ($M = 46.7\%$, $t(28) = 2.96, p < .01$).

Foreign language vocabulary. McLoone et al., (1986) examined the effects of two types of memory strategy instruction--mnemonic or directed rehearsal--on the vocabulary acquisition of 60 seventh and eighth grade students with learning disabilities. Results indicated that students who received instruction in the mnemonic method significantly outperformed subjects instructed in the direct rehearsal strategy.

History. Mastropieri and Scruggs (1988) evaluated the effects of teacher-implemented mnemonic instruction of content-area information (US history) using different mnemonic techniques. Twenty-seven students with learning disabilities in grades 7-8 from low socioeconomic backgrounds were assigned to either a mnemonic

instruction or a traditional instruction groups. Student in the mnemonic instruction group outperformed students in the traditional instruction group. These results were true for both immediate testing and eight weeks after intervention. Additionally, students and their teachers positively assessed the mnemonic instruction materials and the degree to which they were perceived as facilitating content learning and recall.

Science. Mastropieri, Scruggs, and Levin (1985) conducted two experiments in which students were taught hardness levels of minerals according to (a) keyword-pegword mnemonic, (b) a questioning procedure, or (c) free study. In the first experiment 90- ninth grade students with learning disabilities were divided into two groups (i.e., high- or low- reading achievers). Within each achievement level, 15 students were assigned randomly to each of the three experimental conditions. Results indicated that regardless of the student's achievement level the students who received instruction in the mnemonic condition out recalled all of groups. Likewise, in experiment 2, 45 seventh grade students without disabilities were assigned to the same treatment groups as experiment 1. Results of this study indicated that students in the mnemonic group continued to outperform students in the other groups.

Additionally, King-Sears, Mercer, and Sindelar (1992) conducted a study that examined the use of mnemonics to learn and remember information. Keyword mnemonics were used in two of three instructional procedures taught to 30 students with learning disabilities and 7 students with emotional or behavioral disorders in the sixth, seventh, and eighth grades, and included 34 males and 3 females. Students were assigned to one of three treatment groups (a) systematic teaching, (b) systematic teaching with an imposed (teacher-provided) keyword mnemonic, and (c) systematic teaching with an

induced (student-provided) keyword mnemonic. Students were required to learn and remember definitions of unfamiliar science terms. Results of these investigations indicated that when students were taught new vocabulary definitions using an imposed keyword mnemonic, the students remember more definitions.

Although not listed in the Scruggs et al. (2010) review, there are studies that have been conducted in mathematics as well (e.g., Maccini & Hughes, 2000; Maccini & Ruhl, 2000; Manalo, Bunnell, & Stillman, 2000; Test & Ellis, 2005) that have been effective with students with learning disabilities. It is important to examine all content areas when Mnemonic Strategies in Mathematics

A total of seven first-letter mnemonic strategies have been identified to teach mathematical problem solving skills to students with learning disabilities (i.e., FAST DRAW, RIDE, RIDGES, SIGNS, SQRQCQ, SOLVE, STAR). Of the seven strategies identified, four empirical studies (i.e., FAST DRAW: Cassel & Reid, 1996; SIGNS: Watanabe, 1991; STAR: Maccini & Ruhl, 2000; Maccini & Hughes, 2000) have been conducted that examined the effectiveness of the mnemonic strategy. More specifically, studies by Maccini and Ruhl (2000), Maccini and Hughes (2000), and Watanabe (1991) were the only studies that taught secondary students to use mnemonic strategies to solve word problems.

Intervention studies. Watanabe (1991) developed the word problem solving strategy SIGNS that requires students to visually represent the word problem. SIGNS stands for (a) survey question, (b) identify key words and labels, (c) graphically draw problem, (d) note type of operation(s) needed, and (e) solve and check problem. This study was conducted with middle school students who had mild disabilities using a single

subject design. During the first step students were taught to read the problem and underline numerals and/or number words (i.e., RUN). Next, students looked for key word that gave them hints about the operation to be performed (e.g., altogether) and labeled words that described the objects being dealt with in the problem. Thirdly, students drew a picture to represent what the problem was asking. Fourthly, students were taught to think about the operation and/or equation that best described the drawing and to write it down. During the final step students answered the problem they created in step four and used a calculator to check their work. This strategy was developed and reportedly implemented successfully, but the results of the study were never published bringing into question the efficacy of the strategy for increasing the problem solving skills of secondary students with learning disabilities.

The STAR strategy was first developed by Maccini (1998). Since that time two empirical studies have examined the effects of the STAR strategy on the problem solving skills of students with learning disabilities. First, Maccini and Ruhl (2000) conducted a pilot study to determine the effects of the STAR strategy on problem solving skills of students with learning disabilities. A multiple probe across participants design was employed to examine the effects of the strategy on the solution of algebra problem involving subtraction of integers. Three male students with learning disabilities received instruction within a graduated teaching sequence (CSA) and applied the STAR strategy to effectively solve the problem. In the first stage of the STAR strategy students search the word problem by (a) reading the problem carefully, (b) asking the questions: “What do I know? What do I need to find? and (c) writing down the facts. Second, students translate the problem into an equation in picture form by (a) choosing a variable, (b) identifying

the operation(s), and (c) representing the problem using CSA. Third, students answer the problem. Last, students review the solution by (a) rereading the problem, (b) asking the question, “Does the answer make sense? Why?”, and (c) checking their answer. Results of this study indicated that students improved their ability to represent and solve word problems involving subtraction of integers, and students maintained treatment effects over varying time intervals. Several limitations of this study were identified. First, the study was conducted at the end of the school year causing a threat to the internal validity of the study. Next, there were no cue cards or worksheets to help the students memorize the steps of the STAR strategy. Finally, student’s performance on generalization measures were low suggesting that it may be necessary to use more complex problems and vary the story lines of the word problems to better match problems student may face in a variety of contexts.

Additionally, Maccini and Hughes (2000) investigated the effects of the STAR strategy within a graduated teaching sequence (i.e., concrete, semi-concrete, abstract) on the representation and solution of problem-solving skills of six secondary students with learning disabilities using a multiple probe across participants design. Participants were enrolled in a resource modified introductory algebra course, and assessment scores indicated that students were performing two years below grade level. Results indicated that all participants increased problem-solving skills following instruction in CRA and implementation of the STAR strategy. Although students demonstrated improvement in problem solving skills some students did not remember all of the steps of the STAR strategy, making it necessary to set mastery criteria.

Theoretical studies. Fay (1965) developed the problem solving process, SQRQCQ, which stands for the following terms and respective actions (a) *Survey*. Read the problem quickly to get a general understanding of it; (b) *Question*. Ask what information the problem requires; (c) *Read*. Reread the problem to identify relevant information, facts, and details needed to solve it; (d) *Question*. Ask what operations must be performed, and in what order, to solve the problem; (e) *Compute/Construct*. Do the computations, or construct the solution; (f) *Question*. Ask whether the solution process seems correct and the answer reasonable

Snyder (1988) developed the mathematical mnemonic problem solving strategy RIDGES in an effort to provide upper elementary and high school students a structure to follow when they are solving word problems. The mnemonic RIDGES stands for read the problem, I know statement, draw a picture, goal statement, equation development, and solve the equation. In the first step the students read the problem for understanding which may include rereading the problem. The second step requires the students to create an “I know statement.” Students list the given information in the problem regardless of the relevance. In the third step students are instructed to draw a picture, in which Snyder suggests is the most important step, where the students determine relevant information. Fourth, students create a goal statement that is expressed in their own words that focuses on the question the problem is asking. Fifth, students create an appropriate equation to solve the problem using words or formulas. Last, students solve the equation. The information given in the problem is plugged into the equation created in the fifth step. As students become familiar with the steps they are encouraged to make modifications as

need to meet their needs. There were no data presented that demonstrated the effectiveness of this strategy.

One instructional manual and one study investigated the use of the mnemonic FAST DRAW to increase student's mathematical problem solving skills. The FAST DRAW strategy was first introduced by Mercer and Miller (1992) in the Strategic Math Series. The FAST DRAW strategy builds upon an earlier mnemonic computation strategy DRAW. DRAW stands for (a) discover the sign, (b) read the problem, (c) answer, or draw and check, and (d) write the answer. Once students have learned this strategy they are taught the FAST DRAW strategy which serves as a way for students to analyze and solve multiplication word problems. The FAST DRAW strategy consists of students (a) finding what they are solving for, (b) asking "what are the parts of the problem, (c) setting up the numbers, and (d) tying down the sign. After these steps are complete students then use the DRAW strategy to continue solving the problem.

Cassel and Reid (1996) conducted a study to determine the effects of self-regulated strategy instruction on word problem solving skill improvement of students with mild disabilities. A multiple probe across participants designed was employed to investigate the effects of the strategy and instructional procedures on four elementary students with disabilities (i.e., 2 with learning disabilities and 2 with mild intellectual disabilities) performance in solving simple addition and subtraction word problems. The mnemonic strategy FAST DRAW was used to assist students in remembering the strategy steps. After reading the problem aloud the students were to (a) find and highlight the question, then write the label; (b) ask what are the parts of the problem then circle the numbers needed; (c) set up the problem by writing and labeling the numbers; (d)

re-read the problem and tie down the sign (decide if you use addition or subtraction); (e) discover the sign (recheck the operation); (f) read the number problem; (g) answer the number problem and; (h) write the answer and check by asking if the answer makes sense. Strategy usage was determined by whether students highlighted the question, circled the numbers, placed the larger number at the top of the problem, and wrote a label. The percentage of strategy usage steps was defined as the number of times in a phase that the strategy step was used divided by the total number of problems in the phase. Results indicated that all students were able to successfully master the strategy and improve their performance to at or above 80% which was the criterion set for mastery. Although results indicated the FAST DRAW strategy was effective in increasing problem solving skills, the strategy was used in combination with self-monitoring, self-instruction, direct instruction, and meta-cognitive skill modeling, thus making it impossible to isolate the effects of the strategy.

Mercer and Mercer (1993) mention the RIDE strategy as a mnemonic strategy that identifies the steps needed to solve story problems successfully. The steps include (a) read the problem, (b) identify the relevant information, (c) determine the operations and unit for expressing the answer, and (d) enter the correct numbers and calculate and check the answer. Although this strategy appears to follow similar sequence steps of other problem solving strategies, there is no published evidence to verify its effectiveness.

There are two versions of the SOLVE strategy, one for upper elementary students and one for students in middle grades. First, the SOLVE: Action Problem Solving was developed by Enright (1987a,b,c) as a part of the Enright Math System published by Curriculum Associates. There were a total of three skill books that covered problem

solving for whole numbers, fractions, and decimals and percents. The mnemonic SOLVE was used to teach the five steps of problem solving. The first letter mnemonic SOLVE stood for (a) study the problem, (b) organize the facts, (c) line up a plan, (d) verify your plan with computation, and (e) examine your answer. Next, Mercer (1992) designed the SOLVE strategy to cue upper elementary students to answer multiplication facts from 0 to 81. SOLVE stands for (a) See the sign; (b) Observe and answer (if unable to answer, keep going; (c) Look and draw; (d) Verify your answer; and (e) Enter your answer. In the first step of the SOLVE strategy students see the sign and decide which mathematical operation to use (i.e., add, subtract, multiply, divide). Next, they observe the numbers and answer the problem. At this point if they are unable to answer the problem they continue on to the next step. During the look and draw step students use graphic representation of the problem through the use of tally marks. Next, students verify their answers by recounting the graphic representations in the previous step (i.e., check the first number and representations, check the second number and representations, and check the answer and representations) to ensure accuracy. The last step of the strategy requires the students to record their answer in the appropriate space. Although the steps of this strategy worked well with upper elementary students, younger students had difficulty understanding some of the components of this strategy such as the words solve and verify. Therefore, the previously mentioned mnemonic DRAW was created for younger students.

The original version of the SOLVE as seen in the three part series developed by Enright (1987a, b, c) is no longer in print, but the strategy is still being used as a part of the Algebraic Thinking Program (Enright, Mannhardt, & Baker, 2004). The Algebraic Thinking program is a product of the National Training Network and has been

implemented in 13 school districts across the United States. The SOLVE strategy is credited with being the “corner stone” of the Algebraic Thinking program. The steps of the SOLVE strategy remained the same as the previously mentioned strategy with the exception of the “v” step which currently stands for verify your plan with action instead of computation. When looking at each of the steps individually during the first step, *study the problem*, students highlight or underline the question and then proceed by asking themselves, “What is the problem asking me to find?” Students then write the question in their own words. During the next step, *organize the facts*, students identify each fact in the word problem; eliminate unnecessary facts by putting a line through it; and then list all necessary facts. The next step, *line up a plan*, involves the students choosing an operation (i.e., add, subtract, multiply, divide), and telling in words how they are going to solve the problem without using words. Next, students *verify their plans with action* by estimating their answer then carrying out their plan by solving the problem. Lastly, students *examine their results* by asking themselves if their answer makes sense (i.e., check what the problem was asking them to find); is their answer reasonable (i.e., check their estimate), and is their answer accurate (i.e., check their work). During this last step students write their answer to the problem in a complete sentence. Although, there is data on the National Training Network website that indicate that the Algebraic Thinking program is successful, there are no empirical studies to validate the effectiveness of the SOLVE strategy on increasing mathematical problem solving skills of students with learning disabilities at the secondary level.

Summary of Research Foundation for the Current Study

Evident through research, students with learning disabilities at the secondary level exhibit memory deficits (Bryant, Bryant, & Hammill, 2000; Bryant, Hartman, & Kim, 2003; Ginsburg, 1997; Cooney & Swanson, 1987) which may contribute to their academic failure, hence leading to low graduation rates (Witzel et al., 2001). Learning strategy instruction and explicit instruction have both been identified as ways to help students succeed in content area classes (Gersten et al., 2008; NMAP, 2008; Schumaker & Deshler, 1992). Swanson (1999) suggested that the most effective form of teaching students with learning disabilities is to combine components of direct instruction (e.g., teacher-directed lecture, discussion, and learning from books) with components of strategy instruction. Additionally, the Center on Instruction recommends teaching students to solve problems using multiple/heuristic strategies. Additionally, Maccini, McNaughton, and Ruhl (1999) recommended step-by-step prompts for problem solving in algebra. Research across varying content areas has demonstrated that mnemonic strategy instruction can be an effective strategy for students with learning disabilities (e.g., Manalo, Bunnell, & Stillman, 2000; Pressley, Levin, & Delaney, 1982). While mnemonics have been heavily researched in other areas little research has been conducted in mathematics to see if mnemonics may be effective in this area as well.

Although there is a strong implication that mnemonics are beneficial in math instruction, there is limited research that suggests that explicit instruction in mnemonic strategies is effective in mathematics for students with learning disabilities at the secondary level. Specifically, one problem solving mnemonic strategy (i.e., STAR) has empirical data to support its effectiveness at increasing the mathematical problem solving

skills of students with learning disabilities at the secondary level. While there are other mnemonic strategies (e.g., FAST DRAW, SOLVE) being used by secondary teachers across the country, these strategies lack published empirical research to support to support their effectiveness for students with learning disabilities.

More specifically, the Algebraic Thinking program is being implemented across the United States by districts and individual schools with the SOLVE strategy as one of its major components, yet there have been no empirical studies conducted to validate the effectiveness of the SOLVE strategy. Considering the positive outcomes of mnemonic strategies in other content areas and by addressing some of the concerns raised in using mnemonic strategies with students with learning disabilities, additional research in the use of mnemonic strategies with mathematical problem solving is warranted.

Therefore, the purpose of this study was to examine the effectiveness of explicit instruction in the SOLVE Strategy on the mathematical problem solving skills of secondary students who have been identified as having a specific learning disability. Specifically, learning strategy and explicit instruction was combined and the SOLVE strategy was taught using the eight stages of instruction established as the explicit-intensive model of instruction by the KU CRL (Schumaker, & Deshler, 1992). The following research questions were addressed: (a) what are the effects of the SOLVE Strategy on the mathematical problem solving skills of secondary students with learning disabilities?, (b) does training in the SOLVE Strategy increase students accuracy in solving word problems, (c) does training in the SOLVE Strategy increase standardized mathematical reasoning scores?, and (d) is it feasible, based on classroom time constraints, for teachers to embed the SOLVE Strategy within their instruction?

CHAPTER 3: METHOD

Participants

Six students were recruited to participate in this investigation. The participants for this study were eighth-grade students ranging in age from 12 to 16 years old enrolled in the participating school. Students who participated in the study met the following inclusion criteria: (a) identified as having a specific learning disability based on psychoeducational evaluations from an outside agency; (b) computed one-step mathematical equations (i.e., score of at least 70%; equations involving whole numbers and decimals), but not in word problem format (i.e., score of less than 60%) as measured by pretest; (c) obtained a score on a standardized math test, the Woodcock-Johnson® III (WJ III; Woodcock, McGrew, & Mather, 2001) that is at least two grade levels below their current grade level; (d) had consistent attendance (i.e., absent less than two times per month); and (e) recommended by their teacher to participate.

Relevant characteristics of the participants are presented in Table 1. Ages of the students, gender, and intelligence quotient (IQ) scores are reported.

Table 1: Student characteristics

Student	Grade	Age	Gender	Race	IQ	Disability
Taylor	8	13	M	W	106	SLD
Chris	8	13	M	W	96	SLD
Herman	8	14	M	W	102	SLD
Zee	8	14	M	Af/A	99	SLD
Alvin	8	14	M	W	92	SLD
Hugh	8	13	M	W	105	SLD

The researcher obtained all informed consent (i.e., teachers and parents) and student assents using the format approved by the Institutional Review Board (IRB) at the University of North Carolina at Charlotte. The informed consent and student assent forms were signed and returned before participants began to participate in the investigation.

Setting

The study took place in the southeastern part of the United States in a private high school exclusively for students with a specific learning disability or attention deficit hyperactivity disorder. Demographic data for the overall school population included 74% White, 13% African American, and 13% Multiracial students. The school had a total enrollment of approximately 120 students in Kindergarten through Grade 12.

The upper school (i.e., Grades 8-12) offers a college preparatory curriculum with an eight period day. Students also have a preestablished supervised study hall each day to provide tutorial support and support for study habits. This study was conducted during the supervised study hall in a private classroom.

Independent Variable

The independent variable was explicit instruction of the SOLVE Strategy using the eight stages of instruction (Schumaker & Deshler, 1992). The SOLVE Strategy is a

mathematical problem solving strategy designed to assist students with solving mathematical word problems. This strategy was developed by Brian Enright in 1987, and is currently a part of the entire National Training Network mathematics curriculum. SOLVE is a mnemonic that directs the students through a series of steps for effective problem solving.

The SOLVE Strategy consisted of five steps. During the first step, “Study the problem,” students (a) highlighted, (b) circled, or (c) underlined the question in the word problem. The students then ask themselves, “What is the problem asking me to find?” The students wrote the answer to this question in their own words. During step 2, “Organize the facts,” students (a) identified each fact in the word problem by “striking” the facts, (b) eliminated unnecessary facts by putting a line through it, and (c) listed all necessary facts. The next step, “Line up a plan,” involved the students choosing an operation or operations (i.e., add, subtract, multiply, divide), and telling in words how they were going to solve the problem without using numbers. During step 4, “Verify your plan with action,” students estimated their answer to the word problem and then carried out the plan they created in the “L” step by computing the equation that they created. The final step, “Examine your results,” called for students to make a logical decision about the appropriateness and accurateness of their final answer. Students asked themselves (a) does my answer makes sense (check what the problem was asking them to find); (b) is my answer reasonable (check their estimate), and (c) is my answer accurate (check their work). The last thing that the students did was write their answer to the problem in a complete sentence (See Appendix F for sample completed problems using the SOLVE Strategy).

Dependent Variables

The primary dependent variables were strategy use and scores on researcher-devised problem solving test probes. The third and fourth dependent variables were pre- and posttest measures on a test of strategy knowledge and scores on a standardized mathematical assessment (WJ III).

Strategy use test. To obtain repeated measures of students' use of the SOLVE Strategy, a pool of 50 eighth grade mathematical word problems was created by the researcher and randomly selected and sequenced for each student. A mathematics expert validated the word problems to ensure they were grade level appropriate validated the word problems used in this study. This level of word problems (i.e., Grade 8) was chosen to provide information on performance at the students' current grade level because this was the level at which they are expected to perform in general education classes. The students were allowed to use calculators during all phases of the study. For each test probe, the students were asked to read five word problems and use the SOLVE Strategy to answer the problem. Students were able to have the questions read aloud to them upon request. To measure use of the strategy, students were awarded one point for each step and sub-step of the strategy. A total of 10 points was available per word problem for the strategy use score of 50 points per test probe (See Appendix A for scoring sheet).

Mathematical computation test. Each probe test contained five word problems in which the students were asked to solve the mathematical word problem. One point was awarded for correctly setting up the equation, and one point was awarded for each correct response for a total of 10 points per test probe (See Appendix B for scoring sheet).

Strategy knowledge test. The strategy knowledge test was used to measure the students' knowledge of the steps of the SOLVE Strategy as a pre- and posttest measure. It included five short-answer questions that required students to list and explain the strategy steps and all of the components of each step. An answer key was used to specify the boundaries for correct responses.

Standardized math test. To measure mathematical reasoning the WJ III (Woodcock et al., 2001) was administered to students prior to and after intervention. The Applied Problems subtest was administered. Forms A and B of the WJ III was used for pre- and posttesting respectively.

The Applied Problems test requires analysis of math problems before solving them. To solve the problems, the individual must listen to the problem, determine the procedure to be followed, and then perform relatively simple calculations. Because many of the problems include extraneous information, deciding on the appropriate mathematical operations and determining which numbers to include in the calculation is required.

Data Analysis Procedures

Experimental design. A multiple-probe-across participants design (Cooper, Heron, & Heward, 2007; Horner & Baer, 1978) was used to determine the effects of the SOLVE Strategy on the problem solving skills of students with learning disabilities. This experimental design was used to show that changes in the level or trend of students' performance occurred when and only when the intervention was in place. Baseline began at the same time for each group of students. Each group of students began intervention in a staggered fashion so that changes were made for one group of students at a time while

the other groups of students remain in the baseline condition. Once the group of students in the intervention phase showed stability in their performance, the next group of students was introduced to the intervention. Initial baseline included a minimum of five data points for all students and was collected simultaneously across students to establish percentage of strategy usage and correct response for each test probe question. The intervention condition included teaching using the eight stages of instruction followed by a maintenance and generalization phase.

There were three groups of students (i.e., two students in each group) who began intervention in a staggered fashion so that changes were made for one group of students at a time while other students remain in the baseline condition. The group of students with the lowest baseline data began intervention first. Once students in the first group reach mastery (i.e., 80% on strategy use; 70% correct response) and/or demonstrate an increasing trend after controlled practice, students in the second group began instruction. Data continued to be collected on the remaining group of students in the baseline condition. The same procedure was used to introduce the intervention to the final group of students. Students moved to maintenance phase once a minimum of five data points at grade level have been collected and scored at or above mastery level during intervention.

Data analysis. Data in this study were analyzed by using visual analysis (Tawney & Gast, 1984). Data points were displayed graphically and then judged relative to (a) stability of baseline conditions, (b) changes in instructional variables between conditions, and (c) changes in mean student performance between conditions. All of those factors were combined to determine if a functional relationship exists between the independent variable and the dependent variables.

Additionally, a pretest-posttest analysis was employed to compare the standardized mathematical reasoning scores earned on the WJ III before and after instruction. Specifically, the researcher was looking at age and grade equivalency, means, and standard deviations.

Data Collection and Procedures

Instructor. The primary instructor for this study was a full-time doctoral candidate in Special Education at UNC Charlotte who has five years of experience teaching secondary students with high-incidence disabilities in a large urban public school district. She holds a North Carolina Teaching License and Master's Degree in Special Education: General Curriculum.

Data collector. A first year doctoral student in the Special Education at UNC Charlotte assisted the primary researcher with fidelity and reliability data collection. She has eight years of teaching experience with students with learning disabilities. She currently holds a masters degree in special education and North Carolina Teaching Licensure in the areas of emotional and behavior disorders and K-12 general curriculum.

Baseline. During baseline, no instruction was provided to students. They were given the cue card with the meaning of the SOLVE Strategy (i.e., Study the problem, Organize the facts, Line up a Plan, Examine your results) and helpful hints for solving word problems. Students had approximately 30 minutes to complete the test probe, and the percentage of strategy use and correct response were recorded.

SOLVE Instruction. The students received instruction in the SOLVE Strategy in sessions ranging in length from 30 to 45 minutes, depending on the content being taught during that lesson over the course of approximately two weeks. More specifically, the

researcher adapted the SOLVE Strategy, which is a mnemonic metacognitive strategy, and taught it using the “eight stages of instruction” (Schumaker & Deshler, 1992). The eight stages of instruction are based on research-validated explicit instructional tactics shown to be highly effective for teaching learning strategies to students with learning disabilities (Schumaker & Deshler, 2006; Swanson 1996).

During the initial instructional session, Stage 1: Pretest, the students completed a pretest to assist them with understanding why they are ineffective at solving word problems. The students were asked to make a commitment to actively learn and use the SOLVE Strategy (See Appendix E for learning contract). Each step of the SOLVE Strategy was explained to the students.

During the next three instructional sessions Stages 2 and 3 (Describe and Model respectively) were introduced. During the Describe Stage the instructor explained the specific step of the SOLVE Strategy and explained to students the benefits of using the strategy. Stage 3: Model, allows the instructor to model for students how to implement each of the steps. The instructor did this by “thinking aloud” to demonstrate for students how to perform the sequence of steps. Students completed practice problems with the instructor at the conclusion of each lesson. Each lesson contained six elements: (a) advance organizer, (b) describe, (c) model, (d) guided practice, (e) independent practice, and (f) feedback.

During Lesson 2, the instructor described and modeled in detail the “S” and “O” steps of the SOLVE Strategy and sub steps for each. In Lesson 3 students were taught the “L” step and its sub-steps. This was the only step of the SOLVE Strategy that was taught

on this day. The next day of instruction, Lesson 4, students were taught steps “V” and “E” of the SOLVE Strategy along with their sub-steps.

Stages 4 and 5 (Verbal Practice and Controlled Practice and Feedback respectively) began immediately following Lesson 4. During verbal practice students practiced explaining and naming each step and sub-step of the SOLVE Strategy. After successfully being able to explain and list the steps and sub-steps of the SOLVE Strategy, students moved to Stage 5. Additional practice mathematical word problems were provided in which students were required to use all the steps of the strategy. If the students earn a score at or above mastery level (i.e., 70% on the mathematical computation test, 80% on the Strategy Use Test) on the practice probes, they moved up to the next math grade level (e.g., sixth- to seventh-grade) (See Appendix F for a sample completed probe). In subsequent sessions, Stage 6: Advanced Practice and Feedback, students continued to practice and receive individual feedback on their performance until they reach mastery on at least five eighth grade mathematical word problem test probes (See Appendix G for progress charts). Students completed the test probes after instruction the same day. Additionally, they were allowed to use their cue card with the step of the SOLVE Strategy and helpful hints for solving word problems as they did during baseline conditions.

Instructional materials. The instructional lessons on the SOLVE Strategy used was adapted from the Algebraic Thinking Curriculum by the National Training Network (Enright, Mannhardt, Baker, 2004) and organized in a notebook to ensure that instruction is standardized across the three groups of students. It consisted of scripted step-by-step

instructions for each lesson as well as visual aids to be used during instruction (See Appendix H for a sample scripted lesson).

Posttest procedures (Stage 7). After completion of instruction and mastery of two eighth grade mathematical word problem test probes, students were administered Form B of the WJ III. They were also administered the student social validity survey and strategy knowledge test in a group setting. The students completed each instrument independently, and there was no time limit for test completion.

Maintenance and generalization procedures (Stage 8). Two generalization tests were administered to the students on solving inequalities from their math class (i.e., one during baseline and one after intervention). At least 2 maintenance tests were administered to students after intervention (i.e., 2 weeks and 6 weeks).

Instruments and Measures

Procedural fidelity checklists. To assess fidelity with instructional procedures a checklist was used to measure researcher adherence to the instructional sequence for the lessons. It contained several instructor behaviors: provide an advance organizer, discuss the purpose of the lesson and provide rationales for the lesson, state expectations for student behavior, describe a step of the strategy or how to use the strategy, model the strategy, provide practice opportunities with feedback, and provide a post organizer. The actual number of instructor behaviors varied from lesson to lesson depending on the checklist and what is being taught. The delivery of each instructional lesson was recorded using an audio recorder; no student data were collected from these recordings. A trained doctoral student completed the fidelity checklist by listening to at least 30% of recorded instructional lessons. The scripted lesson plans were used as the checklist. If the scorer

hears the instructor produce one of the teacher behaviors listed on the checklist, one point was awarded for that behavior. Zero points were awarded for behaviors not demonstrated. Dividing the number of instructor-behaviors observed by the total number of behaviors planned and multiplying by 100 calculated a percentage score.

Social validity data. Social validity data were collected to measure social acceptability of procedures and outcomes. Students were given a questionnaire consisting of 10 questions using a Likert scale format to assess student satisfaction with the SOLVE Strategy. Additionally, the math teachers received a short questionnaire examining their perceptions of the relevance, impact, and feasibility of teaching this strategy to students in a traditional high school math course. Items emphasize perceptions of effectiveness, and the potential for future use.

Time required for instruction. Instructional time was recorded on log sheets with dates, start and stop times (including hours and minutes). Instructional time began when the instructor starts (or restarted) instruction with the students. It ended when the students began practicing the strategy independently. Student time began when the teacher started (or restarted) independent practice. If an interruption occurred, or when the students stopped practicing and turned in their work recording of student time ended. Therefore, throughout the logs several start and stop times were recorded for each lesson.

Interrater reliability. The primary researcher of the study and one other data collector collected interrater reliability. Reliability checks were completed for the strategy use test and the mathematical computation test for 30% of the tests taken across all phases of the study (i.e., baseline, instruction, intervention, maintenance). All reliability scores were calculated using an item-by-item method by dividing the number

of agreements by the number of agreements plus disagreements, and then multiplying by 100.

CHAPTER 4: RESULTS

Findings of the study are presented below. Results for interrater reliability and treatment integrity are presented first followed by results for each research question.

Interrater Reliability

Student's Use of the SOLVE Strategy

The outside observer collected interrater reliability data on 30% of the probes for the first primary dependent variable (i.e., strategy use) using item-by-item scoring. Overall, interrater reliability ranged from 86% to 100% with a mean of 96%. During baseline, interrater reliability ranged from 86% to 100% with a mean of 93%. During instruction, interrater reliability ranged from 88% to 100% with a mean of 96%. During intervention, interrater reliability ranged from 92% to 100% with a mean of 98%.

Student's Correct Response

The outside observer collected interrater reliability data on 30% of the probes for the second primary dependent variable (i.e. correct response). Overall, interrater reliability ranged from 97% to 100% with a mean of 98%. During baseline, interrater reliability ranged from 90% to 100% with a mean of 98%. During instruction, interrater reliability ranged from 70% to 100% with a mean of 97%. During intervention, interrater reliability was 100%.

Treatment Integrity

To ensure intervention procedures were implemented as intended, treatment fidelity data were collected for 30% of all lessons distributed evenly across participants. Audio recordings of the sessions were used for collecting treatment integrity data by comparing scripted lessons to behaviors performed by the instructor to ensure that the instruction followed as prescribed. Treatment integrity ranged from 92% to 100% with a mean of 97.5%.

Dependent Variables

Research Question 1: What are the effects of the SOLVE Strategy on the mathematical problem solving skills of secondary students with learning disabilities?

Research Question 2: To what extent does training in the SOLVE Strategy increase accuracy on grade level mathematical word problems?

Results for each participant are presented in Figures 1 through 4. Each graph shows participant results across baseline, post-intervention (2 weeks after baseline), and maintenance. Data for students' knowledge of the SOLVE Strategy and accuracy on grade level mathematical word problems are presented as number correct. Results indicated a functional relation between instruction in the SOLVE Strategy and students' increased accuracy on grade level mathematical word problems.

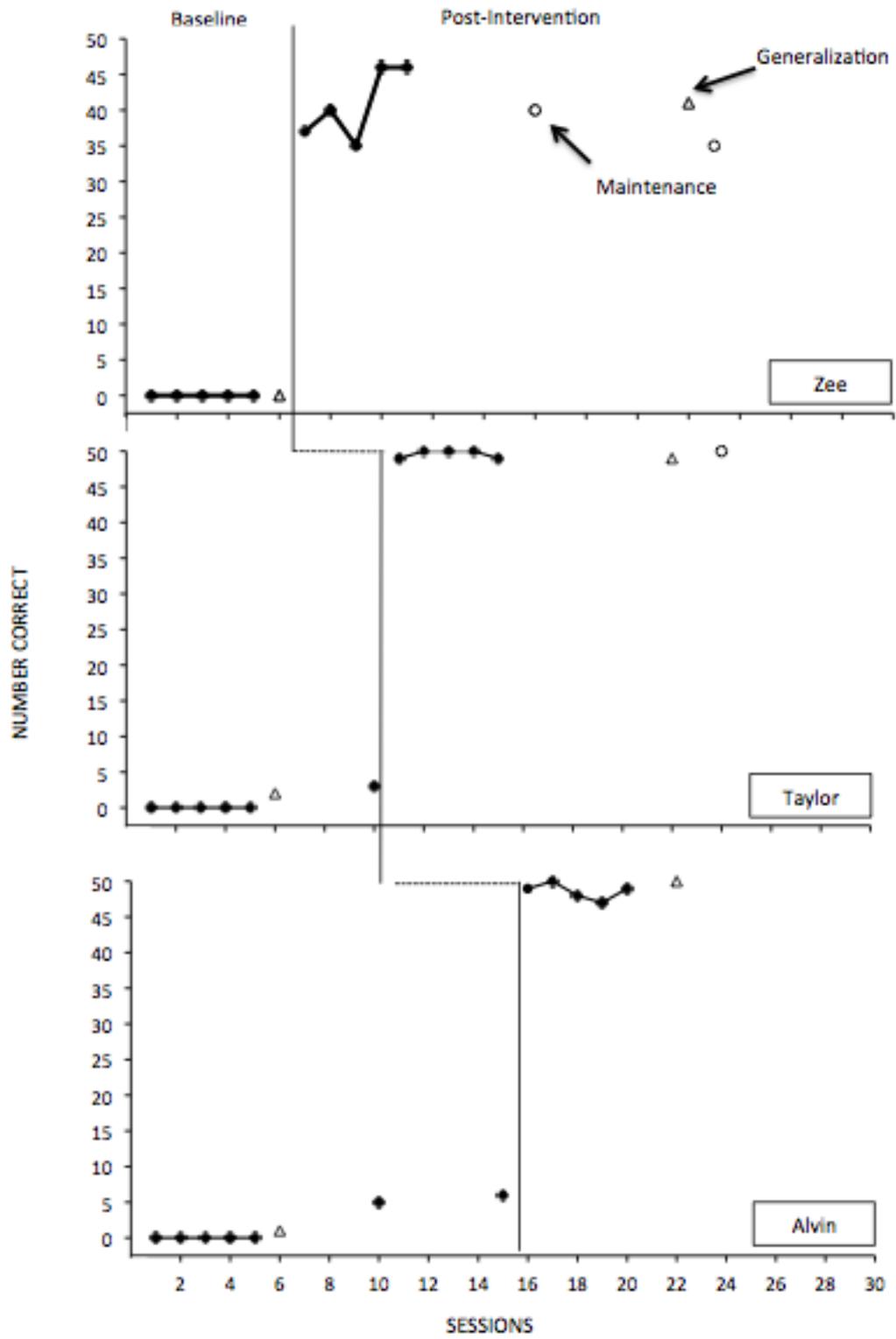


Figure 1. Percent of students' knowledge of the SOLVE strategy (group 1)

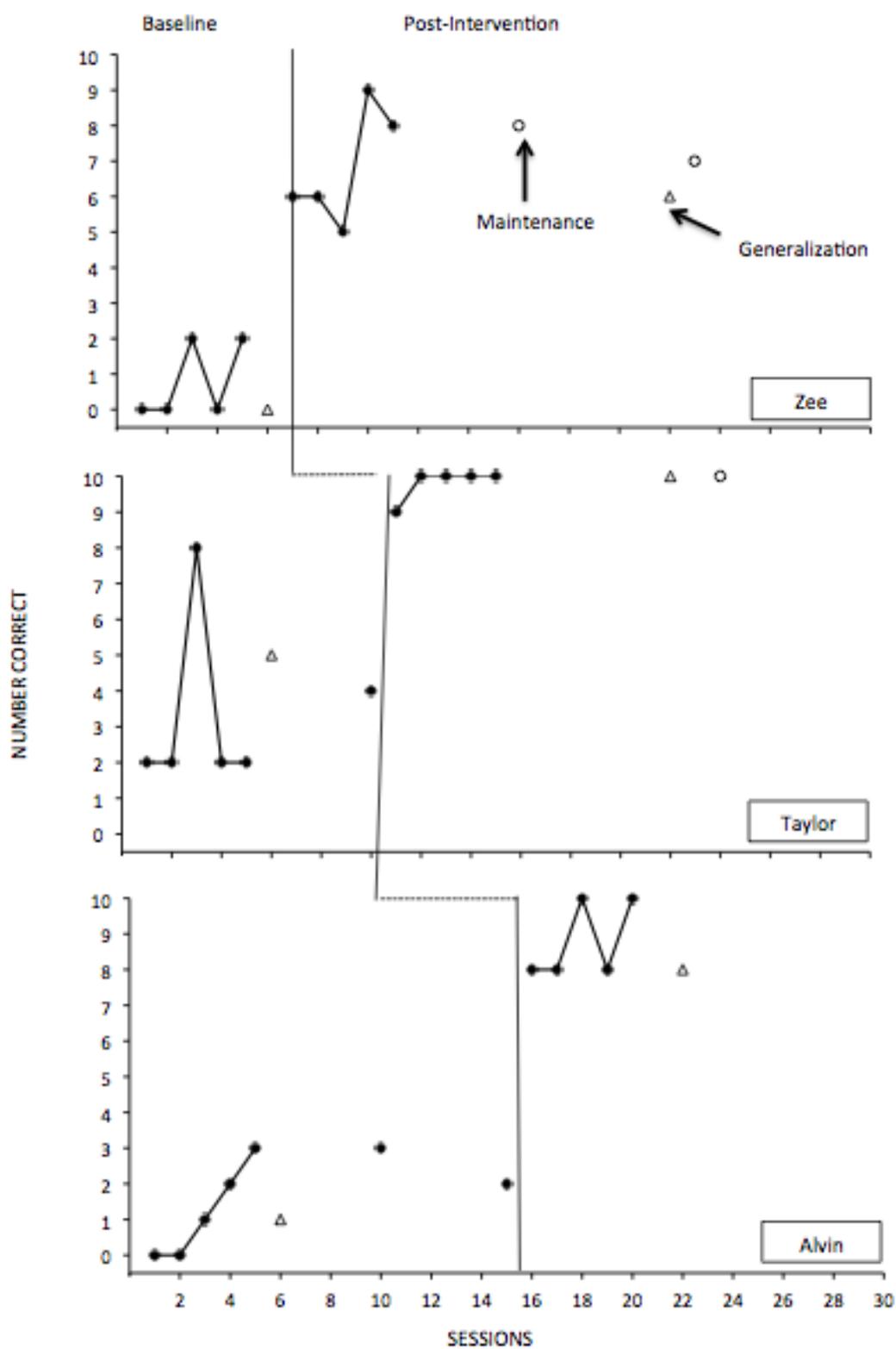


Figure 2. Percent of students' accuracy of word problems (group 1)

Zee. During baseline, Zee's performance on strategy use was stable with scores ranging from 0% to 0% correct with a mean of 0%. Zee's correct response scores ranged from 0% to 20% with a mean of 8%.

During instruction in the SOLVE Strategy, Zee successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores ranged from 82% to 84% with a mean score of 81%; and correct response scores ranged from 50% to 100% with a mean score of 78%. The following table displays Zee's performance during the instructional phase of the SOLVE Strategy.

Table 2. Zee's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	82%	90%
6	82%	100%
7	76%	50%
7	84%	70%

During intervention, Zee continued to show an increasing trend in strategy use and correct response with scores for strategy use ranging from 70% to 92% with a mean of 82%, and correct response scores ranging from 60% to 90% with a mean of 68%. On a generalization measure during baseline Zee scored a 0% for both strategy use and number correct. Following intervention Zee's score on strategy use was 82%, and for correct response his score was 60%.

Taylor. During baseline, Taylor's performance on strategy use was stable with scores ranging from 0% to 0% correct with a mean of 0%. Taylor's correct response scores ranged from 0% to 0% with a mean of 0%.

During instruction in the SOLVE Strategy, Taylor successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores ranged from 90% to 100% with a mean score of 96%; and correct response scores ranged from 80% to 90% with a mean score of 90%. The following table displays Taylor's performance during the instructional phase of the SOLVE Strategy.

Table 3. Taylor's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	100%	100%
6	98%	80%
7	90%	90%

During intervention, Taylor continued to show an increasing trend in strategy use with scores ranging from 98% to 100% with a mean of 99.6%. Taylor's correct response scores ranged from 90% to 100% with a mean of 98%. On a generalization measure during baseline Taylor scored a 0% for both strategy use and number correct. Following intervention Taylor's score on strategy use was 98%, and for number correct his score was 100%.

Alvin. During baseline, Alvin's performance on strategy use was stable with scores ranging from 0% to 12% correct with a mean of 3.1%. Taylor's correct response scores ranged from 0% to 30% with a mean of 15.7%.

During instruction in the SOLVE Strategy, Alvin successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores were 100%; and correct response scores ranged from 90% to 100% with a mean score of 96.7%. The following table displays Alvin's performance during the instructional phase of the SOLVE Strategy.

Table 4. Alvin's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	100%	100%
6	100%	100%
7	100%	90%

During intervention, Alvin continued to show an increasing trend in strategy use with scores ranging from 94% to 100% with a mean of 97%. Alvin's correct response scores ranged from 90% to 100% with a mean of 88%. On a generalization measure during baseline Alvin scored a 0% for both strategy use and number correct. Following intervention Alvin's score on strategy use was 100%, and for number correct his score was 80%.

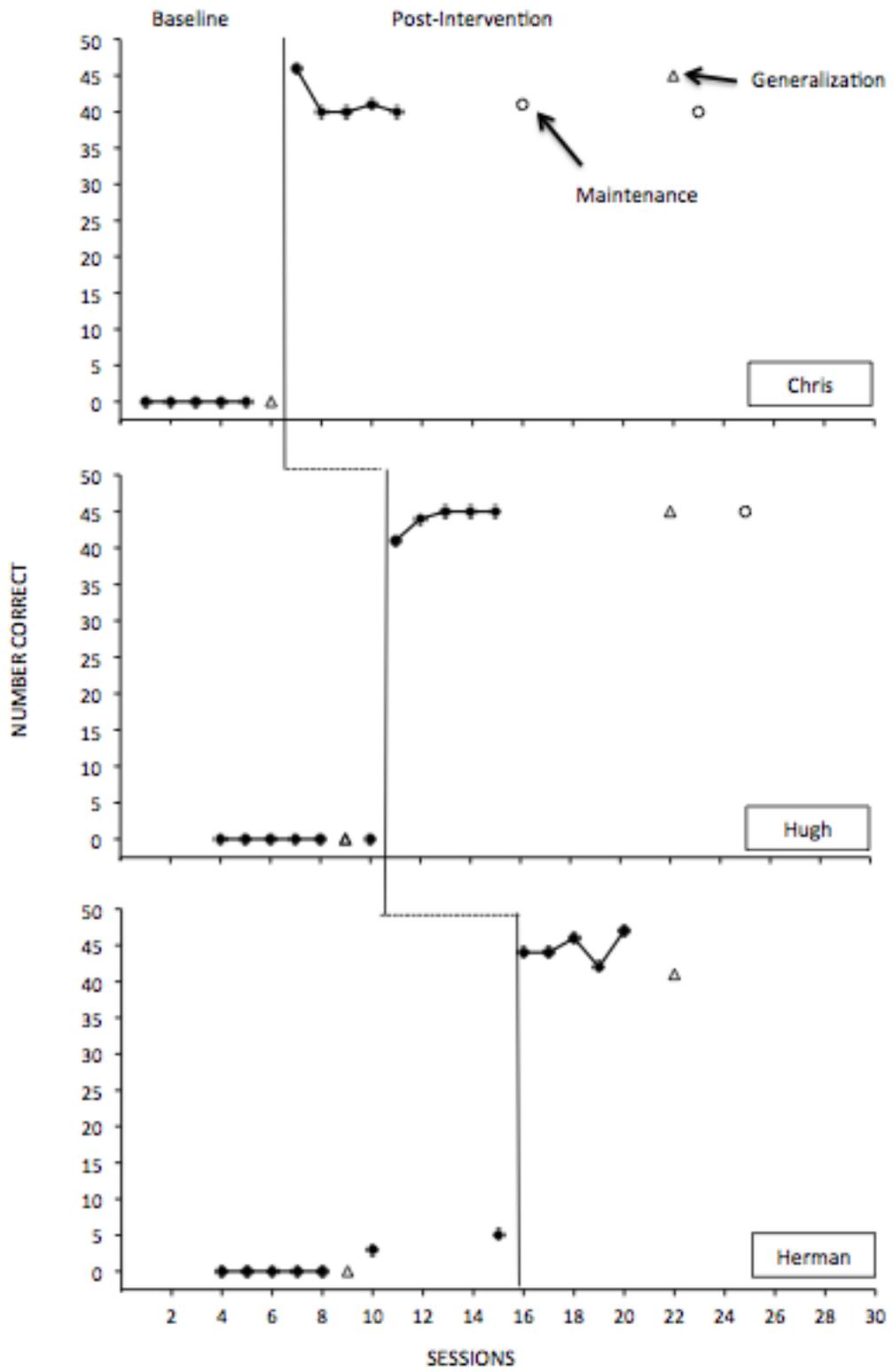


Figure 3. Percent of students' knowledge of the SOLVE strategy (group 2)

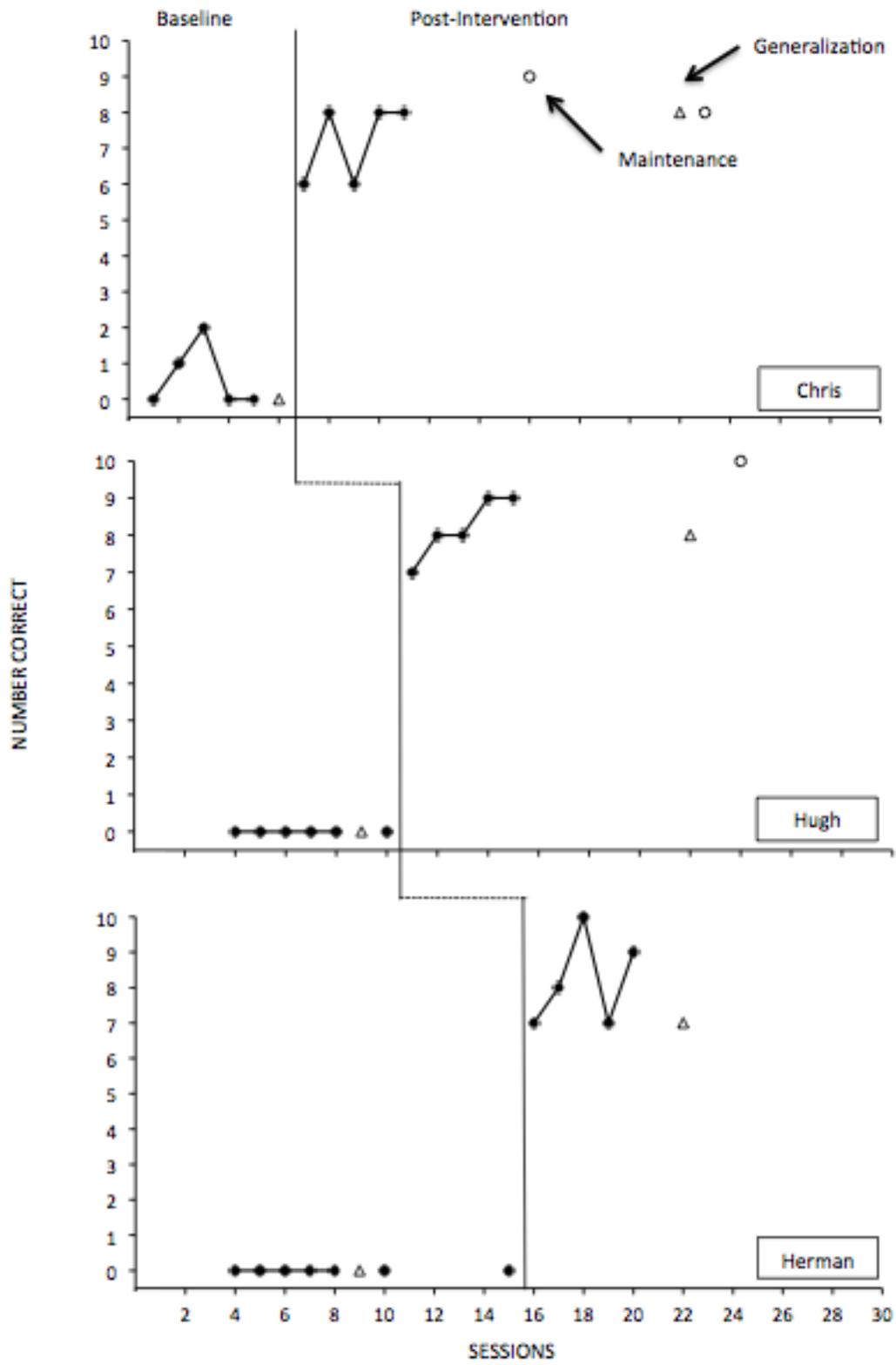


Figure 4. Percent of students' accuracy of word problems (group 2)

Chris. During baseline, Chris's performance on strategy use was stable with scores ranging from 0% to 0% correct with a mean of 0%. Chris's correct response scores ranged from 0% to 20% with a mean of 6%.

During instruction in the SOLVE Strategy, Chris successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores ranged from 80% to 92% with a mean score of 83.5%; and correct response scores ranged from 70% to 100% with a mean score of 82.5%. The following table displays Chris's performance during the instructional phase of the SOLVE Strategy.

Table 5. Chris's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	92%	80%
6	80%	80%
7	82%	100%
7	80%	70%

During intervention, Chris continued to show an increasing trend in strategy use with scores ranging from 80% to 96% with a mean of 82.8%. Chris's correct response scores ranged from 60% to 100% with a mean of 72%. On a generalization measure during baseline Chris scored a 0% for both strategy use and number correct. Following intervention Butter's score on strategy use was 90%, and for number correct his score was 80%.

Hugh. During baseline, Hugh's performance on strategy use was stable with scores ranging from 0% to 0% correct with a mean of 0%. Hugh's correct response scores ranged from 0% to 0% with a mean of 0%.

During instruction in the SOLVE Strategy, Hugh successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores ranged from 80% to 100% with a mean score of 88%; and correct response scores ranged from 90% to 100% with a mean score of 98%. The following table displays Hugh's performance during the instructional phase of the SOLVE Strategy.

Table 6. Hugh's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	80%	100%
6	84%	100%
7	100%	90%

During intervention, Hugh continued to show an increasing trend in strategy use with scores ranging from 82% to 90% with a mean of 88%. Hugh's correct response scores ranged from 70% to 90% with a mean of 82%. On a generalization measure during baseline Hugh scored a 0% for both strategy use and number correct. Following intervention Hugh's score on strategy use was 90%, and for number correct his score was 80%.

Herman. During baseline, Herman's performance on strategy use was stable with scores ranging from 0% to 0% correct with a mean of 0%. Herman's correct response scores ranged from 0% to 0% with a mean of 0%.

During instruction in the SOLVE Strategy, Herman successfully completed the mathematical probes and reached mastery of 70% on accuracy and 80% or higher for strategy use. Strategy use scores ranged from 84% to 92% with a mean score of 89.3%; and correct response scores ranged from 80% to 100% with a mean score of 93.3%. The following table displays Herman's performance during the instructional phase of the SOLVE Strategy.

Table 7. Herman's performance during instructional phase

Grade Level	Strategy Use	Correct Response
5	92%	100%
6	84%	80%
7	92%	100%

During intervention, Herman continued to show an increasing trend in strategy use with scores ranging from 84% to 94% with a mean of 89%. Herman's correct response scores ranged from 70% to 100% with a mean of 82%. On a generalization measure during baseline Herman scored a 0% for both strategy use and number correct. Following intervention Herman's score on strategy use was 82%, and for number correct his score was 70%.

Strategy Knowledge Test

Overall results of the Strategy Knowledge Test indicate an increased level of strategy knowledge for all participants from pretest to posttest. Table 8 provides detailed pre/posttest results for each participant.

Table 8: Strategy knowledge test results

Student	Pre-Test	Post-Test
Zee	0%	100%
Chris	0%	91%
Hugh	0%	91%
Taylor	0%	100%
Alvin	0%	91%
Herman	0%	91%
<i>Mean (SD)</i>	<i>0 (0)</i>	<i>94 (4.648)</i>

A Wilcoxon signed-rank test was run to determine whether or not there was a statistically significant difference between pre and posttest scores. Results indicated that there was a statistically significant difference between pre- and posttest scores ($Z = -2.271, p = .023$).

Research Question 3: To what extent does training in the SOLVE Strategy increase standardized mathematical reasoning scores?

To measure the extent to which training in the SOLVE Strategy increased standardized mathematical reasoning scores students were administered the Applied Problems subtest of the Woodcock Johnson III (Woodcock et al., 2001). Form A was

administered prior to intervention and Form B was administered upon completion of training in the SOLVE Strategy. Results of the pre and post measures are displayed in Table 9.

Table 9. Students performance on the WJII

Student	Pre-Test Age Equivalency	Pre-Test Grade Equivalency	Post-Test Age Equivalency	Post-Test Grade Equivalency
Zee	11-7	6.2	13-0	7.7
Chris	11-1	5.7	13-6	8.2
Hugh	>30	18	17-5	13.0
Taylor	>30	16.9	>28	>18.0
Alvin	10-9	5.3	12-3	6.7
Herman	8-11	3.6	11-2	5.6
<i>Mean (SD)</i>	<i>17.30 (10.68)</i>	<i>9.28 (6.39)</i>	<i>16.10 (6.67)</i>	<i>10.03(5.07)</i>

A Wilcoxon signed-rank test indicated that instruction in the SOLVE Strategy did not elicit a statistically significant change in in WJ-III text scores for students age equivalency ($Z = -.314, p = .753$) and grade equivalency ($Z = -.943, p = .345$).

Social Validity

Research Question 4: What are teachers opinions about using the SOLVE Strategy within their instruction?

Research Question 5: What are student perceptions of using the SOLVE Strategy in their everyday mathematics classes?

Participants and participants' classroom teacher responded to a survey related to their social attitudes of the SOLVE Strategy. The teacher survey contained seven

questions; six of which could be answered using a 5-point Likert scale (i.e., strongly agree, agree, not sure, disagree, strongly disagree). In order to obtain a numerical range, values were assigned to each of the 5 points (i.e., 5 = strongly agree, 1 = strongly disagree). Table 10 presents the results of the teacher survey.

Table 10: Social validity teacher survey

Question	Response
1. Instruction in the SOLVE Strategy is relevant for my students based on the mathematics curriculum and required testing.	4
2. Given the time required to teach the SOLVE Strategy; I feel that it could be taught in the general education classroom with a larger group of students.	5
3. Given the outcomes, I would use the strategy following the prescribed instructional procedures.	5
4. I am considering using the intervention for other students in future.	4
5. Student's ability to solve word problems increased in accuracy and consistency during the intervention.	3
6. I am considering sharing this information with other teachers within my school.	5

Scores from six questions ranged from 3 to 5 indicating that the teacher agreed that the SOLVE Strategy was relevant to his students based on the mathematical curriculum. The teacher also strongly agreed that he would/could teach the strategy to a

larger group of students, follow the prescribed instructional procedures, and share the strategy with other teachers within his school. He also agreed that he would use this strategy with his students in the future. The teacher was asked an additional question of what changes/additions would he suggest for the intervention. He indicated that he would have “Changed the time they did it to “class time” & had it apply to the problems they were currently working on so it didn't feel like it was “extra.”

Following intervention, students were given a social validity survey that contained eight questions; seven of which could be answered using a 5-point Likert scale (i.e., strongly agree, agree, not sure, disagree, strongly disagree). In order to obtain a numerical range, values were assigned to each of the 5 points (i.e., 5 = strongly agree, 1 = strongly disagree). Table 11 presents the results of the student survey.

Table 11: Social validity student survey

Questions	Mean Score Responses
1. Before I learned the SOLVE Strategy I was not good at solving mathematical word problems.	3
2. After I learned the SOLVE Strategy I was able to attack and solve word problems correctly.	3
3. I know what steps I can take to get started solving a word problem.	4
4. I have started using the SOLVE Strategy in my math class.	2

- | | |
|--|---|
| 5. I feel comfortable using the SOLVE Strategy while I solve word problems in class. | 3 |
| 6. I would consider sharing the SOLVE Strategy with other students at my school. | 2 |
| 7. Since learning the SOLVE Strategy I can see a change in my grades in my math class. | 2 |
-

Scores from the first seven questions ranged from 2 to 4 indicating that the students did not agree that the SOLVE Strategy was beneficial to them. Half of the students agreed that before they learned the SOLVE Strategy they were not good at solving mathematical word problems. By the end of the study all students agreed that they knew what steps to take to get started solving a word problem, and that they were comfortable using the SOLVE Strategy. The students were asked an additional question of what changes/additions would you suggest if this strategy was to be taught to another group of students. Of the six students four of them responded to question eight in which they were asked what changes/additions they would suggest if this strategy was to be taught to another group of students. Response from students ranged from “I don’t know, you did well” to “Only use certain steps.”

Anecdotal data from students revealed that they thought the SOLVE Strategy was beneficial to them, but the reason they had not used it in class was because they could not spend “20 minutes” on one problem. After the conclusion of all eight stages of instruction the students agreed that if they could choose which steps of the strategy they could use then they would be more likely to use it in class. Students also revealed that the reason

they would not share the strategy with other students in their grade was because none of the students would listen to them. They did not indicate that they would not share the strategy with other students because they did not think it would be beneficial.

CHAPTER 5: DISCUSSION

The purpose of this study was to examine the effectiveness of explicit instruction in the SOLVE Strategy (a previously developed strategy) on the mathematical problem solving skills of students at the secondary level who have been identified as having a specific learning disability. Specifically, this study investigated the effects of the SOLVE Strategy on the mathematical problem solving skills of secondary students with disabilities. A multiple probe across participants design was employed to determine the impact of the independent variable (i.e., instruction in the SOLVE Strategy) on the primary dependent variables (i.e., strategy use, correct response, strategy knowledge, mathematical reasoning score). The intervention was implemented with six 8th grade students with specific learning disabilities. Results indicate a functional relation between SOLVE Strategy usage and improved problem solving performance for all six target students. Additionally, all participants were able to generalize the SOLVE Strategy to other mathematic topics and concepts. Finally, the teacher and students felt the intervention was socially acceptable.

In general, these findings are consistent with previous studies on problem solving instruction for students with specific learning disabilities indicating that students with SLD can learn problem solving strategies (e.g., Maccini & Hughes, 2000; Maccini & Rhoul, 2000). Findings and discussion points are presented in this chapter organized by the five research questions. Additionally, limitations of the study, suggestions for future research, and implications for practice are discussed.

Effects of the Intervention on the Dependent Variables

Research Question 1: What are the effects of instruction in the SOLVE Strategy on the mathematical problem solving skills of secondary students with learning disabilities?

Students demonstrated a dramatic increase in strategy use scores across all instructional phases of the study. One important component of the intervention was explicit instruction in the SOLVE Strategy. Training was provided to the student's using the eight-step instructional sequence created by Deshler, Alley, Warner, and Schumaker (1981) to promote strategy acquisition and generalization. Because learning strategy instruction focuses on making the students more active learners by teaching them how to learn and use what they have learned to solve problems; the SOLVE Strategy supplied struggling students with the same tools and techniques that efficient learners use to help them understand and learn new material or skills (Luke, 2006). Consistent with previous research on learning strategies (e.g., Mercer, Lane, Jordan, Allsopp, & Eilsele, 1996; Scheuermann, Deshler, & Schumaker, 2009; Swanson & Deshler, 2003) this study demonstrated that consistent, intensive, explicit instruction and support were key components for instructional success.

Consistent with previous mathematics research on the difficulties students with SLD experience with problem solving and self-monitoring (e.g., Maccini & Ruhl, 2000; Montague & Bos, 1990), the low mean strategy usage scores of 1 during baseline indicate that the current participants experienced difficulty applying effective problem-solving strategies when solving mathematical word problems. Specifically, students were unable to identify necessary facts to assist them with correctly solving the word problem. Following explicit instruction in the SOLVE Strategy, students' scores improved with a

mean strategy usage score of 45. As a requirement, before students could proceed to other phases of instruction, a mastery level of 80% had to be obtained on strategy use to ensure that students were able to correctly apply the problem solving procedures.

Research Question 2: To what extent does training in the SOLVE Strategy increase accuracy on grade level mathematical word problems?

Findings from this study also indicated a functional relation between instruction in the SOLVE Strategy and students ability to set up and correctly solve mathematical word problems. Students demonstrated an increase on the number of correct responses from baseline to post-intervention across all phases of the study.

During baseline, the mean accuracy score for correct response was 1. Overall, baseline performance was variable among participants with some students exhibiting more difficulty than others. Once students were taught the SOLVE Strategy, the variability in student's performance for problem set and solution decreased and scores increased. These findings are similar to Maccini and Ruhl (2000) and Maccini and colleagues (1999) in that after intervention students were able to more accurately set up appropriate equations and solve the word problems correctly. Therefore, strategy instruction involving general problem-solving strategies, self-monitoring training, and effective teaching elements improved students' ability to correctly set up and solve mathematical word problems.

Generalization. Following instruction in the solve strategy students completed a generalization measure and two maintenance tests. Compared to mean baseline scores for strategy use of 1, following instruction students' mean generalization scores on strategy use increased to 45. Compared to mean baseline scores for correct response of 1,

following instruction students' mean generalization scores for correct response increased to 7.8. These results replicate earlier findings from Hutchinson (1993) and Maccini and Ruhl (2000).

Effectiveness of SOLVE Strategy on Standardized Mathematical Test

Research Question 3: To what extent does training in the SOLVE Strategy increase standardized mathematical reasoning scores?

Student performance on standardized tests is a major concern with the increase of testing accountability (Sireci, Li, & Scarpati, 2003), the SOLVE Strategy may offer a way to help students increase their scores on standardized measures of mathematical reasoning. Students in the current study were given the WWJ III before instruction in the SOLVE Strategy began and once again at the conclusion of the study. Results of this study indicated that there was not a significant increase on students' posttest scores on the WJ III from their pretest scores following instruction in the SOLVE Strategy.

The CCSS for Grade 8 explicitly states that students should be able to solve equations as a process of reasoning and provides a clear statement of what should be taught. With more attention focused on mathematical reasoning and the application of mathematical skills to word problems, it is important to teach students strategies that will address their cognitive processing and memory deficits.

One possible solution is to teach students the SOLVE Strategy to address these memory deficits as even students with higher achievement scores would not attempt to solve mathematical word problems in class prior to intervention in this study which is why they were still included even though their achievement level was above grade level.

This indicates that even high performing students benefited from instruction in the SOLVE Strategy to assist them in solving mathematical word problems.

Discussion of Social Validity Findings

Research Question 4: What are teachers opinions about using the SOLVE Strategy within their instruction?

Research Question 5: What are student perceptions of using the SOLVE Strategy in their everyday mathematics classes?

This study assessed the social validity of the SOLVE Strategy intervention and outcomes based on the perceptions of the general education teacher and study participants. Social validity data were collected to evaluate the social importance of the intervention and the social importance of behavior change based on effects of the intervention (Cooper & Wolf, 1978; Cooper et al., 2007).

The social validity questionnaires assessed teachers' perceptions of the acceptability of the intervention and the effect the intervention had on students' performance in class. Additionally, participants were asked to evaluate the social acceptance of the intervention and the social importance of behavior change.

Teacher's perception of the intervention and feasibility of implementation in general education classrooms. Participants' classroom teacher indicated that instruction in the SOLVE Strategy helped students improve their performance on word problems. Specifically, the teacher stated that prior to intervention students would not attempt to solve word problems when they encountered them in class or on homework assignments. Now, even if the students are unsure of themselves when presented with word problems they at least attempt to solve them. The teacher also stated that he thought the

intervention should have been implemented in his classroom instead of study hall. His perception was that the students viewed the strategy as “extra work” and it was not as meaningful to them because it was not a part of their actual math class.

When examining the feasibility of implementing the SOLVE Strategy in the general education classroom it was important to look at the amount of time required for instruction and practice with the strategy. In the current study instruction in the SOLVE Strategy required 1.5 hours of initial instructional delivery and 3 hours of supervising practice activities and providing feedback. The teacher reported that this was an acceptable amount of time to teach the students the strategy without taking away from the course requirements when the strategy was taught over several days.

Students’ perceptions of the acceptability of the intervention and importance of the SOLVE Strategy. Participants in this study were unsure whether the SOLVE Strategy intervention helped them attack mathematical word problems, was easy to use, and would use it in the future. Participants in this study either agreed or strongly agreed that the SOLVE Strategy intervention taught them how to begin and work through mathematical word problems.

Limitations and Future Directions for Research

While the results of this study are promising, there are several limitations and implications for future research that should be considered. First, as with most studies using a single-subject research design, this study included a small number of participants (i.e., 6 participants) which limits the generalizability of these results to a larger population of students causing a potential threat to external validity. Additionally, this study was implemented in a suburban private school where the students faced more

significant learning challenges because they could not succeed in public schools. While these limitations limit generalizability of findings, future research should continue to investigate SOLVE as a method for teaching problem solving skills to students with disabilities to build generality via systematic replications (Horner et al., 2005). Future research should be conducted with various student populations (e.g., students from more culturally and linguistically backgrounds) as well as with students in other geographic locations to determine if the SOLVE Strategy is an effective intervention for teaching problem solving skills to students at-risk for, or with, other disabilities.

Second, because of the research design, data may not accurately reflect students' full understanding and ability to use the SOLVE Strategy due to fatigue. For instance, in both baseline and intervention phase's five data points were collected for each student totaling 50 word problems. Additionally, students completed a minimum of three instructional probes (i.e., 15 word problems) and four more probes for generalization and maintenance data (i.e., 20 word problems). In total students independently complete a minimum of 65 word problems in two weeks and 85 total for the entire study. Future research may want to use a group design instead of single-case design to avoid testing fatigue.

Third, no long-term maintenance data were collected in this study. Specifically, maintenance data for this study were collected two and six weeks after each student exited the intervention phase. Response maintenance refers to "the extent to which a learner continues to perform the target behavior after a portion or all of the intervention responsible for the behavior's initial appearance in the learner's repertoire has been terminated" (Cooper et al., 2007, p. 615). Although study participants maintained

knowledge of the SOLVE Strategy and increased levels of accuracy on word problems two and six weeks after intervention it is unknown whether students would maintain the knowledge of the SOLVE Strategy and increased accuracy on word problems for a longer, extended period of time. Future research should consider collecting maintenance data over an extended period of time (e.g., 3 months, 6 months).

Fourth, because more intervention strategies are needed that can be embedded within instruction it is difficult to determine how useful this intervention may be for use in the general education classroom setting. Although the teacher reported that the procedures were reasonable and would be willing to use the strategy as a supplement to his instruction, the researcher implemented the intervention and data collection procedures. The effects of the intervention may be more meaningful if the classroom teachers actually implemented the SOLVE Strategy intervention in the general education classroom setting as a supplement to instruction. Future research should focus on implementing the SOLVE Strategy intervention in the general and/or special education classroom.

Finally, the primary researcher provided instruction to the students. Although the researcher did not create the SOLVE strategy and received standard professional development in the instructional tactics, it is unknown whether other teachers can help students to produce similar results.

Common Core State Standard 8.EE.7 states that students should be able to solve linear equations in one variable with one solution, infinitely many solutions, or no solutions. Students are expected to also show which of these possibilities is the case by successively transforming the given equation into simpler forms, until an equivalent

equation of the form $x = a$, $a = a$, or $a = b$ results (where a and b are different numbers). Additionally, students solve linear equations with rational number coefficients, including equations whose solutions require expanding expressions using the distributive property and collecting like terms. Consequently, the word problems used in this study partially addressed CCSS 8.EE.7 in that only word problems that contained whole numbers and decimals were used. Because of this, the difficulty level of the word problems were harder to control and do not fully represent the variety of problem types students are expected to master at Grade 8. Future research should expand problem types to include other mathematical concepts such as inequalities or proportional reasoning.

Implications for Practice

While most interventions for students with SLD focus on procedural knowledge (Maccini & Hughes, 1997; Mastropieri et al., 1991) this study focused on meta-cognitive awareness. For that reason this study has several implications for practice. First, instruction in the SOLVE Strategy helped students improve problem solving skills by attending to critical elements (e.g., what the problem was asking them to find, key information in the problem, writing and carrying out an accurate plan for solving the problem) and correctly solving mathematical word problems. Although all students reached 80% mastery criterion on strategy use, the L-step of the SOLVE Strategy presented the most difficulty for students. During this step students were required to choose an operation or operations and write in words how they would solve the word problem without using numbers. This required students to fully understand what the problem was asking them to find and showed an in depth understanding of how and why they would solve the problem that way. Because students think differently, and their

plans may not be alike, more time may be required for teaching this step. Additionally, practitioners may adapt the SOLVE Strategy so that it can be embedded within instruction in the general education classroom. Previous research on learning strategy instruction has shown that unless students are provided with ample opportunities to practice using a strategy, they will not use the strategy correctly and will rarely use it independently (Scanlon, Deshler, & Schumaker, 1996).

Second, the SOLVE Strategy intervention was implemented during study hall providing practitioners a logical solution for implementing this strategy. Students were able to receive individual corrective feedback on their strategy use and were provided with ample opportunities to practice using the strategy. With students failing the secondary mathematics curriculum there is a need for a resource room and/or supported inclusion model to provide intensive-explicit instruction (i.e., a curriculum assistance class).

The University of Kansas Center for Research on Learning (KU-CRL) developed a framework called the Content Literacy Continuum to allow for a range of supports and interventions including explicit strategy instruction in a resource classroom. According to the Strategic Learning Center, content refers to the information and concepts that teachers have identified as critical knowledge for students to learn in that content area. Students have achieved Content Literacy when they have the skills and strategies that they need, to not only master the content, but also have the ability to manipulate and generalize those skills and strategies to other learning situations (Ehren, Lenz, & Deshler, 2004). The Content Literacy Continuum is a schoolwide framework of supports with tools of the Strategic Instruction Model (Deshler et al., 2001) that consist of five levels with each

level increasing in intensity that meet the varying needs of high, average and low achievers. The first two levels are for all students, while Levels 3, 4 and 5 focuses more on the needs of those students who struggle with learning (Lenz et al., 2005).

With Level 2 interventions teachers embed instruction in selected learning strategies (Schumaker & Deshler, 2006) in core curriculum courses through direct explanation, modeling, and required application in relation to content assignments. They describe strategies for acquiring, storing, and expressing course information, design learning tasks that promote practice of the strategies, and provide feedback on students' use of the strategies as they learn content. The method used to teach the SOLVE Strategy in this study can be viewed as a Level 2 learning strategy.

Third, the study addressed self-regulation training via the SOLVE Strategy by having students ask themselves questions while problem solving. Self-regulation training (i.e., the sub-steps of the SOLVE Strategy) helped cue students to important processes (e.g., identifying important information, eliminating unnecessary information, lining up a plan) for correctly setting up and solving word problems. Additionally, students' being able to verbally cue themselves is important because many students with SLD experience difficulty applying appropriate problem solving strategies and exhibit deficiencies in monitoring their metacognitive processes (Montague & Bos, 1990).

Fourth, given that the CCSS promote higher achievement in mathematics, specifically Algebraic thinking (CCSS, 2012), the SOLVE Strategy may be used to increase students' scores on standardized assessments of mathematical reasoning. Because one educational challenge facing American society is the gap in academic achievement on standardized tests among subgroups in schools including students with

disabilities and students from low-income communities (Kim & Sunderman, 2005) this study offers a way to bridge this gap by providing students with a self-regulation strategy that equips them with similar problem solving skills as their peers.

Finally, the low-cost, easy, and efficient use of the SOLVE Strategy is an important implication for practitioners. The cost of implementing this strategy was low in that two reams of paper were used to photo copy all materials, file folders for each student, one pack of colored pencils, and two sheets of laminate paper for the cue card. In rural and urban schools, teachers benefit from using strategies that are low cost as additional resources may not be available to them to purchase more expensive learning strategy curriculums.

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APPENDIX A: STRATEGY USE SCORING GUIDELINES

S Score 1 point for underlining, circling, or highlighting the question.
Score 1 point for writing the correct answer to the question, “What is this problem asking me to find?”

O Score 1 point for identifying the facts, which can be done by striking the facts, or circling the facts.
Score 1 point for some eliminating unnecessary facts, which can be done by drawing a line through the fact.
Score 1 point for listing all necessary facts, which must be written down on the answer sheet.

L Score 1 point for choosing an operation or operations (i.e., +, -, x, ÷).
Score 1 point for writing a plan that does not contain numbers (i.e., numerical or written words).

V Score 1 point for estimating the answer.
Score 1 point for carrying out the plan they wrote in the “L” step.

E Score 1 point for writing the answer as a complete thought.

Total Points for strategy usage 10 points per question for a total of 50 points per test probe.

SOLVE Usage Score Sheet										
Student Name: _____ Probe #: _____ Grade Level: _____										
Question #	S		O			L		V		E
1										
2										
3										
4										
5										
Total Each Column										
Total for Each Step										
										Total Score ____/50 Points

APPENDIX B: COMPUTATION SCORING GUIDELINES

Correct Equation Score 1 point if the equation is written correctly.
 Score 0 points for incorrect equations.

Correct Response Score 1 point if the correct response is given.
 Score 0 points for incorrect responses.

Total points for correct response 2 points per question for a total of 16 points per test probe.

Score Sheet			
Student Name: _____ Probe #: _____ Grade Level: _____			
Question #	Correct Equation	Correct Response	
1			
2			
3			
4			
5			
Total Correct Score			Total Score <u> </u> /10 Points

APPENDIX C: STRATEGY KNOWLEDGE PRE- AND POST-TEST

1. List the steps of the SOLVE Strategy.

S

O

L

V

E

2. When you organize the facts there are three things that you need to do, what are they?

a. _____

b. _____

c. _____

3. The second sub-step of the L step of the SOLVE Strategy requires that you line up a plan without using _____.

4. How can you determine if your solution to a problem is reasonable?

5. What is the first thing you should ask yourself once you come up with an answer to the word problem?

APPENDIX D: STEPS FOR THE SOLVE STRATEGY AND HELPFUL HINTS CUE CARDS

STEPS FOR THE SOLVE STRATEGY

Study the problem

Organize the facts

Line up a plan

Verify your plan with action

Examine your results

Helpful Hints:

1. Use the problem solving strategies you have learned previously
2. Note key information
3. Show all of your work

APPENDIX E: LEARNING CONTRACT

I, _____, agree to learn the SOLVE Strategy. If

I work hard, I will learn how to approach word problems so that I am more likely to solve it correctly. This will help me understand math and get better grades.

Student Signature

Instructor Signature

Date

APPENDIX F: SAMPLE COMPLETED PROBE

Name: _____

Grade Level: 8

Date: _____

Probe #: 1

1-Step word problem

1. Keith's mom paid him for keeping the yard looking good for a month. He mowed, watered, and groomed the yard. He went to the mall and spent \$17.84 on a CD, \$28.40 on a pair of shorts, and \$30.00 on a new pair of sunglasses. He had \$13.76 left in his wallet when he left the mall. How much did his mom pay him for doing the lawn this month?

S

O

L

V

E

2-Step word problem

2. Joe bought 3 pairs of pants each costing the same amount and a shirt costing \$12. He spent a total of \$63. How much was each pair of pants?

S

O

L

V

E

1-Step word problem

Keith's mom paid him for keeping the yard looking good for a month. He mowed, watered, and groomed the yard. He went to the mall and spent \$17.84 on a CD, \$28.40 on a pair of shorts, and \$30.00 on a new pair of sunglasses. He had \$13.76 left in his wallet when he left the mall. How much did his mom pay him for doing the lawn this month?

S—The amount mom paid Keith for doing the lawn

O—CD - \$17.84

APPENDIX F: SAMPLE COMPLETED PROBE (CONTINUED)

Shorts - \$28.40

Sunglasses - \$30.00

Had left - \$13.76

L—Add all amounts together

V—Estimate: \$100.00

$$\$17.84 + \$28.40 + \$30.00 + \$13.76 = \$90.00$$

E—yes, yes, yes

She paid him \$90.00 for doing the lawn.

2-Step word problem

Joe bought 3 pairs of pants each costing the same amount and a shirt costing \$12. He spent a total of \$63. How much was each pair of pants?

S—the cost of a pair of pants.

O—All facts are necessary

3 pairs of pants – all same cost

Shirt \$12

Total spent \$63

L—subtraction, division

Create an equation relating the cost of one pair of pants, p , multiplied by number of pants purchased plus cost of the shirt equal to the total spent.

V—under \$20

$$\begin{array}{r} 3p + 12 = 63 \\ -12 \quad -12 \\ \hline 3p = 51 \\ \frac{3p}{3} = \frac{51}{3} \\ p = 17 \end{array}$$

APPENDIX F: SAMPLE COMPLETED PROBE (CONTINUED)

E—yes, yes, yes

Each pair of pants cost \$17.

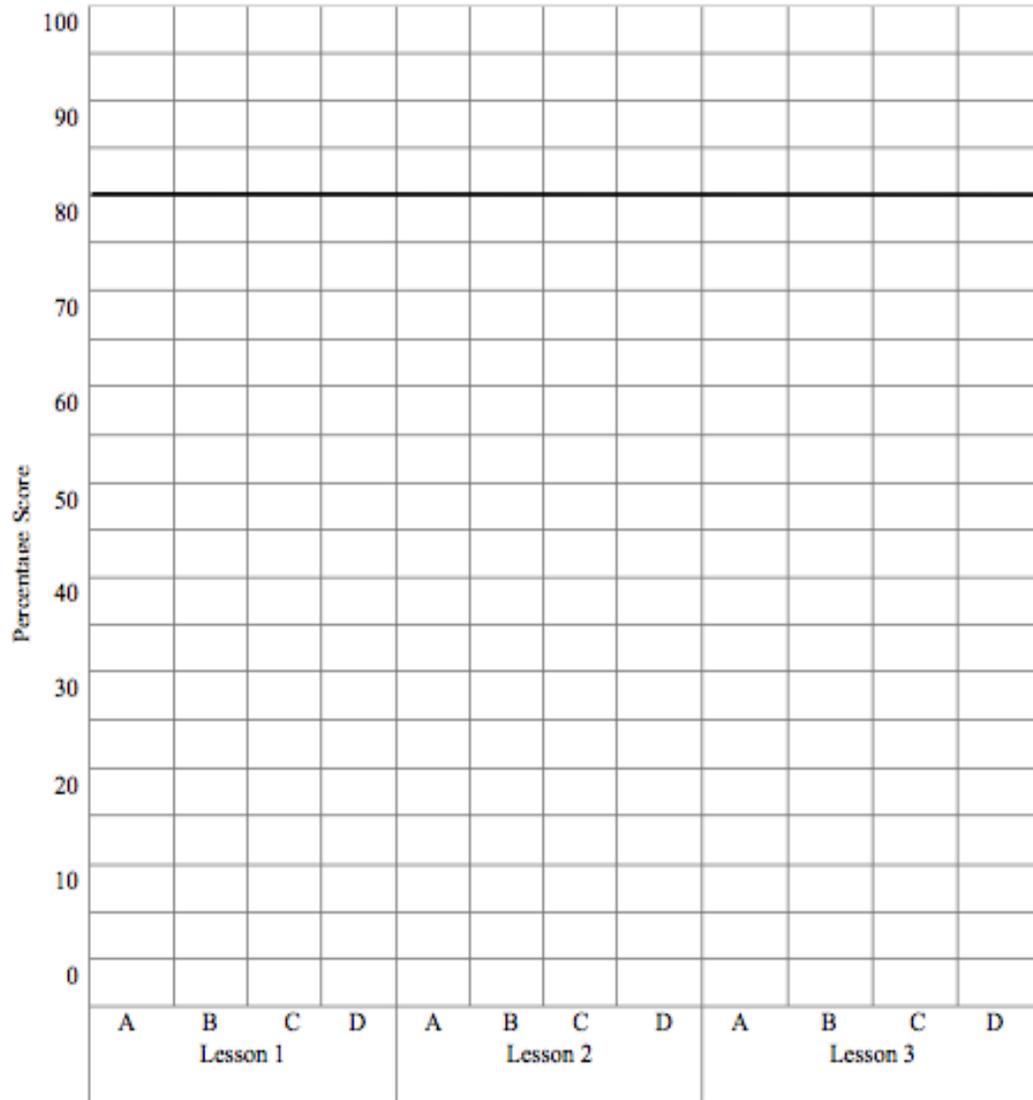
APPENDIX G: PROGRESS CHARTS

Management Chart

Student Names	/ / / / / / / / / / / /									
Pretest										
Describe & Model: Lesson 1										
Describe & Model: Lesson 2										
Describe & Model: Lesson 3										
Verbal Practice										
Controlled Practice										
Advanced Practice										
Posttest										
Generalization										

APPENDIX G: PROGRESS CHARTS (CONTINUED)

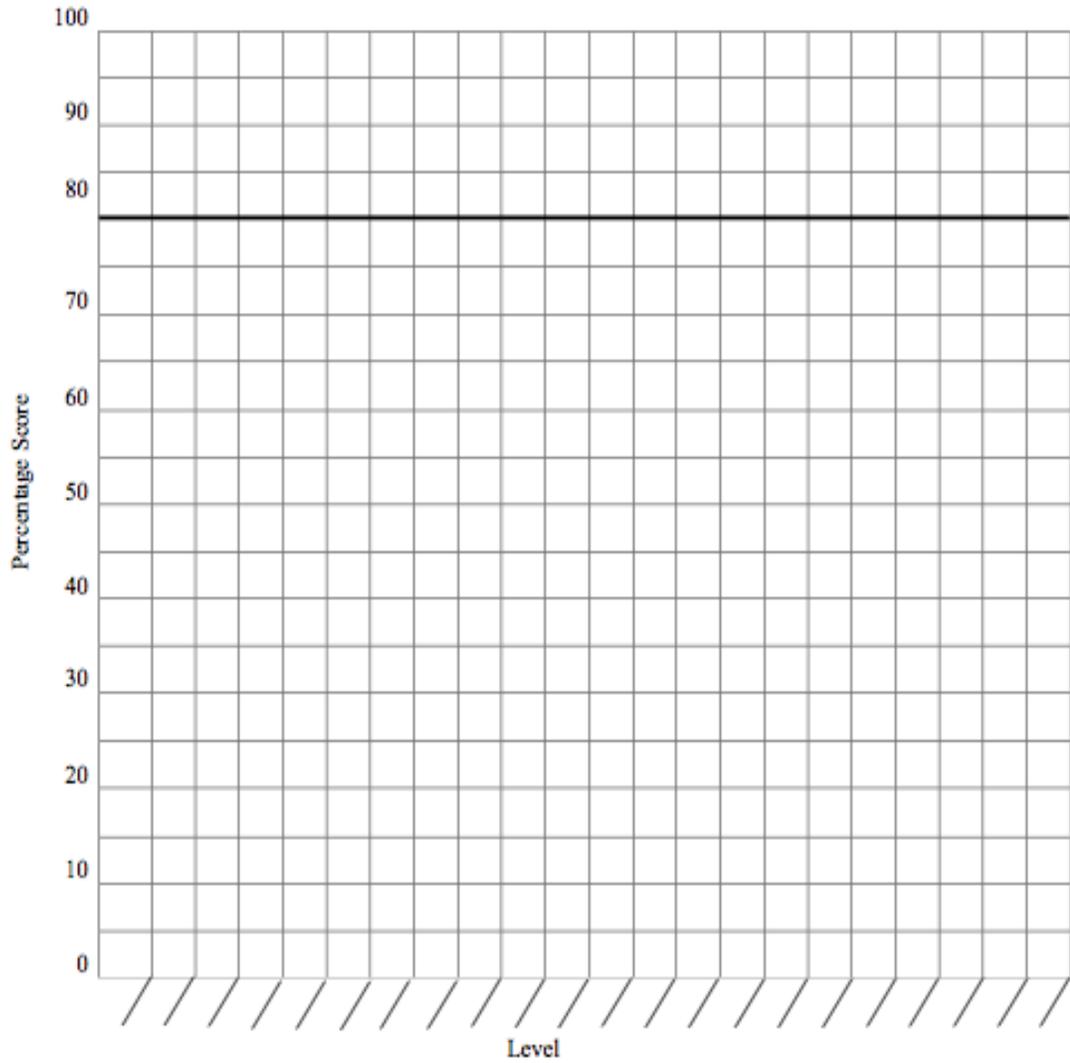
Progress Chart for Stages 2 & 3



Master Level = 80%

APPENDIX G: PROGRESS CHARTS (CONTINUED)

Progress Chart for Stages 5 & 6



Mastery Level = 80%

APPENDIX H: SCRIPTED LESSON PLANS

Stage 1: Pretest	Materials
<p>___ Advance organizer: “Today we are going to find out two things. First, we need to know whether you can solve one- and two-step equations. Second, we need to know if you can solve those same equations when they are asked in a word problem. For that reason, I will give you some math problems that were written for students at your grade level.”</p> <p>___ Distribute the materials. (1) Test paper, (2) Steps of the SOLVE strategy and helpful hints Card</p> <p>___ Give instructions for the pretest. “Each of you should have a test paper in front of you. You may write on the test paper. Be sure to show all of your work and use any strategy that you know to help you complete your work.”</p> <p>___ Solicit and answer questions.</p> <p>___ Instruct the students to begin, and monitor their work. (Students will be given 20 minutes to complete the test. Additional time will be given if needed)</p> <p>___ Collect the tests. [Students should place their test in their folder provided by the instructor]</p> <p>___ Score the tests.</p> <p>___ Communicate the results to the students</p> <p>___ Fill out the Management Chart</p>	<ol style="list-style-type: none"> 1. Copies of the pre-assessment 2. Management chart 3. Scoring sheets 4. Steps of the SOLVE strategy and helpful hints Cards. 5. Student folders

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

<p>Lesson 2</p> <p>Stages 2 & 3: Describe & Model – <i>Introduction to the SOLVE Strategy</i></p>	<p>Materials</p>
<p>Essential Question(s): Why is it important to have a strategy for solving word problems? Why is it important to study a problem?</p> <p>___ 1. Instruction will begin by stating the goals of the lesson.</p> <p>“For the next few days you are going to learn a math strategy to help you understand and solve word problems. You will be able to use this strategy for a variety of concepts that involve word problems.”</p> <p>What to do:</p> <p>___ Teacher will facilitate a discussion on the difference between the problem and the question when analyzing word problems. This discussion should take 5 minutes. Teacher will conclude the discussion by summarizing the following points: “The problem is the entire paragraph. The question is normally one sentence in that paragraph that determines what math work needs to be done in order to arrive at a correct solution.”</p> <p>___ State the purpose of the SOLVE Strategy. “SOLVE” is a way to ATTACK a word problem. We often do not know where to begin, but SOLVE gives us a starting point; that starting point is “S”.</p> <p>___ Give each student three sheets of different color construction paper.</p> <p>___ Teacher demonstrates for students how to create the SOLVE foldable.</p> <p>___ Describe the first step of the SOLVE Strategy “The first step of the SOLVE Strategy is Study the Problem. When we study the problem we (1) highlight, circle, or underline the</p>	<ol style="list-style-type: none"> 1. Smartboard 2. Colored construction paper 3. Markers, pens, and pencils 4. Note sheets with word problems. 5. Cue Cards 6. Student folders

question. (2) Ask, what is this problem asking me to find?" Student will write these steps on their foldable.

_____ Model for students exactly what to do for each of the following word problems to complete the 'S' step. "Okay, the first thing that you do for the 'S' step is highlight, circle, or underline the question. Go ahead and write that in your foldable. The second thing you do is ask yourself the question, 'what is this problem asking me to find?' The last thing you do for the 'S' step is write the answer as a complete thought. Let's look at the first problem and complete the 'S' step together." [Demonstrate the 'S' step using the first 4 problems with the students using think alouds following the above described procedures].

_____ Conduct the Independent Practice Activity. "Now you are ready to try using the 'S' step on your own. I will give you some word problems, and you will S the problem."

Students will complete problems 5-8 independently and receive corrective feedback from the instructor.

Problem 1: Spence shot three times as many baskets as Drew, while Carney shot 12 more baskets than Drew. If Spence and Carney shot the same number of baskets, how many baskets did each of them shoot?

Problem 2: The school board had to make budget cuts to avoid going into the negative. One item they cut was funding for drivers education in the high schools. Money was available to offer drivers' training to only 40 high school students. If 125 students signed up to take drivers' training how many of those students would not be able to receive it?

Problem 3: In order to improve its image, the Clown Brothers Carnival Co. agreed to give all the parking fees to the local school to buy computer equipment. Parking cost \$3 per car. On the night of the carnival, 400 parking spaces were empty in the lot. The lot could park 6,000 cars. How much money was raised parking cars?—Blue p. 37

Problem 5: Elizabeth and 2 of her friends ordered from Pizza

Hut for dinner. Elizabeth's parents gave the three of them \$20.00 to spend. They split the rest of the cost evenly between them. The cost of the pizza dinner was \$44.00 total. How much did each of them have to pay for the dinner? Answer- \$8.00

Problem 6: Sam wants to build a low fence around his garden. The length of the garden is 15 feet and the width is 10 feet. How much fencing material will Sam need to enclose the garden? Answer-50 feet

Problem 7: Mark worked for a lawn service during the summer. He earned \$10 for each yard he mowed and \$6 for each set of hedges he trimmed. He mowed 3 hours each day. How much did he make last week if he mowed 4 yards and trimmed 3 sets of hedges?—Blue p. 37

Problem 8: John set a goal of swimming 20 laps in the pool every week during the summer. On Monday and Wednesday, he swam 5 laps each day. On Tuesday and Thursday he swam 2 laps each day. How many laps does he need to swim on Friday to complete his laps for the week? Answer 6 laps—Blue p. T51

____ Describe the second step of the SOLVE Strategy “Great job everyone; it appears that everyone has the hang of the ‘S’ step. Now it is time to move to the next step. The second step of the SOLVE Strategy is Organize the Facts. When we organize the facts there are three things that we do. Let’s write the steps in our foldables: (1) Identify each fact, (2) Cross out unnecessary facts, (3) List all necessary facts. Student will write these steps on their foldable.

____ Model for students exactly what to do for problems 1-4 of the above word problems to complete the ‘O’ step. Mention that not all word problems will have unnecessary information. “Let’s look at the first four word problems that we looked at together. Okay, as I read the word problem I want you to say ‘FACT’ every time I come to a different fact in the problem.” It helps engage students when you read the problem out loud to have them separate out the facts by saying “FACT” or softly tapping their desks at the end of each fact. When you first introduce “O” you will want to clearly identify each individual fact. “Now that we have identified all of the facts it is time for us to eliminate all unnecessary information. Let’s go through

each fact one at a time to see if the information is needed to answer the question.” Making a list of the facts is very important. “Now that we have eliminated unnecessary information we need to list all necessary facts.” Follow the same procedures for word problems 2-4. Identifying unnecessary data is a very important part of “O”. Make sure you constantly ask your students “WHY” a fact is necessary or unnecessary. In training, we used an index card with “U” (for unnecessary) on the top and “N” (for necessary) on the bottom. You could also have your students give a “thumbs up” for necessary and a “thumbs down” for unnecessary. Remember that some facts could be necessary to one student, but unnecessary to another student. It is acceptable as long as they give you accurate reasons as to why they feel the fact is necessary or unnecessary.

___ Conduct the Independent Practice Activity. “Now you are ready to try using the ‘O’ step on your own. I will give you some word problems, and you will complete the O step of the SOLVE Strategy.”

Students will complete problems 5-8 independently and receive corrective feedback from the instructor.

___ Summarize: (5 minute Q & A) (1) What is the main question in Step “S”? Answer: What is the question asking me to find? (2) What is the difference between the problem and the question? Answer above (3) What is the main benefit of Step “S”? Answer: It gives a starting point (4) What do most facts deal with in word problems? Answer: Numbers (5) Can a fact be included in the question? Answer: Yes (6) Are all facts necessary, so need to be listed? Answer: No (7) What should be considered when determining whether a fact is necessary? Answer: look at the “S” question: what is the problem asking me to find?

___ Preview the next lesson. “Today you learned how to study the problem and organize the facts in a word problem. Tomorrow we are going to learn how to line up plans to solve word problems. Place your Cue Cards and worksheets in your folders.”

___ Solicit and answer any questions the students may have. File completed word problems.

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

<p>Lesson 3</p> <p>Stages 2 & 3: Describe & Model – <i>L-Step</i></p>	Materials
<p>Essential Question(s): Why is it important to have a plan before trying to solve a problem?</p> <p>___ Introduce and describe</p> <ul style="list-style-type: none"> • Review the purpose of the previous lesson. “In the last lesson, you were introduced to the first two steps of the SOLVE Strategy.” Ask the following questions: 1) What is the main question in Step “S”? Answer: What is the question asking me to find? (2) What is the difference between the problem and the question? Answer above (3) What is the main benefit of Step “S”? Answer: It gives a starting point (4) What do most facts deal with in word problems? Answer: Numbers (5) Can a fact be included in the question? Answer: Yes (6) Are all facts necessary, so need to be listed? Answer: No (7) What should be considered when determining whether a fact is necessary? Answer: look at the “S” question: what is the problem asking me to find? • State the purpose of today’s lesson. “As we reviewed, there are 5 steps to the SOLVE Strategy. You have already learned the first two. Today, you are going to learn how to line up a plan based on the information you gathered from the first two steps of SOLVE.” • State expectations. “Your job today is to listen carefully, take notes, and participate in the discussion. Later you will be completing at least two word problems on your own.” <p>What to do:</p> <p>___ Teacher will facilitate a discussion on the hardest step for students. Stress that the rule of L is, “There is never only one right way”! You will be discussing your different plans to the word problems that we will be solving. As long as a plan is mathematically sound, it can be correct.” All students do not look at problems the same way and often create several different ways to solve them. They need to be able</p>	<ol style="list-style-type: none"> 1. Smartboard 2. Foldables 3. Pens, and pencils 4. Note sheets with word problems. 5. Cue Card 6. Student folders

to answer WHY their plan works.

____ Have students take out their foldable that they started the previous class session.

____ Describe the first 'L' step of the SOLVE Strategy. "L stands for Line Up a Plan." When we line up a plan there are several things we need to remember. (1) Choose an operation or operations you think will solve the problem, (2) Verbally state the plan for solving (there should be no numbers used at this state). The facts listed in "O" should be used in writing the plan. The plan can be referred to as a verbal expression. The main rule of "L" is that there is "Never Only One Right Way." As long as the plan will answer what the problem is asking you to find it is correct. Students need to be able to answer WHY their plan works.

____ Model for students exactly what to do for each of the following word problems to complete the 'L' step.

Students will complete problems 5-8 independently and receive corrective feedback from the instructor.

Problem 1: Spence shot three times as many baskets as Drew, while Carney shot 12 more baskets than Drew. If Spence and Carney shot the same number of baskets, how many baskets did each of them shoot?

Problem 2: The school board had to make budget cuts to avoid going into the negative. One item they cut was funding for drivers education in the high schools. Money was available to offer drivers' training to only 40 high school students. If 125 students signed up to take drivers' training how many of those students would not be able to receive it?

Problem 3: In order to improve its image, the Clown Brothers Carnival Co. agreed to give all the parking fees to the local school to buy computer equipment. Parking cost \$3 per car. On the night of the carnival, 400 parking spaces were empty in the lot. The lot could park 6,000 cars. How much money was raised parking cars?—Blue p. 37

Problem 5: Elizabeth and 2 of her friends ordered from Pizza Hut for dinner. Elizabeth's parents gave the three of them \$20.00 to spend. They split the rest of the cost evenly between them. The cost of the pizza dinner was \$44.00 total. How much did each of them have to pay for the dinner? **Answer- \$8.00**

Problem 6: Sam wants to build a low fence around his garden. The length of the garden is 15 feet and the width is 10 feet. How much fencing material will Sam need to enclose the garden? **Answer-50 feet**

Problem 7: Mark worked for a lawn service during the summer. He earned \$10 for each yard he mowed and \$6 for each set of hedges he trimmed. He mowed 3 hours each day. How much did he make last week if he mowed 4 yards and trimmed 3 sets of hedges?—Blue p. 37

Problem 8: John set a goal of swimming 20 laps in the pool every week during the summer. On Monday and Wednesday, he swam 5 laps each day. On Tuesday and Thursday he swam 2 laps each day. How many laps does he need to swim on Friday to complete his laps for the week? **Answer 6 laps—Blue p. T51**

____ Summarize: (5 minute Q & A) (1) Why is it important in Step L to use words instead of the numbers from the problem? **Answer:** If words are used, the plan will work no matter what numbers are used (2) What four operations need to be remembered when setting up a plan?

Answer: Addition, subtraction, multiplication, division (3) Does Step L need to be very detailed with a great deal of words? **Answer:** It depends on the word problem itself. Some will be very simple, so do not need as many words or details. (4) Is there only one correct way to solve a problem? **Answer:** No, people think differently so many solutions may be correct. (5) When calculating $5 + 4 \cdot 7$, what might happen if one student added before multiplying, and another student multiplied before adding? **Answer:** Due to order of operations, they would arrive at different solutions. (6) How would you organize your plan for a word problem with many facts included? **Answers will vary, but should have a logical basis.** (7) How would you determine which operation(s) to choose when reading a word problem? **Answer:** Variety of answers will be given, but should include: looking at the word wall, looking for key phrases, words, ideas, and visualizing the data in a real world way that makes sense to them.

____ Preview the next lesson. “Today you learned how to line up a plan for one- and two-step word problems. Tomorrow we are going to learn how to verify your plan with action and examine your results.”

____ Solicit and answer any questions the students may have.

____ File completed word problems.

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

<p>Lesson 4</p> <p>Stages 2 & 3: Describe & Model – V- and E-Steps</p>	Materials
<p>Essential Question(s): How do you determine what operations and steps are needed when creating a plan for word problems? Why is it helpful to check your work once you calculate an answer?</p> <p>___ Introduce and describe</p> <ul style="list-style-type: none"> • Review the purpose of the previous lesson. “In the last 2 lessons, you were introduced to the first three steps of the SOLVE Strategy.” Ask the following questions: 1) What is the main question in Step “S”? Answer: What is the question asking me to find? (2) What is the difference between the problem and the question? Answer above (3) What is the main benefit of Step “S”? Answer: It gives a starting point (4) What do most facts deal with in word problems? Answer: Numbers (5) Can a fact be included in the question? Answer: Yes (6) Are all facts necessary, so need to be listed? Answer: No (7) What should be considered when determining whether a fact is necessary? Answer: look at the “S” question: what is the problem asking me to find? • State the purpose of today’s lesson. “So far you have learned the first three steps of the SOLVE Strategy. Today, you are going to learn the last two steps which are "Verify your plan with action," and "Examine your results."" • State expectations. “Your job today is to listen carefully, take notes, and participate in the discussion. Later you will be completing at least three word problems on your own.” <p>What to do:</p> <p>_____ This lesson focuses on making an estimate, and then carrying out the plan from Step “L”. The same problems from Lessons 1 & 2 are used to best show the connection between Step “L” and Step “V”. It is not necessary to have students recopy the SOL step from those problems. They can just add the “V” step on to what they have already completed so far.</p>	<ol style="list-style-type: none"> 1. Smartboard 2. Foldables 3. Pens, and pencils 4. Note sheets with word problems. 5. Cue Card 6. Student folders

____ Have students take out their foldable that they started the previous class session.

____ Describe the first V step of the SOLVE Strategy. “Once we have come up with a plan for our word problem, the next step is to *Verify your plan with action*. The first thing you do is make an estimate of the answer. The second thing you do is to carry out the plan you wrote in the ‘L’ step with action. This means that you are actually going to solve the numerical expression or equation that you created.”

____ Estimation is an important part of “V”. Discuss how estimation is a mental math process. Students with good estimation skills can eliminate 2 answers on a standardized test, which makes the chance of a correct answer even greater. It is much harder for students who don’t know their facts to make an estimate. Take 5 minutes for this discussion.

____ Go over the “V” step on the first 3 problems from Lessons 1 & 2.

____ Model for students exactly what to do for each of the following word problems to complete the ‘V’ step.

____ Help students come up with better estimations by asking questions like, “Will the answer be greater than zero?” “Will the answer be larger than the numbers in your facts?” “Will you end up with a smaller number?”

Students will complete problems 5-8 independently and receive corrective feedback from the instructor.

____ After students have completed all 8 of the previous problems move on to the last step of the SOLVE Strategy—Examine Your Results.

____ We have come to the point where everything is pulled together with the addition of final step “E”. “E” is very important because by re-reading the question, checking your work, and writing your answer as a complete thought, students normally find any mistakes that they may have made in solving the problem.”

____ “The last step in the SOLVE Strategy requires you to Examine Your Results. To do this there are 3 questions that you need to ask yourself. (1) Did I answer what I was asked to find in ‘S’? (2) Is my answer accurate? (3) Is my answer reasonable?”

____”You check for accuracy by looking over your computation in ‘V.’ You can check to see if your answer is reasonable by comparing it to your estimate. The last step in ‘E’ is for you to write your answer as a complete thought.”

____Model for students exactly what to do for each of the above word problems (i.e., problems 1-3) to complete the ‘E’ step.

Students will complete problems 5-8 independently and receive corrective feedback from the instructor.

____Summarize: (5 minute Q & A) (1) In Step “V”, what needs to be done before calculating with the numbers? **Answer:** Make an estimation. (2) How should Step “V” compare with Step “L”? **Answer:** The number calculations should match the word plan. (3) How should Step “V” compare with Step “O”? **Answer:** The numbers to be used in the calculations should be the ones listed in Step “O”. (4) Before writing out the complete sentence in Step “E”, what is the first thing to check? **Answer:** S: Does my answer make sense? (Check Step “S”). (5) Before writing out the complete sentence in Step “E”, what is the second thing to check? **Answer:** R: Is my answer reasonable? (Check the estimate). (6) Before writing out the complete sentence in Step “E”, what is the third thing to check? **Answer:** A: Is my answer accurate? (Check with another student, the teacher, a calculator, or redo the math.) (7) How do all five steps of SOLVE link together? **Answer:** To determine which facts to write in O, you need to look at the S question. To determine the plan for L, you have to look at the question from S and the facts from O. To do the math work in Step V, you have to use the plan from L and the numbers from O. To write out the sentence in E, you have to answer the S question with the answer calculated in V.

____Preview the next lesson. “Today we completed the last two steps of the SOLVE Strategy. Tomorrow we are going practice all of the steps of the strategy verbally. All of you need to make sure that you know the process for each step, and that you are able to verbally tell me what to do for each step. You will also have some practice problems to complete using all 5 steps.”

____Solicit and answer any questions the students may have.

____File completed word problems.

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

Lesson 5 Stage 4: <i>Verbal Practice</i>	Materials
<p>___ Advance organizer:</p> <ol style="list-style-type: none"> Review the purpose of the previous lesson. “Over the past few days you have been learning how to use the SOLVE Strategy to solve mathematical word problems.” State the purpose of this lesson. “Today we will discuss what you have learned and ensure that you know what to do as you use the strategy. Then you will learn to name the steps of the SOLVE Strategy.” Provide a rationale for the lesson: “If you understand and can name the steps, you will be able to tell yourself what to do when you are trying to use the strategy while solving a word problem.” State expectations: “During our discussion, I expect you to pay close attention and to participate when I call on you. Later I will give each of you a quiz, and you will have to answer all my questions correctly to move to the next stage of instruction.” <p>___ Conduct the verbal elaboration exercise. “First, let’s make sure you understand what you are to do for each step of the strategy and why you are to do it. I will ask you some questions, and I want you to answer them to show your understanding.</p> <ul style="list-style-type: none"> What is the main question in Step “S”? Answer: What is the question asking me to find? What is the difference between the problem and the question? Answer above What is the main benefit of Step “S”? Answer: It gives a starting point What do most facts deal with in word problems? Answer: Numbers Can a fact be included in the question? Answer: Yes Are all facts necessary, so need to be listed? Answer: No What should be considered when determining whether a fact is necessary? Answer: look at the “S” question: what is the problem asking me to find? Why is it important in Step L to use words instead of the numbers from the problem? Answer: If words are used, the plan will work no matter what numbers are used What four operations need to be remembered when setting up a 	<ol style="list-style-type: none"> Student folders Management chart Scoring sheets Steps of the SOLVE strategy and helpful hints Cards. Verbal Practice Quiz

plan? **Answer:** Addition, subtraction, multiplication, division

- Does Step L need to be very detailed with a great deal of words? **Answer:** It depends on the word problem itself. Some will be very simple, so do not need as many words or details.
- Is there only one correct way to solve a problem? **Answer:** No, people think differently so many solutions may be correct.
- When calculating $5 + 4 \cdot 7$, what might happen if one student added before multiplying, and another student multiplied before adding? **Answer:** Due to order of operations, they would arrive at different solutions.
- How would you organize your plan for a word problem with many facts included? **Answers will vary, but should have a logical basis.**
- How would you determine which operation(s) to choose when reading a word problem? **Answer:** Variety of answers will be given, but should include: looking at the word wall, looking for key phrases, words, ideas, and visualizing the data in a real world way that makes sense to them.
- In Step “V”, what needs to be done before calculating with the numbers? **Answer:** Make an estimation.
- How should Step “V” compare with Step “L”? **Answer:** The number calculations should match the word plan.
- How should Step “V” compare with Step “O”? **Answer:** The numbers to be used in the calculations should be the ones listed in Step “O”.
- Before writing out the complete sentence in Step “E”, what is the first thing to check? **Answer:** S: Does my answer make sense? (Check Step “S”).
- Before writing out the complete sentence in Step “E”, what is the second thing to check? **Answer:** R: Is my answer reasonable? (Check the estimate).
- Before writing out the complete sentence in Step “E”, what is the third thing to check? **Answer:** A: Is my answer accurate? (Check with another student, the teacher, a calculator, or redo the math.)
- How do all five steps of SOLVE link together? **Answer:** To determine which facts to write in O, you need to look at the S question. To determine the plan for L, you have to look at the question from S and the facts from O. To do the math work in Step V, you have to use the plan from L and the numbers from O. To write out the sentence in E, you have to answer the S question with the answer calculated in V.

____ Introduce the rapid-fire verbal rehearsal exercise. “To help you memorize the strategy steps, we are going to do an exercise called ‘rapid-fire verbal rehearsal.’ I will show you how to do it. I will act as

the leader of the group. I'll be pointing to each person in the succession. When I point to you, I want you to name the next step of the SOLVE Strategy. This is called 'rapid-fire' because you are trying to fire back the name of the step to me as rapidly or quickly as you can after I point to you. Thus, when I point to you, name the step as quickly as you can, and try not to look at the board, you may; however, don't rely on it too much because I am going to take it away after a few rounds of the activity. Instead, try to rely on the mnemonic devise 'SOLVE' and your own memory."

___ Explain what to say. "This is what you should say when you name the steps: The first person I point to will say, 'Study the Problem,' the second person will say, 'Organize the facts.' The third person will say, 'Line up a Plan,' and we will continue until we get through all of the steps.

___ Lead the verbal rehearsal exercise with cues on the Smartboard. "Let's see how fast we can go and how quickly we can memorize the steps. This should be easy for you since you know most of the steps already. Okay, let's begin."

___ Lead the exercise without cues on the Smartboard.

___ Administer the written quiz.

___ Instruct the students to begin, and monitor their work. (Students will be given 20 minutes to complete the test. Additional time will be given if needed)

___ Collect and review the quizzes

___ Provide feedback

___ Fill out the Management Chart

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

Lesson 6—3Days Stage 5: <i>Controlled Practice</i>	Materials
<p>___ Advance organizer:</p> <ol style="list-style-type: none"> 1. Review the purpose of the previous lesson. “Last time we met, you practiced talking about the SOLVE Strategy.” 2. State the purpose of this lesson. “Today and several more days you will practice using all the steps of the SOLVE Strategy on mathematical word problems.” <p>___ Distribute Probe.</p> <p>___ Direct the students to begin practicing. Remind students to tell themselves the SOLVE Steps as they practice to ensure that they use all the steps.</p> <p>___ Supervise the practice activity. Listen to and watch the way students are using the steps of the strategy. Score one or two problems for each student. Give immediate corrective feedback if necessary.</p> <p>___ Collect the materials.</p> <p>___ Score each student’s performance. Using the appropriate answer key, score each student’s products. Calculate the percentage of points the student earned.</p> <p>___ Provide feedback to students.</p> <ol style="list-style-type: none"> a. Provide positive feedback. b. Provide corrective feedback. c. Stress fluency in using the strategy d. Review the answer results <p>___ File completed probe in student folders.</p> <p>___ Fill out the Management Chart</p> <p>**Note: 80% mastery required to move to next grade level**</p>	<ol style="list-style-type: none"> 1. Student folders 2. Management chart 3. Scoring sheets 4. Steps of the SOLVE strategy and helpful hints Cards. 5. Foldable 6. Controlled Practice Probe

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

Lesson 7—Several Days Stage 6: Advanced <i>Practice and Feedback</i>	Materials
<p>___ Advance organizer:</p> <ol style="list-style-type: none"> 3. Review the purpose of the SOLVE Strategy. 4. Introduce the practice activity. “Today and the next few days, you will practice using the SOLVE Strategy on more and more difficult mathematical word problems.” 5. State expectations. “You will begin today by practicing the strategy with materials on your grade level. 6. Provide instructions. “Each time you are assigned a new set of words problems. After you get your word problems, how will you begin?” Answer: By using the SOLVE Strategy or the S-step. 7. Explain what to do. “I think you know what to do now. I will be circulating among you, but raise your hand if you have completed the assignment. I will check that it is complete.” <p>___ Ensure the students have the materials, and instruct them to begin.</p> <p>___ Circulate, record progress, and provide help and feedback.</p> <p>___ Collect the materials.</p> <p>___ Score each student’s performance. Calculate the percentage of points the student earned. Identify students who will need individual help the next session.</p> <p>___ Provide feedback to students. Provide positive feedback b. Provide corrective feedback.</p> <p>___ Instruct students to progress through the grade levels. When records indicate that a student is using the strategy correctly and independently AND is earning scores of 80% and above, tell the student that he/she can move up to the next grade level for the next practice activity (This will be written down for students).</p> <p>___ File completed probe in student folders. Fill out the Management Chart</p> <p style="text-align: center;">**Note: 80% mastery required to move to next grade level**</p>	<ol style="list-style-type: none"> 1. Student folders 2. Management chart 3. Scoring sheets 4. Steps of the SOLVE strategy and helpful hints Cards. 5. Foldable 6. Advanced Practice Probe

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

Lesson 8 Stage 7: Posttest	Materials
<p>___ Advance organizer: “Today we are going to find out two things. First, we need to know whether you can solve one- and two-step equations. Second, we need to know if you can solve those same equations when they are asked in a word problem. For that reason, I will give you some math problems that were written for students at your grade level.”</p> <p>___ Distribute the materials. (1) Test paper, (2) Steps of the SOLVE strategy and helpful hints Card</p> <p>___ Give instructions for the posttest. “Each of you should have a test paper in front of you. You may write on the test paper. Be sure to show all of your work and use any strategy that you know to help you complete your work.”</p> <p>___ Solicit and answer questions.</p> <p>___ Instruct the students to begin, and monitor their work. (Students will be given 20 minutes to complete the test. Additional time will be given if needed)</p> <p>___ Collect the tests. [Students should place their test in their folder provided by the instructor]</p> <p>___ Score the tests.</p> <p>___ Communicate the results to the students</p> <p>___ Fill out the Management Chart</p>	<ol style="list-style-type: none"> 1. Copies of the post-assessment 2. Management chart 3. Scoring sheets 4. Steps of the SOLVE strategy and helpful hints Cards 5. Student folders

APPENDIX H: SCRIPTED LESSON PLANS (CONTINUED)

Lesson 9 Stage 8: <i>Generalization</i>	Materials
<p>___Have students bring their textbooks to the session along with their homework.</p> <p>___Advance organizer:</p> <ol style="list-style-type: none"> Review the previous lesson(s). “Now that you are masters of the SOLVE Strategy, you can use your new tool in lots of places, on a variety of reading materials, and in combination with the other strategies you know.” State the purpose of this stage of instruction. “Remember, this strategy is like money in your savings account in the bank. You have invested a lot of time in learning the SOLVE Strategy. Now you’re going to learn how to use that investment wisely. Just like money, if you try to use the strategy in the wrong places, it won’t pay off for you. Thus, today we’ll discuss situations where you might use the SOLVE Strategy. We’re going to get ready to recognize those situations and use the strategy.” State expectations. “As we discuss how you will be using this strategy, I expect you to pay attention and contribute to the discussion.” <p>___Discuss rationales for generalizing the SOLVE Strategy. “What are some of the reasons why you should use the SOLVE Strategy outside of this classroom along with other strategies you know?”</p> <p>___Discuss the importance of individual effort in the generalization process. “We’re going to be spending some time on generalization because often students learn something new and forget to use it. It’s similar to buying a new CD for which you’ve saved for several weeks, and never playing it.”</p> <p>“You have already expended a great deal of effort learning this new strategy. Unfortunately, you won’t have success unless you expend a bit more effort each time using it is appropriate. In the long run, that effort will pay off in higher test scores, better grades, improved understanding, and a base of knowledge that you can use for the rest of your life.”</p> <p>___Discuss situations where the strategy is applicable. Example Math class, science class, etc.</p>	<ol style="list-style-type: none"> Copies of generalization probes Management chart Scoring sheets Steps of the SOLVE strategy and helpful hints Cards Probes Student folders

___ Discuss using the strategy in combination with other strategies.

___ Discuss adapting the strategy.

___ Discuss the tool box analogy. “The SOLVE Strategy is one of the tools in your learning toolbox. It’s like one of the tools you might use to build a house. If you leave the hammer in your toolbox and never use it, you won’t get very far in building a house. That tool is critical to the building process. Likewise, the SOLVE Strategy is a critical tool to the learning process. You use the SOLVE Strategy to make sure that you understand and can solve the word problems that are presented to you. It is one of the ways that you build your knowledge base.”

___ Discuss the knowledge-base analogy. “Your knowledge base refers to all the information you know and can use to help you live your life successfully. Your knowledge base is like a huge building with many floors. In a tall building, each floor is built solidly before the next floor can be added. This is how your knowledge base grows. If you know something, you can add new knowledge on top of it. You won’t be able to add new knowledge until the first floor of your knowledge base is stable. That means you have to understand some information before you can add more.”

___ Introduce the generalization assignments. “You will be applying the SOLVE Strategy and the other strategies you know to a variety of materials.”

___ Distribute the generalization probe.

___ Circulate, monitor the student’s work, and provide help and feedback

___ Score the probe.

___ Communicate the results to the students

___ Fill out the Management Chart

APPENDIX I: SOCIAL VALIDITY QUESTIONNAIRES

Social Validity Questionnaire (Teacher Form)

Teacher: _____ Date: _____

This questionnaire consists of 7 items. For each item, please indicate the extent to which you agree or disagree with the statement. Please indicate your response to each item by circling one of the five responses to the right for questions 1-6 and provide a written response for questions 7.

Questions	Responses				
1. Instruction in the SOLVE Strategy is relevant for my students based on the mathematics curriculum and required testing.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
2. Given the time required to teach the SOLVE Strategy; I feel that it could be taught in the general education classroom with a larger group of students.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
3. Given the outcomes, I would use the strategy following the prescribed instructional procedures.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
4. I am considering using the intervention for other students in future.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
5. Student's ability to solve word problems increased in accuracy and consistency during the intervention.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
6. I am considering sharing this information with other teachers within my school.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
7. What changes/additions would you suggest for the intervention? (Use the back if necessary)					

APPENDIX I: SOCIAL VALIDITY QUESTIONNAIRES (CONTINUED)

Social Validity Questionnaire (Student Form)

Student: _____

Date: _____

This questionnaire consists of 7 items. For each item, please indicate the extent to which you agree or disagree with the statement. Please indicate your response to each item by circling one of the five responses to the right for questions 1-7 and provide a written response for questions 8.

Questions	Responses				
1. Before I learned the SOLVE Strategy I was not good at solving mathematical word problems.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
2. After I learned the SOLVE Strategy I was able to attack and solve word problems correctly.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
3. I know what steps I can take to get started solving a word problem.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
4. I have started using the SOLVE Strategy in my math class.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
5. I feel comfortable using the SOLVE Strategy while I solve word problems in class.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
6. I would consider sharing the SOLVE Strategy with other students at my school.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
7. Since learning the SOLVE Strategy I can see a change in my grades in my math class.	Strongly Agree	Agree	Not Sure	Disagre e	Strongly Disagree
8. What changes/additions would you suggest if this strategy was to be taught to another group of students? (Use the back if necessary)					

APPENDIX J: LETTERS OF CONSENT AND ASSENT



UNC CHARLOTTE
The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001

College of Education
Department of Special Education
and Child Development
704/687-2531
FAX 704/687-2916

Parent Consent Form for
Participation in Educational Research

November 1, 2012

Dear Parent or Guardian:

I am Shaqwana Freeman, a doctoral student of Dr. Christopher O'Brien, from the Special Education Department at the University of North Carolina at Charlotte. I am excited to request permission for your child to participate in a research study to be used for my dissertation. I am conducting a research study on how well instruction in the SOLVE Strategy, a mathematical word problem solving strategy; will increase student's ability to successfully solve mathematical word problems. In other words, I want to find out if teaching students a way to attack mathematical word problems (SOLVE Strategy) will improve their math scores.

Students who participate in the study will meet the following inclusion criteria: a) identified as having a specific learning disability; b) able to compute one-step mathematical equations, but not in word problem format as measured by a pretest; c) obtain a score on a standardized math test, the Woodcock-Johnson® III (WJ III; Woodcock, McGrew, & Mather, 2001) that is at least two grade levels below their current grade level; d) has consistent attendance (i.e., absent less than two times per month); and e) recommended by his teacher to participate.

If you agree for your child to participate in this study, your child will be asked to complete the following activities:

7. Take part in 10 instructional sessions over the course of 2 weeks. Each instructional session will last for 30 minutes during study hall as not to interfere with instructional class time.
8. During these instructional sessions your child will: (1) be taught the SOLVE Strategy, (2) create a foldable that includes all of the steps of the SOLVE Strategy that can be used in their regular mathematics class, (3) practice using the strategy by solving word problems from their math class.

The study will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only Dr. O'Brien and I will have access to information from your child. Participation in this study is voluntary. Your decision whether or not

APPENDIX J: LETTERS OF CONSENT AND ASSENT (CONTINUED)

to allow your child to participate will not affect the services normally provided to your child. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

As teachers we are always seeking effective strategies for improving academic performance. We hope to use what we learn from this study to offer suggestions of how to better teach students how to solve mathematical word problems.

Any information about your child's participation, including their identity and the school, is completely confidential. The following steps will be taken to ensure this confidentiality:

1. I will code all data using pseudonyms (made up names) before the information is brought back to the research team. Educational data including grade, age, gender, ethnicity, and intelligence quotients will be collected, but will not be linked to a specific student in final reports or shared with other members of the research team.
2. Data collected will be stored in my office in a locked cabinet at the University of North Carolina at Charlotte.
3. The data will be presented using pseudonyms (made up names) in final reports.
4. All data that will be transferred to a digital format will be inputted on a password protected computer on a secure network.
5. Audio recordings of the sessions will be destroyed at the conclusion of the study.

Should you have any questions or desire further information, please feel free to contact

Ms. Shaqwana Freeman
Principal Investigator
Special Education Department
University of North Carolina at Charlotte
Charlotte
Charlotte, NC 28223
(704) 687-5751
smfreema@uncc.edu

Dr. Christopher O'Brien
Associate Professor
Special Education Department
University of North Carolina at
Charlotte, NC 28223
(704) 687-8855
christopher.obrien@uncc.edu

Keep this letter after completing and returning the signature page to me.

UNC Charlotte wants to make sure that you are treated in a fair and respectful manner. Contact the university's Research Compliance Office (704-687-1871) if you have questions about how you or your child are treated as a study participant. If you have any questions about the actual project or study, please contact Dr. Christopher O'Brien (704)-687-8855 (christopher.obrien@uncc.edu)

Sincerely,

Shaqwana M. Freeman
Doctoral Candidate

APPENDIX J: LETTERS OF CONSENT AND ASSENT (CONTINUED)

Please sign and return this page.

I have read the information in this consent form. I have had the chance to ask questions about this study and about my child's participation in the study. My questions have been answered to my satisfaction. I am at least 18 years of age, and I agree to allow my child to participate in this research project. I understand that I will receive a copy of this form after it has been signed by me and the researcher of this study.

Signature of Parent/Guardian

Printed Parent/Guardian Name

Printed Name of Child

Date

Researcher's Signature

Date

APPENDIX J: LETTERS OF CONSENT AND ASSENT



The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001

Teacher Consent Form for
Participation in Educational Research

November 1, 2012

Dear Teacher:

I am Shaqwana Freeman, a doctoral student of Dr. Christopher O'Brien from the Special Education Department at the University of North Carolina at Charlotte. I am excited to request permission for your participation in a research study to be used for my dissertation. I am conducting a research study on how well instruction in the SOLVE Strategy will increase student's scores ability to successfully solve mathematical word problems. In other words, I want to find out if teaching students a way to attack mathematical word problems will improve their math scores. All of the instruction will occur during the regular school day (i.e., study hall) and take approximately eight weeks. Students will be divided into three groups, and each group will receive instruction in the SOLVE Strategy for 30 minutes per day for approximately 2 weeks. There will be eight student participants, one teacher, and two researchers.

If you agree to participate in this study, you will be asked to complete the following activities:

1. Provide students with directions to complete their test probe for that day from a scripted lesson plan once they have mastered the SOLVE Strategy.
2. Provide students with corrective feedback based on their work performance as suggested by the researchers.
3. Turn in students completed practice and test problems to the researchers.
4. Complete a questionnaire at the end of the study about your experience using the SOLVE Strategy.

The study will be explained in terms that your students can understand, and your students will participate only if he is willing to do so and I receive parental permission. Only Dr. O'Brien and I will have access to information from you and your students. Participation in this study is voluntary. Even if you give your permission to participate you are free to end participation at any time. As teachers we are always seeking effective strategies for improving academic performance. We hope to use what we learn from this study to offer suggestions of how to better teach students how to solve mathematical word problems.

APPENDIX J: LETTERS OF CONSENT AND ASSENT

Any information about your students' and your participation, including their identity and the school, is completely confidential. The following steps will be taken to ensure this confidentiality:

6. I will code all data using pseudonyms (made up names) before the information is brought back to the research team.
7. Data collected will be stored in my office in a locked cabinet at the University of North Carolina at Charlotte.
8. The data will be presented using pseudonyms (made up names) in final reports.
9. All data that will be transferred to a digital format will be inputted on a password protected computer on a secure network.
10. For portable devices, such as a laptop computer and a flash drive, will be locked in a container for transporting and when not in use.

Should you have any questions or desire further information, please feel free to contact

Ms. Shaqwana Freeman
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Keep this letter after completing and returning the signature page to me.

UNC Charlotte wants to make sure that you are treated in a fair and respectful manner. Contact the university's Research Compliance Office (704-687-1871) if you have questions about how you or your child are treated as a study participant. If you have any questions about the actual project or study, please contact Dr. Christopher O'Brien (704)-687-8855 (christopher.obrien@uncc.edu)

Sincerely,

Shaqwana M. Freeman
Doctoral Candidate

APPENDIX J: LETTERS OF CONSENT AND ASSENT (CONTINUED)

Please sign and return this page.

I have read the information in this consent form. I have had the chance to ask questions about this study and about my participation in the study. My questions have been answered to my satisfaction. I am at least 18 years of age, and I agree to participate in this research project. I understand that I will receive a copy of this form after it has been signed by me and the researcher of this study.

Signature of Teacher

Printed Teacher Name

Date

Researcher's Signature

Date

APPENDIX J: LETTERS OF CONSENT AND ASSENT (CONTINUED)



College of Education
Department of Special Education
and Child Development
PHONE 704/687-2531
FAX 704/687-2916

Student Assent Form for
Participation in Educational Research

Dear Student:

As you know I attend school just like you do. I am asking you to take part in my research study because I am trying to learn more about how instruction in the SOLVE Strategy will help you increase your scores in your mathematics class.

If you agree to be in this study, I will ask you to do a few things over the next few weeks. I will ask you to put forth your best effort to learn the strategy, I will ask you to practice solving some word problems with me and on your own, and then I will ask you questions about how you liked using the SOLVE Strategy. All of the instruction will occur during study hall, and you will be placed into one of three groups. Each group will receive instruction in the SOLVE Strategy for 30 minutes per day for approximately 2 weeks and all sessions will be audio recorded. Once the study is complete I will destroy all of the audio recordings.

I hope that this new way of attacking word problems will help you and other students learn to solve mathematical word problems better, but I can't be sure it will. This study will not hurt you. When I am done with the study I will write a report. I will not use your name in the report.

You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can ask me next time. Signing your name at the bottom means that you agree to be in this study.

Signature of Student

Printed Name of Student

Date

Researcher's Signature

Date

APPENDIX K: LETTER OF SUPPORT

Maria M. Leahy
Associate Head of School
The John Crosland School
5146 Parkway Plaza Blvd.
Charlotte, NC 28217
November 6, 2012



Shaqwana Freeman
Department of Special Education and Child Development
University of North Carolina at Charlotte
9201 University City Blvd
Charlotte, NC 28223

Dear Shaqwana:

I am writing to commit support of your project, teaching students the SOLVE Strategy to help increase their problem solving skills in mathematics. The need for increased knowledge and implementation of effective teaching practices is essential to the future achievement of students in our schools.

Our school recognizes the need for students and teachers to have access to teaching strategies that reflect best practice. Being able to obtain, view, and study best practice examples is essential to the professional growth of teachers. We are excited that this strategy will be available to our teachers and students at no cost.

I am excited to support this project being developed and disseminated at the John Crosland School. Implementation of this project will benefit more than just our school. As the SOLVE Strategy is developed and shared, schools throughout our large metropolitan area will have access to the materials.

Sincerely,

Maria M. Leahy

Maria M. Leahy
Associate Head of School