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Improving the word problem solving abilities of students with disabilities: Cognitive Strategy Instruction (CSI) compared to Schema-Based Instruction (SBI)

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IMPROVING THE WORD PROBLEM SOLVING ABILITIES OF STUDENTS

WITH DISABILITIES: COGNITIVE STRATEGY INSTRUCTION (CSI) COMPARED

TO SCHEMA-BASED INSTRUCTION (SBI)

by

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Abstract

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The purpose of this research was to compare Cognitive Strategy Instruction (CSI) and Schema-Based Instruction (SBI) and determine which is more effective at improving the mathematical word problem solving abilities of eighth grade students with disabilities. Two students with disabilities who were also at risk for mathematics failure were chosen to participate in this study. The research phase consisted of a baseline data collection period followed by an intervention period, a probe, a second intervention period, and a final probe. Cognitive strategy cue cards and schematic diagrams were created for this study. Both Student A and B received their assigned strategy instruction two times a week for two weeks before being administered a probe and switching to the alternate intervention. The participant's scores during the baseline and treatment periods were recorded and analyzed. While both CSI and SBI improved the participants' ability to solve math word problems, schema-based instruction was proven to be more effective.

Table of Contents

Table of Contents (Continued)

List of Figures

List of Tables

Chapter 1

Introduction

Math is applicable to every area of life. Computation, reasoning, and problem solving are all skills that are used daily. Furthermore, increasing evidence suggests that high levels of mathematical and technical skills are needed for most jobs in the 21st century (Xin, Jitendra, Deatline-Buchman, 2005). Thus, it is important for teachers to ensure that all students, including students with disabilities, have those skills. In fact, 2002's No Child Left Behind Act mandates that these students are held accountable to the same high academic standards as general education students.

In order to develop mathematical literacy, students must have an understanding of mathematical facts (i.e., declarative knowledge), rules and procedures (i.e., procedural knowledge), and relationships (i.e., conceptual knowledge) (Hallahan, Lloyd, Kauffman, Weiss, & Martinez, 2005). Students with learning disabilities often have problems in all of these areas. They encounter difficulty recalling basic math facts, recognizing operational symbols, borrowing or carrying numbers, lining up numbers, and applying math algorithms correctly. Compounding the problem is the fact that deficits in math tend to persist and increase over time. To date, most instructional interventions in mathematics tend to focus on basic skills such as computation rather than higher-order skills such as reasoning and problem solving (Xin et al., 2005). As a result, students are taught procedures as opposed to concepts. This hinders their learning in that these students never broaden their understanding of math.

One area of math that is especially difficult for students with learning disabilities is word problems. Word problems often include extraneous information, multiple steps, use of complex syntactic structures, change of number and type of noun used, and indirect language (e.g., using verbs such as "purchased" or "bought" rather than "was given") (Hallahan et al., 2005). While reading problems and lack of basic computation skills often adversely affect the performance of students with learning disabilities, their performance is further hindered by difficulties in problem representation as well as the inability to identify relevant information and select a strategy to solve the problem.

Currently, several instructional strategies are used to teach students with disabilities how to tackle word problems. One commonly used approach is the "key word" approach, which teaches students to use key words to cue them to the correct operation for solving the problem. Using this strategy students learn that terms such as "total" and "more" indicate addition while words such as "less" and "left" indicate subtraction. While this strategy may benefit younger students who have not yet encountered more complex word problems, it is troublesome for older students. According to Parmar et al. (1996), "the outcome of such training is that the student reacts to the cue word at a surface level of analysis and fails to perform a deep-structure analysis of the interrelationships among the word and the context in which it is embedded" (p. 427). Instead of focusing on the relationship between the information that is available in the word problem, students react to cue words— words that often lead them to choose the wrong operation when problem solving.

Instead of using reason to guide their thinking, students adopt a systematic and mechanical approach to problem solving.

Another frequently used strategy is the general heuristic procedure that is common to many mathematics textbooks. This multi-step strategy requires that students read, plan, solve, and check (Jitendra & Star, 2011). This involves: reading the word problem, finding what information is relevant and devising a plan to solve the problem—many times this involves drawing a picture or a diagram, solving the problem, and checking back by rereading the problem to determine whether or not the answer makes sense. Unfortunately, this method is too general for students with learning disabilities and does not provide the necessary scaffolds for those who are not already familiar with the strategies to implement them.

A third approach, cognitive strategy instruction (CSI), explicitly teaches cognitive and metacognitive processes and strategies in order to alleviate the difficulties in both areas that students with disabilities often experience (Montague & Dietz, 2009). Metacognition is the ability to analyze a task, select a strategy for completing the task, and monitor and revise the strategy as needed (Hallahan et al., 2005). It is what allows individuals to adjust to varying task demands and contexts (Montague, 1997).

CSI incorporates specific cognitive strategies (e.g., visualization, verbal rehearsal, paraphrasing, summarizing, estimating) as well as metacognitive strategies (e.g., self-instruction, self-monitoring, self-evaluation) to help students select and monitor strategy use. In other words, it teaches students with learning disabilities how to think and conduct themselves like effective problem solvers.

Cognitive strategy instruction includes seven processes for mathematical word problem solving: reading the problem for understanding, paraphrasing by putting the problem into one's own words, visualizing by drawing a schematic representation, hypothesizing or setting up a plan, estimating or predicting the answer, computing, and checking that the plan and answer are correct (Montague & Dietz, 2009).

The last approach, schema-based instruction (SBI), borrows heavily from schema theory of cognitive psychology to address some of the concerns of traditional problem solving instruction (Jitendra et al., 2011). Before students are able to devise a plan to problem solve, they must first differentiate between relevant and irrelevant information. In order to be able to decide what information is relevant and irrelevant, students must understand how each problem component relates to the other problem components; this is known as a schematic representation (van Garderen & Montague, 2003). Only when students understand the problem structure can they decide what information is missing and choose the correct strategy to solve the problem. Since students with learning disabilities lack this ability, they must be taught systematically and explicitly how to represent word problems conceptually. Thus, schema-based instruction goes beyond the surface features of word problems to identify the problem schema (i.e., semantic structure) and helps students analyze the underlying mathematical relationships that are critical to effective problem solving (Jitendra et al., 2011).

Out of the four aforementioned approaches, only two incorporate National Mathematics Advisory Panel recommendations (e.g., systematic-explicit instruction,

think-alouds, visual representations) and address the deficits of students with learning disabilities—cognitive strategy instruction and schema-based instruction. This study is designed to evaluate whether cognitive strategy instruction or schema-based instruction is more effective at improving the word problem solving abilities of students with disabilities. The sample will consist of two students in an alternating treatments design. One student will be instructed in cognitive strategy instruction before getting switched to schema-based instruction while the second student will begin with SBI before getting switched to CSI.

Research Problem and Hypothesis:

The research question that is being investigated in this study is:

Is cognitive strategy instruction (CSI) or schema-based instruction (SBI) more effective at improving the word problem solving abilities of students with disabilities?

This study will evaluate the effects of cognitive strategy instruction versus schema-based instruction. I hypothesize that schema-based instruction is more effective than cognitive-strategy instruction because SBI teaches a student to understand math conceptually. Students must have conceptual knowledge before they are taught procedural knowledge—otherwise they are merely memorizing a series of steps and will not be able to apply the skills to novel situations.

Key Terms:

Cognitive Strategy Instruction (CSI): An instructional method that explicitly teaches cognitive and metacognitive processes and strategies; it incorporates specific cognitive strategies (e.g., visualization, verbal rehearsal, paraphrasing, summarizing, estimating) as well as metacognitive strategies (e.g., self-instruction, self-monitoring, self-evaluation) to help students select and monitor strategy use.

Heuristic method: A problem solving approach that is common to many mathematics textbooks; the strategy requires that students read the word problem, plan how to solve it, solve the problem, and check back to determine whether or not their answer makes sense.

Key word method: A problem solving approach that teaches students to use key words to cue them to the correct operation for solving word problems.

Schema (plural schemata): A conceptual system for knowledge; schemata represent knowledge about concepts—objects and the relationships they have with other objects, situations, events, sequences of events, actions, and sequences of actions.

Schema-Based Instruction (SBI): An instructional method that combines both the key word and heuristic approaches to solving word problems; it teaches students to analyze the relationships between the different problem components in order to plan how to solve word problems.

Schema theory: A theory based on cognitive psychology that all knowledge is organized into units. Within these units of knowledge, or schemata, is stored information.

Schematic representation: A representation that shows how each problem component relates to the other problem components.

Schematic diagram: A graphic organizer that students complete that shows the relationship of the various problem components to each other.

Students with learning disabilities: Students who have a disorder in one or more of the basic psychological processes involved in understanding or using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia.

Word problem: A mathematical problem presented in a story format.

Implications

The findings of this study are important in that it adds to the current knowledge base on cognitive strategy instruction, schema-based instruction, and interventions for students with disabilities who experience difficulty with math word problem solving. In comparing CSI to SBI the study attempts to uncover whether it is more beneficial to know how to think and act like an effective problem solver or whether it is more useful to recognize the structure of word problems since an understanding of mathematical relationships will facilitate problem solving.

Summary

Many students with learning disabilities experience significant difficulty solving mathematical word problems. Word problems include irrelevant information, multiple steps, indirect language, and complex sentence structures that can pose a problem for students who often also have reading impairments. Out of the four instructional strategies (i.e., key word approach, general heuristic procedure, cognitive strategy instruction, schema-based instruction) that are used to teach students with disabilities how to tackle word problems, only two— cognitive strategy instruction and schema-based instruction—incorporate National Mathematics Advisory Panel recommendations of systematic-explicit instruction, think-alouds, and visual representations to address the deficits of students with special needs. Consequently, this study will focus on CSI and SBI. Two eighth grade students with learning disabilities will be instructed in both strategies and their progress in solving math word problems with each intervention will be monitored.

Chapter 2

Literature Review

<u>Learning Disabilities Overview</u>

Improving the mathematical problem solving abilities of students with learning disabilities has been difficult. These students experience difficulty "in one or more of the basic psychological processes involved in understanding or using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations" (IDEA 2004). However, in addition to having problems with reading, writing, listening, speaking, and math, students with learning disabilities also have deficits in cognitive processes such as perception, attention, memory, and metacognition (Jitendra & Star, 2011).

<u>Math Difficulties of Students with Learning Disabilities</u>

Generally, math errors fall into one of three subtypes: semantic, procedural, or visual-spatial (McLean & Hitch, 1999). Students with semantic math disabilities encounter difficulty reading and writing numbers, show poor mastery of basic math facts, and make operand errors (e.g., adding when there is a subtraction symbol). Those with procedural math disabilities use immature procedures in calculations (e.g., adding 3 + 7 instead of 7 + 3) and struggle to remember sequences in mathematical algorithms, oftentimes confusing the steps in complex operations. Lastly, students with visual-spatial deficits struggle with place value, lining up numbers, and perceiving horizontal and vertical information clearly.

According to the information-processing theory, memory plays a role in learning (Hallahan et al., 2005). Short-term memory holds information for short-term retrieval before either discarding it or sending it to working memory for processing (Hallahan et al., 2005). In working memory, information is processed and manipulated in a range of cognitive tasks (Masoura, 2006). Long-term memory stores information over a long period of time—making it available to be retrieved, processed, and reintegrated with new information by the working memory system in various cognitive tasks (Hallahan et al., 2005).

The components of working memory have specialized roles in math and deficits in working memory have been linked to math learning disabilities (McLean & Hitch, 1999). The phonological loop and the visuo-spatial sketchpad are involved in the storage of domain-specific information—auditory information and visual information, respectively. The phonological loop is responsible for counting, encoding and maintaining arithmetical operands, and holding intermediate information in complex calculations (McLean & Hitch, 1999). The visuo-spatial sketchpad is activated in multi-digit problems where visual and spatial knowledge of column positioning is required and in algebraic and geometric problem solving (McLean & Hitch, 1999). As the command center of the working memory system, the central executive is responsible for many functions involved in mathematics. These include sequencing operations, coordinating multi-step tasks, switching retrieval strategies, directing the flow of information, attending selectively to different inputs, and activating and manipulating information in long-term memory

(McLean & Hitch, 1999). As a result, impairments in any of these components can lead to semantic, procedural, or visual-spatial errors.

These difficulties are magnified for students with learning disabilities when they have to solve word problems. Word problems often include extraneous information, multiple steps, use of complex syntactic structures, change of number and type of noun used, and indirect language (e.g., using verbs such as "purchased" or "bought" rather than "was given") (Hallahan et al., 2005). While reading problems and lack of basic computation skills often adversely affect the performance of students with learning disabilities, their performance is further hindered by difficulties in problem representation as well as the inability to identify relevant information and select a strategy to solve the problem. Consequently, interventions must address these deficits and scaffold student learning. The National Mathematics Advisory Panel (2008) advocates practices that include: systematic-explicit instruction; student think-alouds; visual representations; peer-assisted learning opportunities in which students focus on problem details, observe or are guided by models of proficient students' problem solving; and formative assessments to provide feedback to teachers and students.

Previous Attempts to Improve the Word Problem Solving Abilities of Students with Learning Disabilities

Currently, several instructional methods are used to teach students with disabilities how to tackle word problems. They include the "key word" strategy, the general heuristic approach, cognitive strategy instruction, and schema-based

instruction. While each approach has its merits, only two of the methods incorporate practices that address the deficits of students with special needs.

One commonly used strategy is the "key word" approach, which teaches students to use key words to cue them to the correct operation for solving the problem. Using this method students learn that terms such as "total" and "more" indicate addition while words such as "less" and "left" indicate subtraction. While this technique may benefit younger students who have not yet encountered more complex word problems, it is troublesome for older students. According to Parmar et al. (1996), "the outcome of such training is that the student reacts to the cue word at a surface level of analysis and fails to perform a deep-structure analysis of the interrelationships among the word and the context in which it is embedded" (p. 427). Instead of focusing on the relationship between the information that is available in the word problem, students react to cue words—words that often lead them to choose the wrong operation when problem solving. Instead of using reason to guide their thinking, students adopt a systematic and mechanical approach to problem solving.

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with learning disabilities and does not provide the necessary scaffolds for those who are not already familiar with the strategies to implement them.

A third approach, cognitive strategy instruction, explicitly teaches cognitive and metacognitive processes and strategies in order to alleviate the difficulties with metacognition that students with disabilities often experience (Montague & Dietz, 2009). Metacognition is the ability to analyze a task, select a strategy for completing the task, and monitor and revise the strategy as needed (Hallahan et al., 2005). It is what allows individuals to adjust to varying task demands and contexts (Montague, 1992).

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Cognitive Strategy Instruction vs. Schema-Based Instruction

Out of the four aforementioned approaches, only two incorporate National Mathematics Advisory Panel recommendations and address the deficits of students with learning disabilities—cognitive strategy instruction and schema-based instruction.

Several studies support the effectiveness of cognitive strategy instruction in improving the mathematical problem solving abilities of students with disabilities. Montague and Bos (1986) investigated the effects of cognitive strategy instruction on the math problem solving abilities of six students with learning disabilities. The sample consisted of five males and one female who were between the ages of 15 and

19. Additional criteria for participation in the study included a score at least one standard deviation below the mean on the arithmetic subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R), a reading level of at least fourth grade as measured by the reading achievement cluster of the Woodcock-Johnson Psycho-Educational Battery (WJPB), and a score of 40% of less on a test that consisted of ten two-step word problems.

Prior to beginning the intervention baseline data was collected on each student. The participants were given a pretest; their scores and completion time were recorded. The intervention began once a stable baseline was evident. The instructional sessions lasted 50 minutes and took place during the students' regularly scheduled math class.

The intervention was comprised of strategy acquisition training, strategy application practice, and a posttest. The subjects were taught to read the problem aloud, paraphrase the problem aloud, visualize by drawing a representation of the problem, state the problem, hypothesize a solution, estimate the answer, calculate the answer, and self-check by referring back to the problem and checking each step to determine the accuracy of the operations selected and the solution. In addition, the participants were required to recite the strategy steps from memory. Once they were able to do so, strategy application practice began. On the day before each test, a review session was held. The students were required to verbalize the strategy and practice solving word problems using the strategy. Corrective feedback was provided during these sessions. On the next day the subjects were given the posttest, which consisted of ten two-step math word problems. The mastery

criterion was set at 70% (i.e., seven out of ten questions correct). The participants

were cued to use the strategy. Again, data was collected on scores and test

completion time.

In addition to the posttest, a generalization and maintenance test were also

given. The generalization test consisted of ten three-step math word problems. Its

purpose was to determine if the students were able to generalize the cognitive

strategy instruction training to more complex word problems. A criterion of 50%

was established as the level of acceptability. Two weeks after the generalization test

a maintenance test was given. Similar to the previous tests, it consisted of ten two-

step math word problems. Subjects who scored below a 70% were retrained on the

strategy, provided with practice sessions, and retested. The intervention was

terminated for participants who scored a 70% or higher.

Posttest results indicated that five of the six students improved in their

ability to solve two-step math word problems. The subjects generally solved an

additional five to six word problems correctly after cognitive strategy instruction.

Four students met the criterion of 50% set for the generalization test. However,

Montague and Bos hypothesized that this was due to the fact that the test was given

the day before a two-week school vacation. Three students met the mastery

criterion for the maintenance test.

A second study—also conducted by Montague (1992)—examined the effects

of cognitive strategy instruction combined with metacognitive strategy instruction

on the mathematical problem solving abilities of six students with learning

disabilities. The study participants consisted of two sixth, two seventh, and two

eighth grade students who were randomly selected out of 14 students with learning disabilities. Additional criteria for participation in the study included a full scale IQ of 90 or better on the Wechsler Intelligence Scale for Children-Revised (WISC-R), proficiency in basic operations of whole numbers and decimals as measured by the Woodcock Johnson Psycho-Educational Battery (WJPB), and a score of 60% or lower on a test that consisted of one-, two-, and three-step word problems. The six students were then divided into two treatment groups that were comprised of one sixth, one seventh, and one eighth grade student.

Baseline data was collected on each student before beginning the intervention. This consisted of the students' scores on a pretest consisting of one-, two-, and three-step word problems. The amount of time needed by each student to complete the pretest was also noted.

The intervention was provided in two phases and lasted for four months from February to June. The students were provided with individual intervention sessions in a separate room during their regularly scheduled 55-minute math class. Students in the first treatment group received cognitive strategy instruction (CSI) in Phase 1 and metacognitive strategy instruction (MSI) in Phase 2 while students in the second treatment group received MSI in Phase 1 and CSI in Phase 2. This ensured that all subjects received both cognitive and metacognitive strategy instruction.

Strategy acquisition training was conducted over three 55-minute sessions. It included discussion of strategies currently employed by the students for word problem solving, demonstration of either the CSI or MSI strategy, and guided

16

practice. The CSI students learned the names of the cognitive processes and their descriptions. They consisted of Read (for understanding), Paraphrase (your own words), Visualize (a picture or a diagram), Hypothesize (a plan to solve the problem), Estimate (predict the answer), Compute (do the arithmetic), and Check (make sure everything is right). Students were instructed to use the initial letters of the processes as a mneumonic. The MSI students learned the metacognitive activities associated with each cognitive process; they were Say, Ask, and Check. The MSI students were not required to memorize the metacognitive activities. Testing for the CSI students began when they demonstrated that they were able to recall from memory the cognitive processes. Testing for the MSI students began after the three days of strategy acquisition training. The Phase 1 mastery tests were parallel forms of the pretest and consisted of ten one-, two-, and three-step math word problems. Again, data was collected on the number of correct responses as well as test completion time.

In Phase 2, the CSI students received metacognitive strategy instruction while the MSI students received cognitive strategy instruction. Due to time constraints Montague could not strictly adhere to the mastery criterion for the first treatment (i.e., either seven correct responses on four consecutive tests or seven correct responses on five of seven tests) before introducing the second treatment. However, attempts were made to delay beginning Phase 2 until a stable upward trend was evident on the Phase 1 mastery tests. Again, strategy acquisition training included demonstration of either the CSI or MSI strategy and guided practice. The word problem tests were administered after the three days of strategy acquisition

training. Guided practice sessions were provided to students whose test results fell below seven correct responses.

The mastery tests given at the conclusion of each intervention phase demonstrated the effectiveness of each individual intervention (i.e., CSI versus MSI) as well as revealed the differences that resulted from variations in sequence of instruction (i.e., CSI followed by MSI versus MSI followed by CSI). Results on the Phase 1 mastery tests indicated that three days of cognitive strategy instruction alone did not improve students' ability to solve math word problems. In contrast, three days of metacognitive strategy instruction did improve students' ability to solve math word problems. Results on the Phase 2 mastery tests revealed that two of the students in the first treatment group (i.e., CSI followed by MSI) immediately met the mastery criterion following metacognitive instruction. In contrast, students in the second intervention group (i.e., MSI followed by CSI) required more practice in order to meet the mastery criterion. Montague (1992) hypothesized that interventions are more beneficial when they initially provide cognitive process "anchors" (i.e., labels and descriptions); these "anchors" facilitate the recall of declarative and procedural knowledge and help students apply metacognitive strategies when they are introduced.

In addition to the mastery tests that were given at the conclusion of both intervention phases, both a setting generalization test and a temporal generalization test were administered. The setting generalization test assessed whether or not the students were able to generalize the strategies and maintain their performance under typical classroom conditions. Its results revealed that three students were

able to generalize the strategies and maintain their performance in their regular math class. The temporal generalization test was given three times—the first after a period of up to two months after termination of the intervention sessions, the second was given the October of the next school year, and the third was given the January of the next school year. On the first temporal generalization test, two students met the mastery criterion. On the second temporal generalization test, none of the students met the mastery criterion. After being given two intervention review sessions, the two eighth grade students were assessed for a third time in January and both met the mastery criterion.

The last study (Hutchison, 1993) investigated the effects of cognitive strategy instruction the algebra problem solving abilities of 20 eighth, ninth, and tenth grade students. Additional criteria for participation in the study included a full scale IQ of 90 or better on the Wechsler Intelligence Scale for Children-Revised (WISC-R), classification as "specific learning disabled," proficiency in the four basic operations, and a score of 40% or less on a test consisting of 15 algebra word problems. The students were randomly assigned to the intervention and comparison groups, resulting in groups of 12 and eight, respectively.

Prior to beginning the intervention baseline data was collected on each student. Students were administered two pretests, each consisting of 10 algebra word problems. Three types of algebra word problems were used: relational, proportional, and two-variable two-equation. Data was collected on the students' problem representation (i.e., ability to represent each problem component in

relation to other problem components), problem solution (i.e., the steps taken to solve the problem), and answers.

Students in the intervention group were provided with individual CSI sessions in a learning resource center during their regularly scheduled 40-minute math class. The intervention was provided in two phases. Students were taught how to represent word problems in the first phase; they were taught how to solve the word problems in the second phase. The intervention began with relational word problems before progressing to proportional and two-variable two-equation word problems.

Each session followed a similar set of procedures. First, the instructor discussed with the student the session's purpose as well as their results on pretest measures. Then the student was given a worksheet of five problems and a prompt card with self-questions. Next, the student read the self-questions. The instructor then used a think-aloud to model the strategy for the first and second problems. Next, the student completed the third and fourth problems; prompts, encouragement, and corrective feedback were provided by the instructor during problem completion. Then student completed the fifth problem independently; prompts, encouragement, and corrective feedback were provided after problem completion. Lastly, students were given a posttest. Mastery criterion was set at 80% (i.e., four out of five problems) on three consecutive tests.

Following the posttests, students were assessed with a near-transfer test, a far-transfer test, and a maintenance test. Students were administered transfer tests only on the problem types on which they had reached criterion during intervention.

The near-transfer test consisted of problems that maintained a similar mathematical

structure but altered the surface structure. The far-transfer test consisted of

problems that were similar to the ones used during the intervention but included an

extra step. Six weeks after the transfer tests were given, a maintenance test

consisting of five algebra word problems was administered. The students were

provided with calculators; however, they were not given the prompt cards with self-

questions.

Posttest, transfer, and maintenance results support the effectiveness of

cognitive strategy instruction in increasing the algebra problem solving abilities of

students with learning disabilities. On the posttest, six of the 12 intervention

students reached criterion (i.e., 80% on representation, solution, and answer) on all

three problem types (i.e., relational, proportion, two-variable two-equation). Four

students reached criterion on two problem types while two students reached

criterion on only one problem type. On both the near and far-transfer tests, the

majority of the intervention students reached criterion. Lastly, maintenance test

results showed that ten of the 12 students who met criterion on relational problems

during the intervention were able to maintain their skills. All ten students who

reached criterion on proportion problems were able to maintain their performance.

Five of six students who met criterion for two-variable two-equation problems

maintained their abilities.

Similarly, several studies support the effectiveness of schema-based

instruction in improving the mathematical problem solving abilities of students with

disabilities. Jitendra, Griffin, McGoey, Gardill, Bhat, and Riley (1998) compared SBI

with a traditional basal instruction on the addition and subtraction word problem

solving abilities of 34 elementary students. The sample included 25 students who

either had a learning disability, mild cognitive disability, or emotional disability and

nine students who were considered at-risk for mathematics failure. The study

participants were selected based on teacher identification of students who were

proficient in addition and subtraction but deficient in word problem solving. In

order to be included in the study, students had to score at least 90% on a measure of

addition and subtraction computation skills, score at least 90% on simple action

problems, and score below or at 60% on a pretest consisting of one-step word

problems. Four doctoral candidates and four master's degree candidates who were

blind to the research purposes implemented the interventions using scripted

formats.

The study participants were divided into two groups of 17 students. They

received anywhere from 17 to 20 intervention sessions, each lasting up to 45

minutes. Students in the schema-based instruction group were taught in two

phases. The first phase focused on identifying the different problem types and

mapping the information onto schematic diagrams. In the second phase, students

were taught strategies to solve the problem, and then proceeded solve the problem.

Students in the traditional instruction group were taught using the *Addition-Wesley*

Mathematics basal mathematics program. They were instructed to use a five-step

checklist to solve word problems, which consisted of: understanding the question by

focusing on the question, finding the needed data given in the problem, planning

what to do by guessing and checking, finding the answer by computing with the

operation determined in the previous step, and checking back by rereading the problem to decide whether the answer was reasonable.

Student progress was measured using a pretest, posttest, maintenance test, and generalization test. Results indicated that schema-based instruction is more effective than a traditional basal strategy at improving the ability of elementary students to solve addition and subtraction word problems.

A second study examined the effectiveness of SBI on middle school students. Xin, Jitendra, and Deatline-Buchman (2005) compared the effects of schema-based instruction (SBI) and general strategy instruction (GSI) (i.e., the general heuristic approach) on the word problem solving abilities of 22 middle school students. The participants were selected based on teacher identification of students who were experiencing considerable problems in word problem solving and a score of 70% or lower on a word problem solving pretest consisting of ratio and proportion problems. The sample included 18 students who had learning disabilities, one who had severe emotional disorder, and three who were at risk for mathematics failure. The instructors were two special education doctoral students and two veteran special education teachers who were randomly assigned to the treatment groups. To control for teacher effects, the instructors switched groups halfway through the intervention.

Study participants received 12 hour-long instructional sessions that incorporated explicit teacher modeling, guided practice, corrective feedback, and independent practice. Both groups were taught to follow a four-step procedure of reading to understand, representing the problem, and planning, solving, and

checking. However, the SBI group was taught to identify the problem type and use a schematic diagram to represent and solve the problem, whereas the GSI group were taught to draw pictures to represent information in the problem and facilitate problem solving. Student progress was measured using a pretest, posttest, maintenance test, and follow-up test. Results from these measures indicated that the schema-based instruction students significantly outperformed the general strategy instruction students.

The most comprehensive study incorporating schema-based instruction was conducted by Jitendra, Star, Rodriguez, Lindell, and Someki (2011). The study evaluated the effectiveness of SBI on middle school students' ability to solve proportion word problems, which included ratios, equivalent fractions, rates, and percents. 436 participants were chosen from 21 seventh-grade classrooms at three middle schools; 47 of the students were classified.

The instructors were six seventh-grade teachers who provided scripted instruction during the regularly scheduled mathematics instructional period for 50 minutes daily, 5 days a week, for a total of 29 school days. Five of the teachers taught two schema-based instruction classes and one control class (i.e., regular instruction). The sixth teacher taught two schema-based instruction classes. Students assigned to the control group received regular instruction as mandated by their district curriculum while SBI replaced regular instruction for the treatment (i.e., SBI) students.

Student progress was measured using a pretest, posttest, and a retention test that was given one month after the study ended. The tests utilized questions

24

derived from the Trends in International Mathematics and Science Study (TIMSS),

National Assessment of Educational Progress (NAEP), and state assessments. It

consisted of 19 multiple-choice questions and one short-answer question. Results

indicated that students in the SBI group outperformed students in the control group

on the posttest, supporting the effectiveness of SBI with middle school students. No

significant differences were found on the retention test.

Based on the aforementioned studies supporting the use of cognitive strategy

instruction and schema-based instruction on improving the word problem solving

abilities of students with disabilities, I am interested in examining which method is

more effective. Both approaches incorporate National Mathematics Advisory Panel

recommendations (e.g., systematic-explicit instruction, think-alouds, visual

representations) that seek to address the deficiencies that are characteristic of

students with learning disabilities. Since both methods focus on different aspects of

learning—CSI emphasizes the thinking skills and processes involved in learning

while SBI stresses the identification of problem structure and analysis of underlying

mathematical relationships—my study would attempt to uncover whether it is more

beneficial to know how to think and act like an effective problem solver or whether

it is more useful to recognize the structure of word problems since an

understanding of mathematical relationships will facilitate problem solving.

Chapter 3

Methodology

<u>Subjects</u>

This study compared the effectiveness of cognitive strategy instruction and schema-based instruction on the math word problem solving abilities of students with learning disabilities.

The two participants were selected out of seven students who currently attend the inclusion class for math. An inclusion class is a class in which students with special needs are educated with their non-disabled peers. The elementary school houses kindergarten through eighth grade, and is one out of twelve schools in the district. The school district services approximately 7,000 residential students. This particular school has 626 students enrolled, 12.6% of whom are classified with an IEP. According to the New Jersey Department of Education, this city has a District Factor Group (DFG) of A. DFGs have a scale from "A" to "J", with "J" being the highest. DFGs are an approximate measure of a community's relative socioeconomic status (SES) and are calculated based on percent of adults with no high school diploma, percent of adults with some college education, occupational status, unemployment rate, percent of individuals in poverty, and median family income.

Two eighth grade students who were classified as having a specific learning disability participated in the study. Student A is a 14-year-old Hispanic male; student B is a 14-year-old African American male. Both students attend the inclusion class for math and were identified by their math teacher as having significant difficulty solving word problems. Additional criteria for participation in

26

the study included a full scale IQ in the range of 85 – 115 on the Wechsler

Intelligence Scale for Children-Revised (WISC-R), proficiency in the four basic

operations, and a score of 40% or lower on a test consisting of 10 proportion word

problems.

Student A is a 14-year old eighth grader who is currently in the In-Class

Resource classroom for language arts, math, social studies, and science. His second

marking period SRI score was 667; this translates to a 3.8 reading level. Student A is

able to decode but struggles with comprehension, as he does not monitor his

reading; this often affects his understanding of social studies and science content.

Instruction has focused on teaching him strategies to monitor his reading, how to

stop and summarize the main ideas, how to take notes, as well as using text features

to facilitate understanding of informational texts.

Math is a relative strength for Student A. Based on the results of a functional

math assessment, he functions on a fifth grade level for math. Strategies that have

been successful in the math classroom include: sequential and explicit instruction of

lessons, extensive repetition and practice, providing him with a list of steps for

completing problems, and allowing him to use a calculator.

Student B is a 14-year old eighth grader who is currently in the In-Class

Resource classroom for math, social studies, and science. His second marking

period SRI score was 836; this translates to a 5.3 reading level. Student B

comprehends what he reads but does have difficulty expressing himself, both

verbally and through writing, due to slight receptive and expressive language

deficits. However, when given additional time to make sense of what he has heard

and read, Student B is able to communicate his ideas. Additional strategies that

have been successful include: step-by-step directions, asking Student B to repeat

what he has heard as well as extra time for oral responses.

Math is a relative strength for Student B. Based on the results of a math

assessment, he functions on a sixth grade level for math. Occasionally, he makes

minor computational errors but with the assistance of a calculator and additional

time, Student B is able to keep up with his peers.

Table 1		
General Description of Study Participants		
Description	**Student A**	**Student B**
Gender	Male	Male
Grade	8	8
Race	Hispanic	African American
Age (in years)	15	14-4
Classification	Specific Learning Disability	Specific Learning Disability
IQ	87	85

Procedure

An alternating treatments design was used to examine the effects of the two

interventions—cognitive strategy instruction and schema-based instruction—on

the math word problem solving performance of the study participants. A pretest

(see Appendix A) consisting of ten proportion word problems was administered on

three separate occasions to both participants prior to beginning the intervention.

The students were given calculators to use and were instructed to show all their

work. Additionally, the word problems were read aloud. Test items were modeled

on those used by district benchmark tests, state assessments, and the Glencoe math textbook. Scores were reported as the percentage of correctly answered items (e.g., 7 out of 10 correct is a 70%).

The interventions began once a baseline was established for both participants. Student A began with cognitive strategy instruction. At the end of the CSI instructional phase, Probe 1 (see Appendix B) was administered three times. Then, Student A proceeded to schema-based instruction. Once the SBI instructional phase ended, another Probe 2 (see Appendix C) was administered three times. Conversely, Student B began with schema-based instruction before proceeding to cognitive strategy instruction. The research phases followed a sequence similar to that of Student A (i.e., baseline, SBI, Probe 1, CSI, Probe 2). Treatment was implemented by the study author. Both Student A and B received their assigned strategy instruction two times a week for two weeks before switching to the alternate intervention. Each instructional session lasted thirty minutes and took place in their regularly scheduled math class.

Table 2 **Research Phases**					
	Baseline	**Intervention 1**	**Probe 1**	**Intervention 2**	**Probe 2**
Student A	3 days	CSI (2x's a week for 2 weeks)	3 days	SBI (2x's a week for 2 weeks)	3 days
Student B	3 days	SBI (2x's a week for 2 weeks)	3 days	CSI (2x's a week for 2 weeks)	3 days

Both interventions began with the study author explaining the purpose of the treatment and describing each treatment. Next, the assigned strategy was explicitly modeled with numerous examples. This was followed by guided practice; corrective feedback and additional modeling was provided as needed. Lastly, students solved problems independently. Since computation and reading were not the focus of the study, the word problems were read aloud and calculators were provided.

Cognitive Strategy Instruction

In cognitive strategy instruction students are explicitly taught to use cognitive and metacognitve strategies for math problem solving. CSI includes seven cognitive processes: Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, and Check. Each cognitive process also contains metacognitive components (i.e., SAY, ASK, CHECK) to assist students in monitoring their performance. For example:

> *Jose and Nancy are selling greeting cards to raise money for a school trip. Together they raised $88.50. Nancy sold $67.00 worth of cards. How much money did Jose make selling cards?*

The first cognitive process is Read (for understanding). Students are taught to self-instruct by verbalizing, "Read the problem. If I don't understand, read it again." The problem is read aloud. They are then taught to self-monitor by asking themselves, "Have I read and understood the problem?" Lastly, students are taught to self-evaluate by checking for understanding as the problem is being solved.

The second cognitive process is Paraphrase (in your own words). Again, students are taught to self-instruct by saying, "Underline the important information. Put the problem in my own words."

"Okay…Let's underline $88.50 as the total and that Nancy raised $67.00. So Jose and Nancy raised $88.50 selling greeting cards. Nancy raised $67.00. I need to find out how much Jose raised."

Then they self-monitor by asking, "Have I underlined the important information? What is the question? What am I looking for?" Lastly, students self-evaluate by checking that the information that was paraphrased corresponds to the word problem.

The remaining cognitive processes are modeled in a similar fashion. Students are taught to self-instruct by verbally rehearsing the cognitive process. Self-monitoring then occurs via a self-questioning technique. Lastly, students are taught to self-evaluate by performing a check that corresponds to that specific cognitive process.

Schema-Based Instruction

In schema-based instruction students are taught to use Jitendra and Star's (2011) FOPS strategy through explicit modeling and think-alouds. The FOPS strategy consists of (F) finding the problem type, (O) organizing the information in the problem using the schematic diagram, (P) planning to solve the problem, and (S) solving the problem. For instance:

An artist is mixing red and yellow paint in a ratio of 2 to 3. If the artist adds 9 pints of yellow paint, how many pints of red paint will she add?

In order to find the problem type, the word problem is read aloud and its components are examined. A think-aloud technique is used to explicitly model for students how to think about the word problem.

"Does the problem describe a ratio between two quantities?...Yes, there's a ratio between the red and yellow paint…Is there either an increase or decrease in the

31

two quantities, but with the same ratio?...Yes, the problem says that the paint has to be mixed in a ratio of 2 pints of red to 3 pints of yellow and that the artist used 9 pints of yellow...Since the answer to both questions is yes, I know that this is a proportion problem."

Next, students are introduced to the schematic diagram and shown via a

think-aloud how to organize the problem components using it.

"What are the two things being compared?...Oh, it's red and yellow paint...Is there a ratio between the red and yellow paint?...Yes, a ratio of two red pints to three yellow pints...What else do I know?...Oh, it says that the artist used nine pints of yellow paint...Okay, I'm going to fill in the diagram with everything that is given in the problem...Okay, now what do I need to find out?...I need to find out how many pints of red paint are needed...I can represent what I need to solve for with an X."

After completing the schematic diagram students are shown how to translate

the information contained in it into a math equation. Again, a think-aloud technique

is used.

"What happened to the three red pints for it to become nine red pints?...Oh, it was multiplied by three...Since I know that the second ratio has to be equal to the first ratio of 2/3, I have to multiply the two yellow pints by three also...Since two times three is six, x must equal six."

Finally, the answer is compared with the schematic diagram to see if it makes
sense.

"Okay, when I simplify 6/9 I get 2/3, which is the ratio that was given in the word problem."

Development of Intervention and Materials

The cognitive strategy instruction cue cards (see Figure 1) were modeled on

Montague's (1992) wall charts. These were provided to both students during their

CSI sessions as a reference. Similarly, the schematic diagram (see Figure 2) used

during the SBI instructional sessions was modeled on Jitendra et al.'s (2011)

organizer. These were provided to both Student A and B to help them organize the various word problem components.

Math Problem Solving
Read (for understanding) SAY: Read the problem. If I don't understand it, read it again. ASK: Did I read and understand the problem? CHECK: For understanding as I solve the problem. **Paraphrase (in your own words)** SAY: Underline the important information and put it in my own words. ASK: Did I underline the important information? What is the problem asking me to solve for? CHECK: That the information helps you solve the problem. **Visualize (a picture)** SAY: Draw a picture. ASK: Does the picture fit the problem? CHECK: The picture against the information in the problem. **Hypothesize (a plan to solve the problem)** SAY: Decide what operations are needed. Write the operation symbols. ASK: If I do…what will I get? What do I need to do next? CHECK: That the plan makes sense. **Estimate (predict the answer)** SAY: Round the numbers, do the problem in my head, and write the estimated answer. ASK: Did I round? Did I write down the estimated answer? CHECK: That I used the important information. **Compute (do the math)** SAY: Do the operations in the correct order. ASK: How does my answer compare to the estimated answer? Does the answer make sense? CHECK: That the operations were done in the right order. **Check (make sure everything is right)** SAY: Check my work. ASK: Did I check every step? Did I check my computation? Is the answer right? CHECK: That everything is right. If not, go back. Then ask for help if I need it.

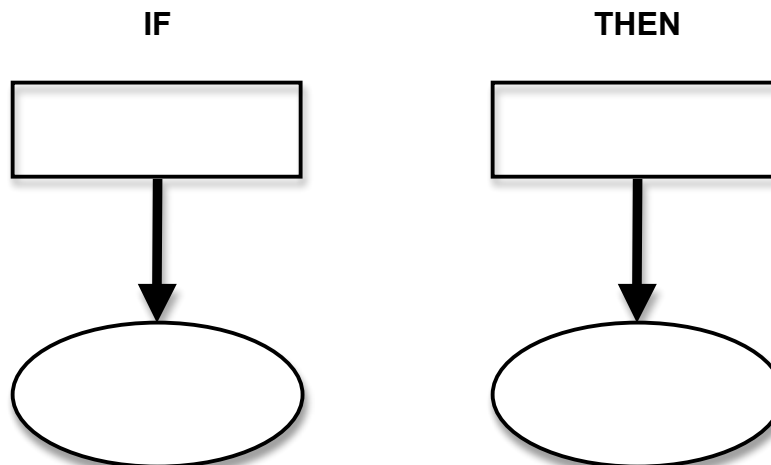*Figure 1.* Cognitive strategy instruction cue cards.

IF   THEN

Figure 2. Schematic diagram.

Chapter 4

Results

<u>Summary</u>

This experimental, alternating treatments design, examined the effects of two interventions—cognitive strategy instruction and schema-based instruction—on math word problem solving performance. The two participants were eighth grade students with learning disabilities, who are in the inclusive classroom for math. They were chosen for the study because they were identified by their math teacher as having significant difficulty with mathematical word problem solving. The research question that is being investigated in this study is:

Is cognitive strategy instruction (CSI) or schema-based instruction (SBI) more effective at improving the word problem solving abilities of students with disabilities?

The research phase followed this sequence: Baseline, Treatment 1, Probe 1, Treatment 2, and Probe 2. Both study participants received their assigned strategy instruction two times a week for two weeks before switching to the alternate intervention. Thus, Student A followed this sequence: baseline, CSI, Probe 1, SBI, and Probe 2. Student B, on the other hand, followed this sequence: baseline, SBI, Probe 1, CSI, and Probe 2. Instructional sessions lasted thirty minutes and took place in the students' regularly scheduled math class. All of the participants' scores during the baseline and treatment periods were recorded and presented in both table and line graph form.

Results

Each score was calculated by dividing the number of correctly answered problems by the total ten problems. For instance, eight correct problems divided by ten total problems would yield a score of 80%.

| Table 3			
Summary of Participant Results			
Date	**Purpose**	**Student A**	**Student B**
2/16	Baseline: Day 1	30	40
2/21	Baseline: Day 2	40	30
2/22	Baseline: Day 3	20	40
2/27	Week 1: CSI	30	N/A
2/28	Week 1: CSI	40	N/A
2/29	Week 1: SBI	N/A	50
3/1	Week 1: SBI	N/A	60
3/5	Week 2: CSI	30	N/A
3/6	Week 2: CSI	40	N/A
3/7	Week 2: SBI	N/A	70
3/8	Week 2: SBI	N/A	70
3/12	Probe 1: Day 1	30	70
3/13	Probe 1: Day 2	40	70
3/14	Probe 1: Day 3	40	60
3/19	Week 3: SBI	40	N/A
3/20	Week 3: SBI	50	N/A
3/21	Week 3: CSI	N/A	50
3/22	Week 3: CSI	N/A	60
3/26	Week 4: SBI	50	N/A
3/27	Week 4: SBI	60	N/A
3/28	Week 4: CSI	N/A	50
3/29	Week 4: CSI	N/A	60
3/30	Probe 2: Day 1	60	60
4/2	Probe 2: Day 2	50	60
4/3	Probe 2: Day 3	50	50
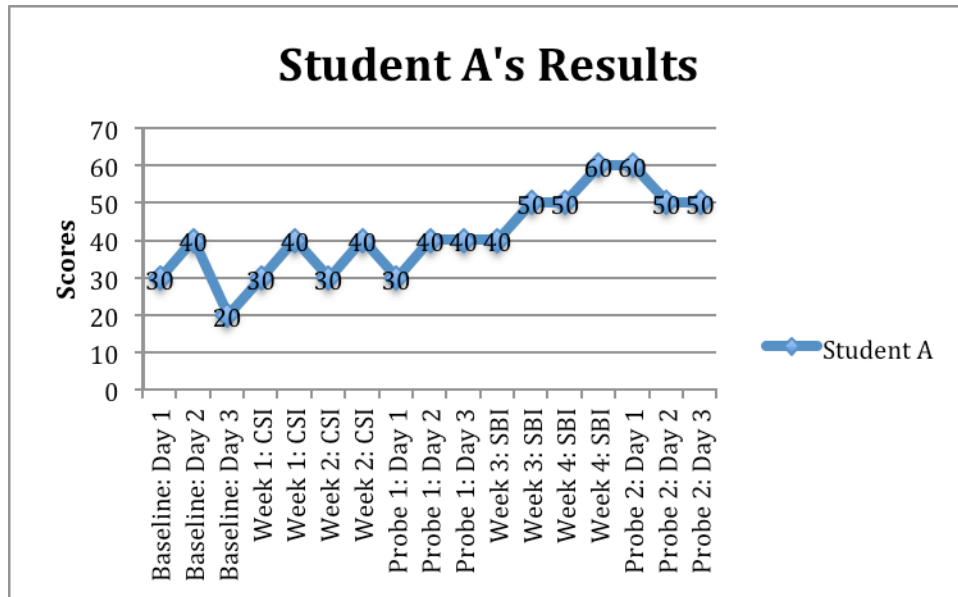
Figure 3. Student A's results

Student A's scores during the baseline were 30%, 40%, and 20%. This resulted in a mean score of 30%, indicating that on average he answered three out of ten word problems correctly. During the first intervention period (Weeks 1 and 2) Student A was trained in cognitive strategy instruction. His results were 30%, 40%, 30%, and 40%. This resulted in a mean of 35%—only a 5% increase from his average score for the baseline. This trend continued during Probe 1. Student A's scores were 30%, 40%, and 40% and resulted in a mean score of 36.6%. The data indicates that CSI was only marginally effective at improving his word problem solving skills.

Student A was trained in schema-based instruction during the second intervention phase (Weeks 3 and 4). His scores were 40%, 50%, 50%, and 60%. This resulted in a mean of 50%, indicating that on average he answered five out of ten word problems correctly. This was an increase of 20% from the baseline and a

13.4% increase from Probe 1. During Probe 2, Student A's scores were 60%, 50%, and 50%. This resulted in a mean score of 53.3%, indicating that not only was SBI effective at improving math word problem solving skills, but it was also more effective than CSI at improving these skills.
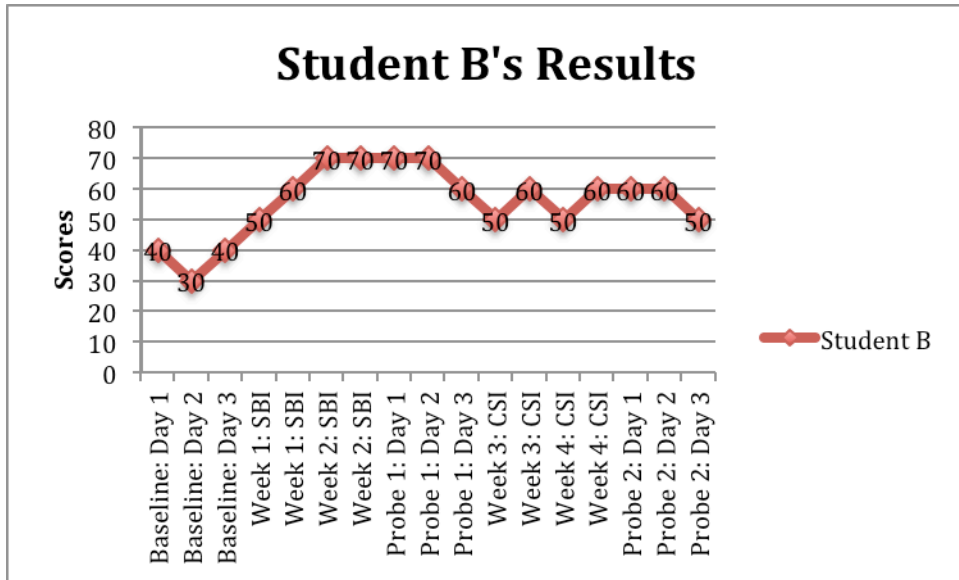

Figure 4. Student B's results

Student B's scores for the baseline were 40%, 30%, and 40%. This resulted in a mean score of 36.6%, indicating that on average he answered three to four out of ten word problems correctly. He performed only slightly better than Student A during the baseline. During the first intervention phase (Weeks 1 and 2) Student B was trained in schema-based instruction. His results were 50%, 60%, 70%, and 70%. This resulted in a mean score of 62.5%, which was a 25.9% increase over his baseline average score. Student B performed similarly during Probe 1—scoring

70%, 70%, and 60%. This resulted in a mean of 66.6%, which was a slight increase of 4.1% over his mean score for the first intervention period.

During the second intervention phase (Weeks 3 and 4), Student B was trained in cognitive strategy instruction. His scores were 50%, 60%, 50%, and 60%, which resulted in a mean of 55%. While this was an 18.4% increase over his baseline mean score of 36.6%, it was a decrease of 7.5% from his mean score of 62.5% for the first intervention period. Student B maintained his performance during Probe 2, scoring a 60%, 60%, and 50%. This resulted in a mean of 56.6%, which was a 1.6% increase from his average in the second intervention period. Based upon the data, SBI was more effective at improving Student B's math problem solving skills.
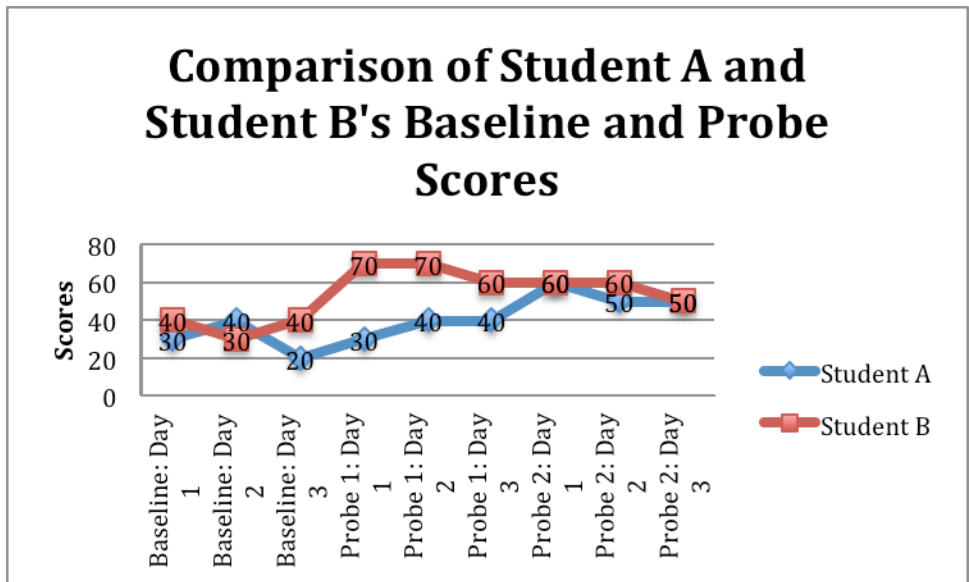

Figure 5. Comparison of student A and student B's baseline and probe scores

Figure 5 compares all of Student A and Student B's baseline and probe scores while Figure 6 only depicts the mean score from the baseline and probes. During the first intervention period, Student A was trained in cognitive strategy instruction while Student B was trained in schema-based instruction. During the second intervention period, Student A was trained in SBI while Student B was trained in CSI. Analysis of these results indicate that schema-based instruction is more effective at improving the math problem solving abilities of the study participants.
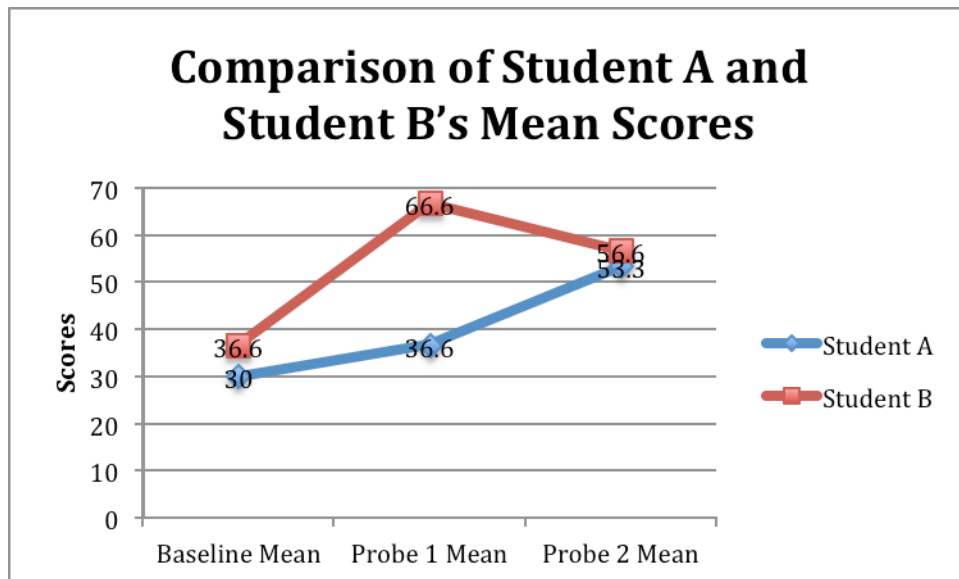

Figure 6. Comparison of student A and student B's mean scores

Chapter 5

Discussion

<u>Review</u>

This study examined the effects of two interventions—cognitive strategy instruction and schema-based instruction—on math word problem solving performance. Two eighth grade students were chosen from the inclusive math classroom after being identified by their teacher as having significant difficulty with mathematical word problem solving. The research phase followed this sequence: baseline, Treatment 1, Probe 1, Treatment 2, and Probe 2. Both study participants received their assigned strategy instruction two times a week for two weeks—for a total of four sessions—before switching to the alternate intervention. Thus, Student A began with cognitive strategy instruction and switched to schema-based instruction while Student B began with SBI and switched to CSI.

The experimental study results were consistent with the body of literature (see Chapter 2) that supported the effectiveness of both cognitive strategy instruction and schema-based instruction in improving the math problem solving performance of students with disabilities. Student A progressed from a baseline average of 30% to 36.6% for Probe 1, and 53.3% for Probe 2. Student B made much larger gains going from a baseline mean of 36.6% to 66.6% for Probe 1, and 56.6% for Probe 2. However, the research question sought to determine which of the two aforementioned interventions was more effective at improving the word problem solving skills of students with disabilities.

As stated in Chapter 1, it was hypothesized that schema-based instruction would be more effective than cognitive strategy instruction because it teaches a student to understand math conceptually. It relates the individual problem components to one another so that the student is able to see the "big picture" in terms of a word problem. The study results seem to support this idea. What was surprising was the fact that SBI was so much more effective than CSI at increasing the participants' abilities to solve math word problems. This conclusion was derived from examining the baseline and probe mean scores of Student A and Student B. Student A had an average score of 30% for the baseline, which was established prior to beginning any of the interventions. After four instructional sessions of CSI, the increase was modest at 36.6% for Probe 1. However, after four instructional sessions of SBI, Student A's mean score had increased to 53.3% for Probe 2. This amounted to an increase of 23.3% as opposed to CSI's increase of 6.6%. Student B had an average score of 36.6% for the baseline. After four instructional sessions of schema-based instruction, the mean score for Probe 1 increased by 30% to 66.6%. After four instructional sessions of cognitive strategy instruction, Student B's average score increased by 20% from the baseline to 56.6% for Probe 2.

Chapter 2 reported on several peer reviewed research articles that discussed the effectiveness of cognitive strategy instruction and schema-based instruction. However, none of those articles compared the two interventions.

While the results of this study supported the original hypothesis that schema-based instruction would be more effective than cognitive strategy instruction at improving the word problem solving skills of students with disabilities, several limitations should be noted. First, the sample consisted of only two students. The small sample size makes it impossible to observe any trends in data and to draw conclusions from that data. Student A and Student B are not necessarily representative of all students with learning disabilities. Just because they were able to improve their math problem solving skills with CSI and SBI does not mean that these interventions would be effective with other learning disabled students. Additionally, because it was a single-subject study it is difficult to determine if the two interventions would be feasible or even effective with larger groups of students. Cognitive strategy instruction was a challenge to explain and model with just one student. It consists of seven components (i.e., Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, Check) and each component has three additional parts that must be practiced and rehearsed (i.e., Say, Ask, Check) to the point of fluency. Even then the study participants still needed to refer to the CSI cue cards. Second, the interventions were implemented in a one-to-one setting. Thus, it is difficult to determine if the participants' improvement was due to the specific intervention or due to the individualized attention that the students received. Third, the intervention periods were short in duration, consisting of only four instructional sessions. It would have been more beneficial to implement the intervention for a longer period of time. This might have resulted in more

substantial gains, especially for Student A who only increased from 30% to 36.6% after four sessions of cognitive strategy instruction. Lastly, the participants were not assessed on whether or not they could maintain or transfer what they had learned. Effective interventions are ones that students can retain and apply to new situations. The purpose of interventions is to enable students to become more independent—to give them a strategy to use so that they become less teacher-dependent and more self-sufficient.

Conclusion

This study has several implications for classroom teachers. First, the study confirms that both cognitive strategy instruction and schema-based instruction are effective interventions for students with disabilities who struggle with solving math word problems. Review of the baseline and probe scores of the study participants indicate that both students were able to improve their math word problem solving skills.

Second, it appears that schema-based instruction was the more effective intervention based on the study participants' mean scores. This could be due to the fact that SBI is easier than CSI to implement. The FOPS strategy consists of components (i.e., finding the problem type, (O) organizing the information in the problem using the schematic diagram, (P) planning to solve the problem, and (S) solving the problem) that are familiar to most students. Additionally, the schematic diagram makes it easy to relate the individual problem components to one another.

During the instructional sessions, both Student A and Student B quickly grasped how to solve problems using the FOPS strategy and the schematic diagram.

Conversely, the participants seemed to have a much harder time grasping cognitive strategy instruction. Each of the seven components (i.e., Read, Paraphrase, Visualize, Hypothesize, Estimate, Compute, Check) had three additional parts (i.e., Say, Ask, Check). This amounted to a total of 21 steps that the students had to become familiar with. Additionally, CSI does not seem to scaffold the components that students may encounter difficulty with. This is especially true for the third component, Visualize, which requires students to draw a picture. Drawing a picture will not facilitate problem solving unless students first understand the relationship between the problem components. Lack of scaffolding is also problematic for the fourth component, Hypothesize, in which students must formulate a plan to solve the problem. Students who encounter difficulty solving math word problems encounter difficulty because they are often not able to figure out what operations are needed to solve the problem. Simply asking them to formulate a plan does nothing to aid them in recognizing which operations are necessary for that specific problem. Thus, one criticism of cognitive strategy instruction would be that it does not provide scaffolding for students who are not already familiar with its components. On the other hand, the strength of CSI lies in the fact that it teaches students with disabilities metacognitive skills. It teaches them how to monitor and self-instruct—skills that many students with learning disabilities lack and skills that are applicable to a variety of areas.

The decision of which intervention—cognitive strategy instruction or schema-based instruction—is more effective depends on the characteristics of the students and the makeup of the classroom. CSI may be more effective for smaller classes with students who lack the ability to monitor their own work. SBI, on the other hand, may be better suited for students who are already capable of self-monitoring and are ready to learn how to organize individual problem components in a way that is meaningful and will facilitate problem solving. In the end, the demands of the classroom will dictate which intervention is more appropriate.

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Appendix A Pretest

Name: Date:

Pretest

Directions: Solve each proportion. Show all your work.

1) An employee working at Best Buy earned $3582 for working 3 months during the summer. What did the employee earn for the first two months?

2) Kaleb started a new job working 15 hours a week. After how many weeks will he have worked a total of 75 hours?

3) During its first 50 days of growth, a sunflower grows about 4 cm per day. Using this rate, after how many days will a sunflower be 60 cm tall?

4) The ratio of boys to girls in a class is 6 to 5. How many girls are there if there are 78 boys?

5) One package of strawberries costs $3. How many packages of strawberries can you buy for $24?

6) Okira reduced the size of a painting to a width of 3.3 in. What is the new height if it was originally 32.5 in tall and 42.9 in wide?

7) Melanie spends 17 hours in a 2-week period practicing the piano. How many hours does she practice in 5 weeks?

8) A snowstorm dumped 18 inches of snow in a 12-hour period. How many inches were falling per hour?

9) Chris drives 125 miles in 2.5 hours. At the same rate, how far will he be able to travel in 6 hours?

10) A piece of cable 8.5 cm long weighs 52 grams. What will a 10-cm length of the same cable weigh?

49

Appendix B Probe 1

Name: _____   Date: _____

Probe 1

Directions: Solve each proportion. Show all your work.

1) If you can buy one can of pineapple chunks for $3. How many can you buy with $21?

2) Ground turkey costs $2.99 per pound. How much will 3.5 pounds cost?

3) Ms. Kelly can type 80 words per minute. How many words can she type in 30 minutes?

4) In a shipment of 400 cars, 8 are found to be defective. How many defective cars should be expected in a shipment of 1200?

5) Hurricane Eileen dropped about 12 inches of rain over a 48-hour period. How much rain is this per hour?

6) Ming was planning a trip to Western Samoa. Before going, she did some research and learned that the exchange rate is 6 Tala for $2. How many Tala would she get if she exchanged $6?

7) Ita took a trip to Mexico. Upon leaving she decided to convert all of his Pesos back into dollars. How many dollars did she receive if she exchanged 42.7 Pesos at a rate of $5.30 = 11.1 Pesos?

8) A dentist sees each of her patients for 25 minutes during a typical appointment. How many patients can she see in a typical 7.5-hour day?

9) You find that your watch gains 2 minutes in 6 hours. How much will it gain in 3 days?

10) Rose can read 22 pages in 30 minutes. How long would it take her to read a 100-page book?

Appendix C Probe 2

Name: Date:

Probe 2

Directions: Solve each proportion. Show all your work.

1) It takes about 25 minutes to create a social studies test. How long will it take to create four different tests?

2) A worker can assemble 15 iPods in 6 hours. At this rate, how many iPods can the worker assemble in a 40-hour work week?

3) Three feet of silk costs $12.99. How much will 2 feet cost?

4) During its first 50 days of growth, a sunflower grows about 4 cm per day. After how many days will a sunflower be 60 cm tall?

5) Gabby is making fruit punch that consists of 2 quarts of juice and 1 quart of seltzer. How much seltzer does she need if she has 5 quarts of juice?

6) Lila bought three cantaloupes for $7. How many cantaloupes can she buy if she has $42?

7) On a map, 1 centimeter equals 3.5 meters. A road is shown on this map that runs for 30 centimeters. How long is this road?

8) Argentina's currency is the Peso. The exchange rate is approximately $3 = 1 Peso. At this rate, how many Pesos would you get if you exchanged $121.10?

9) On a set of architectural drawings for a new school building, the scale is .25 inch = 2 feet. If the lobby is 16 feet, how big is it in the architectural drawing?

10) Water flows out of a kitchen faucet at about 1.5 gallons per minute. How many gallons flow out after an hour?