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**THE EFFECTS OF COGNITIVE STRATEGY INSTRUCTION ON MATH  
PROBLEM SOLVING OF HIGH SCHOOL STUDENTS WITH LEARNING  
DISABILITIES**

by  
Joseph M. DeVecchis

A Thesis

Submitted to the  
Department of Language, Literacy, and Special Education  
College of Education  
In partial fulfillment of the requirement  
For the degree of  
Master of Arts in Learning Disabilities  
at  
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May 1, 2015

Thesis Chair: S. Jay Kuder, Ed. D.

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Joseph M. Devecchis

## **Dedications**

This thesis is dedicated to my wife and children. Theresa, you are my rock and I can't thank you enough for all of your love and support throughout this process. Ryan and Emily, daddy is almost done! I love the two of you very much and I hope you never lose sight of the power of education. I would also like to dedicate this thesis to my parents and in-laws. Mom and Dad, your unending support in everything I have ever done has shaped me into the man I am today. The home cooked meals and babysitting during nights when I had class will never be forgotten. I hope to continue to make you proud each day. Joe and Phyllis, I can never repay you for watching the kids during this process and giving me and my family the vacation of a lifetime last year when I really needed a break before the home stretch of this program.

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## Abstract

Joseph M. DeVecchis

THE EFFECTS OF COGNITIVE STRATEGY INSTRUCTION ON MATH PROBLEM  
SOLVING OF HIGH SCHOOL STUDENTS WITH LEARNING DISABILITIES

2014/15

Dr. S. Jay Kuder Ed. D.

Masters of Arts in Learning Disabilities

The purpose of the study was to examine if Solve It! instruction, a cognitive based strategy instruction program, along with a graphic organizer would increase students understanding of mathematical word problems in the high school classroom setting. The study implemented a pretest-posttest design. There were sixteen participants in the intervention group as well as sixteen students in the control group. The study took place in four different resource mathematics classrooms. The independent variable was a modified version of Solve It! instruction while the dependent variable was a curriculum – based measurement created by the intervention and control group teachers. Overall, all students showed progress throughout the twenty-six day study, however students who were exposed to the intervention showed significantly greater gains.

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## Chapter 1

### Introduction

When secondary-age students who have received instruction in algebra are tested, most can perform the necessary operations to complete an algebraic equation. However, when the student is presented with a word problem where they need to generate and then solve the equation, many have difficulty. This is probably truer for students with learning disabilities. Students with learning disabilities often have not attained the strategies to facilitate problem solving or may have difficulty selecting strategies that are appropriate to the task. In contrast, where a learning disabled student often uses ineffective strategies, students without learning difficulties have a collection of strategies and most can use them effectively to solve problems. To address the issue of problem solving ability, major strides have been made to reform the math curriculum from an emphasis on memorization skills and procedural knowledge to problem analysis, interpretation, and abstract understanding. The use of cognitive strategy based instruction in this study looks to place an emphasis on problem analysis and a general understanding of the mathematical problem-solving process.

The traditional and conventional mathematics curriculum is based on procedural knowledge, such as memorizing operations with little regard to underlying meanings or a sense of why students are using the operations, instead of developing conceptual and strategic knowledge in students (Montague, Warger & Morgan, 2000). This line of thinking appears to be negatively effecting our public school outcomes when it comes to statewide test scores, as well as international scores. In 2012, among the 34 countries who participated in the Programme for International Student Assessment (PISA), the

United States performed below average in mathematics with a rank of 27<sup>th</sup> (Schleicher & Davidson, 2012). The United States spends more money per student than most countries but is not translating to better performance as one in four U.S. students do not reach a proficient level in the PISA. These statistics alone indicate that more research needs to be done on mathematic instruction in this country and the climate of our classrooms needs to adapt in the 21<sup>st</sup> century.

In this study, I examined the effectiveness of implementing cognitive strategy instruction into the resource math classroom. Cognitive strategy instruction is an instructional approach which emphasizes the development of thinking skills and processes as a means to enhance learning. The objective of using cognitive strategy instruction is to enable students to be more strategic when solving a complex math problem. I believe that students who receive intensive training on a cognitive strategy instruction program such as Solve It! will perform better on a post test than students who receive instruction that they have typically seen in their high school career. As a math teacher at a high school for the past nine years, I have seen many initiatives come and go without much improvement in the comprehension of math word problems. Through a mini study on incorporating a cognitive strategy instruction in 2013, I saw immediate results. This led my students to appear more confident and eager to take the state assessment that year.

Similar to reading comprehension, math problem solving is a complex skill that requires basic math skills, reading comprehension, and development of a viable process for solution. A student with learning disabilities will have difficulties with developing a

process for solution of word problem. These students often lack the necessary skills to conceptualize a problem first, and then solve it.

The two research questions examined in this study are:

-Do students who are provided with extensive cognitive based strategy instruction along with a graphic organizer to organize problem details instead of conventional instruction perform better on a curriculum - based measurement?

-After solving problems on a post - test, will students report they understood the question, utilized an appropriate problem-solving strategy, and checked their answer?

This study was conducted across four classrooms in a resource mathematics setting. Two classrooms were designated as the control group where they were instructed to conduct business as usual, and the other two classes implemented cognitive strategy instruction into everyday lessons. The two control classes consisted of a total of sixteen students. Of the sixteen students, ten of them were classified Specific Learning Disability for reading comprehension and math problem solving discrepancies, two were Multiply Disabled and four were classified Other Health Impaired (ADHD). There were nine female students and seven male students. Of the nine females, six were African American and three were White, while the nine boys consisted of seven African Americans and two Hispanic.

The intervention group also consisted of sixteen students. Of the sixteen intervention group students, eight were classified Specific Learning Disability for reading comprehension and math problem solving discrepancies, seven were classified Other Health Impaired (ADHD) and one was classified Emotionally Disturbed. There were ten

male students and six female students. Of the ten male students, eight were African American and two were White, while all six females were African American.

The students with disabilities included some with Specific Learning Disabilities, some who were classified as Other Health Impaired (ADHD), one classified as Emotionally Disturbed, and some with Multiply Disabilities. Specific Learning Disabilities is defined as a disorder in one or more of the basic psychological processes involved in understanding or using language that may manifest itself to struggles in reading, writing and math. Other Health Impaired is defined as being chronically ill and represents a disability characterized by having limited strength and alertness. Multiply Disabled is defined as having the presence of two or more disabilities which causes severe educational needs. Emotionally Disturbed is defined as having a general pervasive mood or unhappiness, inability to build and maintain relations, or a fear of developing relationships with peers or personnel. The students in this study were classified with these four classifications in their Individual Education Programs (IEP) written by the school district. Each student had goals and objectives that needed to be met in their IEP's as well.

The independent variable for this was study was the program *Solve It!*. *Solve It!* is a research based instructional program for teaching students who have difficulty in mathematics and solving word problems. By using *Solve It!*, students learn how to understand the mathematical problems, analyze the information presented, develop a logical plan to answer the question, and then evaluate their solutions (Montague, Warger & Morgan, 2000). *Solve It!* Instruction consists of seven steps. First, students are taught to read the problem for understanding. Second, the students paraphrase the problem by

putting it into their own words. Third, students visualize the problem by creating representations that depict relationships among the problem parts. Fourth, the students hypothesize about problem solutions by selecting appropriate operations, formulas and equations that are needed to solve it. Fifth, the students estimate the answer as a means of later confirming the solution outcome. Sixth, the students try to answer the problem following the steps previously determined. Finally, the students check their answers with their original hypothesis (Krawec, Huang, Montague, Kressler, & Alba, 2012). For the purpose of this study, steps two and three will be eliminated and be replaced with a graphic organizer. In my previous research in 2013, I found that the Solve It! process was too involved and confusing for my students and needed to be modified. Together the intervention and control group teachers created a graphic organizer. The graphic organizer however was only used in the intervention group. Students received a laminated graphic organizer with an example problem worked out to use as a guide.

The dependent variable in this study was a curriculum - based assessment created by both teachers involved in the study. The assessment was composed of ten open-ended mathematical problems. Students needed a general knowledge of percentages, percent change, and proportions. Along with the curriculum - based assessment, students were asked to complete five yes or no questions to demonstrate their use of strategies. They were asked to complete this survey after they answered questions one, three, five, seven, and nine.

In this study, a control group and an intervention group were assigned to analyze the effects of Solve It!, a research based cognitive strategy instruction that was modified with the use of a graphic organizer. The intervention was implemented over a three week

period. It is hypothesized that students who receive Solve It! instruction will perform better on a post - test than students receiving instruction they have typically seen in their school career. If my hypothesis is correct, it could change how we teach math in the high school resource classroom where the instruction is implemented. This instruction could provide teachers with a more structured way to teach and analyze algebraic word problems and give students more strategies to use when problem solving.

## Chapter 2

### Literature Review

#### Learning Disabilities and Math

The process of teaching mathematics to school - aged children has drastically changed in the last twenty years. While processes such as memorization skills and manipulation of formulas is still prevalent, curriculums across the country are now adhering to the Core Content Standards that demand increased academic rigor in the math classroom including the abstract thinking needed to solve word problems. For a student with learning disabilities, mathematical problem solving is extremely difficult because it requires them to apply knowledge of skills and strategies to novel problems (Fuchs, Fuchs, Finelli, Courey & Hamlet, 2004). These students often fall into a trap as being seen as incompetent problem solvers because they cannot perform the necessary steps to successfully complete in depth mathematical problems. Mathematical word problems continue to be a struggle for under achieving learners because of the complexity where the correct solution depends on the accuracy of previous steps (Jitendra, Griffin, Deatline-Buchman, & Sczesniak, 2007). Given that students with learning disabilities have difficulties with rigorous expectations in the classroom due to their unique learning characteristics, modifications need to be implemented in the way they are presented information (Maccini, Mulcahy, & Wilson).

#### Cognitive Strategy Instruction

Cognitive strategy instruction can significantly improve problem solving in students with learning disabilities (Chung & Tam, 2005). As the academic curriculum



changes, so must the instruction provided. Gone are the days where a teacher can demonstrate procedures in a full classroom setting and then provide time for drill and practice (Montague, Warger, & Morgan, 2000). With the 21<sup>st</sup> century classroom becoming more and more inclusive, alternate teaching strategies need to be adapted. Tiered instruction along with differentiated instruction has paved the way for the new special education. Districts around the country are providing students with the Response to Intervention (RTI) program to help alleviate struggles in the early school years so success can be attained down the road. The RTI method has three phases. The first tier provides students with high quality classroom instruction with screenings and group interventions. The second tier is for students who do not progress in tier one and provides for targeted interventions where a special education teacher assists in instruction. If students fail to progress in this tier, they move to tier three where intensive interventions are put into place as well as comprehensive evaluations of the student. Providing students with multiple outlets to understand topics is becoming the new norm. Using tiered lessons and assignments in classrooms allows the children to learn at their level. Other interventions that have been found to improve mathematical problem solving include peer mediated interventions, technology assisted instruction and teaching self-monitoring techniques (Maccini, Mulcahy, & Wilson, 2007).

A review of literature from Maccini, Mulcahy and Wilson from 1995-2006 contained twenty-three articles that demonstrated significant outcomes for secondary mathematics students of both average intelligence and students with learning disabilities. They concluded through their literature review that mnemonic strategy instruction, cognitive strategy instruction, schema-based instruction and video-disc instruction was

beneficial to students with learning disabilities. In 2008, Marjorie Montague compiled seven studies on self-regulation and cognitive instruction in the mathematics classroom to determine its effectiveness. Self-regulation is defined as the ability to regulate one's cognitive activities. The process looked at how to increase student's cognitive processes and improve academic performance (Montague, 2008). Studies conducted by Graham and Harris (2003), Cassel and Reid (1996), Hutchinson (1993), and Chung and Tam (2005) all used modifications of Montague's cognitive routine and reported positive results in cognitive strategy instruction (Montague, 2008). Through the review of literature Montague believed that cognitive strategies, whether cognitive or meta-cognitive, would improve mathematical problem solving in students with Learning Disabilities (Montague, 2008).

For this study, the focus is on cognitive strategy instruction. It is important to understand how individuals process and acquire information to effectively teach cognitive strategy instruction. If executed properly, cognitive strategy instruction can be a favorable alternative to typical classroom instruction (Montague, 1997). A meta-analysis conducted by Swanson that reviewed research over thirty years concluded that the two most effective interventions for students with Learning Disabilities were direct instruction and cognitive strategy instruction (Swanson, 1999).

The purpose of a study conducted by Montague, Enders and Dietz in 2011 was to measure the effects of cognitive strategy instruction on math problem solving in middle school aged students with learning disabilities by implementing a research-based interventional program in inclusive general education classes. Twenty-four schools in Miami took part in the study. Of the twenty-four schools, eight were assigned the

intervention while sixteen were not. The intervention group contained 319 students while the comparison group had 460 students. Seventy-eight students had learning disabilities, 344 were low achieving, and 357 were average achieving students. There were 359 boys and 420 girls. Of this population, fifty-five were Caucasian, 497 were Hispanic, 213 were African American, eight were Asian, and six were categorized as “other”. A total of 563 students were receiving free or reduced lunch (Montague, Enders, & Dietz, 2011). The experimenter was attempting to measure student’s ability to acquire, apply, maintain and generalize math problem solving processes, strategies and skills (Montague, Enders, & Dietz, 2011). This was measured by the administration of curriculum based measurements six times, specifically a baseline and then approximately monthly for the remainder of the school year. The curriculum - based measurements were only administered four times to the comparison group specifically a baseline and then at the third, fifth, and final administrations. The intervention provided was *Solve It!*, a program designed to improve mathematical problem solving of middle school students with Learning Disabilities. *Solve It!*, is a comprehensive strategic routine consisting of seven cognitive processes (read, paraphrase, visualize, hypothesize, estimate, compute, and check). The teachers implementing *Solve It!* instruction were given scripted lessons to teach that incorporated the seven step process. *Solve It!* incorporates explicit instruction in problem solving where highly structured lessons and guided practice are key. While incorporating the intervention, teachers were instructed to provide immediate and corrective feedback on performance as well as give positive reinforcement (Montague, Warger, & Morgan, 2000). Students benefit from positive reinforcement when practicing problem solving so they know what strategies and behaviors will guide them to further

success. Teachers in the comparison group were instructed to conduct business as usual except for giving the curriculum - based measurements. The results indicated that students who received the intervention showed significantly greater growth in math problem solving over the school year than students in the comparison group. The data collected showed that students in the comparison group had a mean score in the beginning of the study of 53 and their final mean was a 56. Students in the intervention group reported a mean score of 50 in the beginning of the study and their final mean score was a 65. Students with learning disabilities outperformed all ability groups in the comparison study, even the average achieving students, by the end of the school year on the curriculum based measurement. The authors stated that the findings of the study concluded that adopting reading and mathematics programs that research has shown to be effective in the inclusive classroom along with progress monitoring is what is most beneficial for students with Learning Disabilities (Montague, Enders, & Dietz, 2011).

A study conducted in 2012 by Krawec, Huang, Montague, Kressler and Melia de Alba looked at the effectiveness of the *Solve It!* strategy instruction on students' knowledge of math problem solving strategies. The researchers wanted to determine if a cognitive strategy routine improved the strategic knowledge of math problem solving. The study was conducted to measure the effectiveness of cognitive instruction along with assisting students solving problems using a seven step method. The study consisted of 161 seventh and eighth grade students. Seventy-eight of the students had a learning disability, while eighty-three were average achieving students. There were ninety-two seventh graders and seventy-nine eighth graders. Of the 161 participants, eighty-two were male and seventy-nine were female. In terms of ethnicity, ninety - six students were

Hispanic, forty-three students were African American, seventeen students were White, and five students were categorized as “other”. There were 111 students on free and reduced lunch plans. The focus of this three year study was to investigate change in students’ math problem solving performance following *Solve It!* instruction. The Math Problem Solving Assessment (MPSA) was used to measure student outcomes. The MPSA is a structured interview that consists of three word problems and thirty-four other items selected from a larger version (Krawec, Huang, Montague, Kressler & Alba, 2012). Students responded to five statements using a five point Likert scale and then solved the math word problems. *Solve It!* instruction was given to the intervention group which included scripted lessons and direct instruction. Teachers implementing the cognitive based strategy instruction attended a three day professional development workshop prior to the beginning of the school year (Krawec, Huang, Montague, Kressler & Alba, 2012). Three days of intensive cognitive strategy instruction were implemented first and then continued once weekly for thirty minute problem solving practice sessions (Krawec, Huang, Montague, Kressler & Alba, 2012). Throughout this process, the *Solve It!* instructional manual was used which included scripted lessons, materials and manipulatives. The comparison group was instructed to conduct their classroom normally. The students who received the intervention reported using significantly more strategies than students in the comparison group (Krawec, Huang, Montague, Kressler & Alba, 2012). Average achieving students reported using significantly more strategies than students with a learning disability as well (Krawec, Huang, Montague, Kressler & Alba, 2012). Analysis showed that the intervention group improved significantly from pretest to posttest on their reported strategy use ( $p < .001$ ), but the comparison group did

not ( $p=1.30$ ) (Krawec, Huang, Montague, Kressler & Alba, 2012). The intervention group reported a pretest  $m$  of 15.78 and a post - test  $m$  of 17.43 while the comparison group showed a pretest  $m$  of 15.19 and a post - test  $m$  of 14.16 (Krawec, Huang, Montague, Kressler & Alba, 2012). Through this research, it is concluded that *Solve It!*, appears to improve students problem solving accuracy by increasing their range of effective strategies, providing them with knowledge and confidence to successfully solve problems.

The previous two studies were follow – ups to a smaller scale study done by Montague, Warger and Morgan in 2000. In this study only eight-four students participated from the Miami area. The study had a control group and intervention group. Students in the intervention group were taught Solve It! instruction in small groups and had to complete a ten question assessment. Results showed that students with Learning Disabilities in the intervention group outperformed average achieving students in the control group (Montague, Warger, & Morgan, 2000). The three studies reviewed on Solve It! instruction all had positive results for those participating in the intervention, which led me to want to try a modified version of it in my classroom. The positive results for students with Learning Disabilities using this strategy has prompted me to include this instruction in a secondary resource mathematics setting.

In 2001, Montague teamed up with Candace Bos to investigate the effect of an eight-step cognitive strategy on verbal math problem solving. Six adolescents between the ages of 15 and 19 were selected from remediation classes in an Arizona high school (Montague & Bos, 2001). The student’s full-scale IQ scores were between 85-115 (which is in the normal range) on the Wechsler Intelligence Scale for Children Revised

(WISC-R). There were five males and one female. The subjects were given a baseline assessment of ten questions and then re-assessed every two weeks for three months. The cognitive strategy instruction provided was an eight step process to train the students in verbal math problem solving. For each question the students were asked to read the problem aloud, paraphrase the problem aloud, visualize, state the problem, hypothesize, estimate, calculate, and self-check. Five of the six subjects made progress after receiving the intervention on the teacher based assessment (Montague & Bos, 2001). All but one subject showed an increase of five to six correct questions from the baseline to their current learning. This study just adds to a plethora of research that states that cognitive strategy instruction is a useful alternative to teach math problem solving.

Strategy based intervention has also been studied on students who are identified as having emotional or behavioral disorders. It is a constant struggle to educate children who exhibit these disorders because of the individual backgrounds they sometimes come from. Students classified as having emotional disorders are typically performing below grade level and make less progress than the typical developing student (Alter, Brown, & Pyle). A study was conducted which used multiple baselines across participants for three elementary school aged children. These children were identified as being Emotionally Disturbed. It was conducted in a self-contained classroom in a public school in a Midwestern city. There were two male participants and one female participant. All three students were African American. Subject 1 was in fourth grade and was nine years old. He had an overall IQ of 67, as measured on the WISC III. Subject 2 was a fourth grade male who also was nine years old. He was diagnosed as Emotionally Disturbed, but also with a specific learning disability in reading comprehension. He had an overall IQ of 89

on the WISC III. Subject 3 was a first grade female who was seven years old. She had an IQ of 101, as measured on the WISC III (Alter, Brown, & Pyle, 2011). Baseline data was collected by students completing a curriculum - based measurement on percent word problems as well as the percentage of time on-task during work sessions. The teacher involved in the intervention attended a training workshop on how to implement teaching strategies to guide students in math problem solving. The teacher delivered explicit and systematic instruction in fifteen minute intervals to the students using cognitive strategies learned at the workshop. Certain strategies that were followed were modeled problem solving, reviewing critical problem solving strategies, and providing rationales for becoming better problem solvers. Following the lesson, the students completed 5 word problem worksheets. After the intervention took place, the students took a post assessment. Subject 1 increased from a 23% to a 52% from his baseline assessment, as well as increasing his on task behavior from 54% to 86%. Subject 2 increased from a 14% to a 50% from his baseline assessment, as well as increased his on - task behavior from 62% to 85%. Subject 3 increased from 18% to a 48% from her baseline assessment, as well as increasing her on task behavior from 67% to 87% (Alter, Brown, & Pyle, 2011). While the study was small and in a highly contained area, it still demonstrated positive results with using a cognitive strategy instruction with students who are Emotionally Disturbed. This study piloted what I hope to be more research in the area of math problem solving of students who are emotionally disturbed.

### **Graphic Organizers**

Graphic organizers are an instructional tool in which students create a pictorial representation of what they are learning (Zollman, 2012). They can be used to sequence



events, assist in comprehension and aid in putting thoughts down on paper. Many students with learning disabilities already have a difficult time with organizational skills. When students enter their mathematics classroom, it is assumed they can read and comprehend complex word problems before even attempting to know the functions, operations and rules to solve the problems. This however is not always the case. In the current study, a graphic organizer was used to help students pull out the important information in word problems and make hypotheses on the task at hand. With the implementation of the Partnership for Readiness for College and Careers (PARCC) exams, improving mathematical problem solving skills is the most important job of a math teacher (Zollman, 2012). The PARCC implements more critical thinking and complex word problems than previous tests administered statewide. Students need to be systematically and explicitly taught how to focus on these problems and increase their repertoire of problem solving strategies. As educators, we need to provide students the tools needed to solve complex mathematical problems they encounter in the 21<sup>st</sup> century classroom. This includes exposing and teaching the students how to use the proper technology to perform on the exam, attaining the appropriate skills to solve the problems, and fostering the knowledge needed to be a successful problem solver.

When a student first reads a mathematical word problem they must first sort the information as essential and non-essential to solving the problem (Zollman, 2012). Graphic organizers assist students in sorting out this information as well as devising a plan to carry out operations to solve the problem. The potential for graphic organizers to assist students with disabilities in math class is endless, but needs to be developed

carefully and concisely. In the current study, the graphic organizer created was done so by modifying the cognitive strategy instruction Solve It!.

Reading mathematical world problems is a complex task. There is a combination of words, numbers, letters, symbols and graphics that the students must comprehend (Braselton & Decker, 1994). The PARCC assessment claims that each problem is written at a 7<sup>th</sup> grade reading level for Algebra 1 students (PARCC). Many students with disabilities are not achieving a 7<sup>th</sup> grade reading level by the time they are in the 9<sup>th</sup> grade and taking Algebra 1. This makes the math teacher encounter another obstacle in training proficient math problem solvers. A study done by Maffei in 1973 found that reading teachers were more effective in teaching word problems to students than mathematics teachers (Maffei , 1973). Math teachers immediately recognize the numbers or operations needed to solve the problem while a reading teacher may focus more on the student reading the passage word for word and comprehending the meaning. Districts across the country have adapted writing across the curriculum for this very reason. As school districts and government officials continue to push for mainstream classrooms in mathematics, we must understand that not all students will be at the reading competence level of that grade level (Ives, 2007).

The use of a graphic organizer can help reduce the stress for a student who has difficulty in reading and instead have them focus on the mathematical terminology, numbers, and operations to successfully solve word problems (Ives, 2007). In the current study, the graphic organizer was created by the intervention and control group teachers to ensure its usefulness in solving word problems involving percent and proportions.

Research on Geary's three different subtypes related to dyscalculia confirmed a

relationship between language skills and mathematical skills (Ives, 2007). Geary conducted research by reviewing previous literature and found that dyscalculia was driven by three subtypes including having difficulties in fact retrieval, learning strategies or procedures, or experiencing visual spatial difficulties that hindered their progress (Educeri, 2004). Students in the 21<sup>st</sup> century classroom are asked to have adequate language and mathematical skills to pass statewide assessments. Graphic organizers can assist in carrying the burden of reading laborious word problems and break them down into simpler equations or expressions. An article published by Ives and Hoy in 2003 looked at suggestions for modifying graphic organizers so they could be used in the 21<sup>st</sup> century math classroom where higher level thinking and more difficult problems are the norm. They concluded through their review that graphic organizers for the math classroom should contain three things. First, the content of the graphic organizer must not be too wordy and contain mathematical analogues. Second, the spatial arrangement must be connected to the topic at hand. Lastly, the graphic organizer should not be a substitute for instruction but rather incorporated along with systemic and explicit instruction (Ives & Hoy, 2003).

Four years after the article published by Ives and Hoy, Ives himself conducted a study in 2007 on the effectiveness of graphic organizers in the secondary Algebra classroom. A two group experimental design was used to determine the effectiveness of using graphic organizers to solve linear equations (Ives, 2007). The study took place in Georgia in a private school. The school consisted of students in sixth through twelfth grade. All students either had a learning disability or attention problems (Ives, 2007). Fourteen students participated in the intervention group that received the graphic

organizers. Ten of the students were male and four of the students were female. The control group consisted of sixteen students in which eleven were male and five were female. There was one Asian-American student in the intervention group and all other students were Caucasian. The control group consisted of all Caucasians. The intervention group was systemically instructed to use graphic organizers in completing system of equations problems while the control group was told to do business as usual. Two weeks after instruction was delivered the students completed a teacher-generated assessment. The intervention group had a mean score that was statistically significantly higher than the mean score for the control group on the teacher-generated assessments ( $F= 3.14, p = .087$ ) (Ives, 2007). The results of the study showed that students who were exposed to and systemically taught how to use a graphic organizer scored better on an assessment than students who did not use a graphic organizer (Ives, 2007). While more research is needed in this area, the positive results in this study are a step in the right direction to assist students in solving word problems. This research is why I have decided to include a graphic organizer into the study to assist in determining the effectiveness of cognitive strategy instruction on math problem solving in the high school classroom.

In summary, it is apparent that instruction in the 21<sup>st</sup> century classroom must adapt to the academic and curricula changes ahead. With the implementation of the Core Content Standards and PARCC, statewide assessments have evolved in containing more complex mathematical problems. Students need to be exposed to different approaches and techniques to assist in solving these problems. Positive results through research have shown that cognitive strategy instruction and graphic organizers assist students with

Learning Disabilities in solving mathematical problems. In a mini study I conducted in 2013, I observed that the intervention Solve It!, while beneficial to students with learning disabilities, was too laborious for them to get through on a consistent basis. Therefore, a modified version of the Solve It! program will be used with a graphic organizer to assist students in mathematical problem solving.

## Chapter 3

### Methodology

#### Setting and Participants

This study took place in two Math Foundations 3 self-contained classrooms in a high school in New Jersey. The course covers the last third of Algebra 1 (Chapters 7-10 of the McDougall Littell Algebra 1 textbook, 2012). Topics that are covered include percentages, proportions, exponents, factoring, polynomials and quadratic expressions. The pre-requisite for the class is passing Math Foundations 1 & 2, which covers chapters one through six of the Algebra 1 textbook. The intervention group started with sixteen students, but by the end of the study had thirteen students. Two students dropped the course due to withdrawing from the school and one student was transferred to another self – contained classroom. The first class met from 8:20 a.m. to 9:04 a.m., while the second class met from 9:08 a.m. to 9:54 a.m. There was one special education teacher in the intervention classroom. Students were seated in columns facing the Smartboard in the classroom, with no students further than three rows back. The control group, who was instructed to conduct business as usual, also took place in two classrooms but was a Math Foundations 2 class. Math Foundations 2 is a course designed for the middle third of the Algebra 1 textbook (Chapters 4-6 of the McDougall Littell Algebra 1 textbook). Topics that are covered include percentages, proportions, solving equations, graphing linear equations and inequalities. The control group both started and finished with sixteen students. The control group classes met from 7:25 to 8:10 a.m. and 1:15 to 1:59 a.m. The teachers in both classes taught percentages, percent of change and proportions for the purpose of this study. As stated previously, students in the current study were

classified as Specific Learning Disability, Other Health Impaired, Emotionally Disturbed and Multiply Disabled.

## **Procedure**

The intervention began by students completing a baseline assessment created by the intervention and control group teacher using KUTA software, as well as a McDougall Littell Algebra 1 textbook by Larson, Boswell, Kanold & Stiff. KUTA is a mathematics program that creates algebraic problems and answer keys to go along with them. The baseline assessment contained ten problems which included mathematical concepts such as percentages, percent of change and proportions. After students completed each pretest problem, they answered a survey consisting of three questions. On this survey, students identified if they used a strategy to solve the problem, if they comprehended the question and if they checked their answer. The test had a time limit of forty-five minutes and all students were able to complete the assessment. The intervention and control group teachers created a rubric together to grade the baseline assessments. Students received full credit or three points if they correctly solved the problem, two points if they had the correct setup but had minor mathematical errors, one point if they correctly setup the problem but failed to attempt to solve it and zero points for not addressing the problem.

In the twenty-six day study, the intervention group was instructed by using a modified version of the Solve It! Instruction method. The Solve It! process was shortened from seven to five steps. The two steps that were eliminated included when the students had to paraphrase the problem and visualize the problem by creating representations that depict relationships among the problem parts. In my previous

research in 2013, I observed those steps as being the most laborious. Each student was given a graphic organizer to assist them in completing problems (Figure 1). The students were instructed to read the word problem and identify key information by highlighting it in the sentence. They were then asked to hypothesize what they believed the answer could be. Next, the students would identify what operations or skills they would need to solve the problem. After the students gathered all the information necessary to solve the problem, they were asked to create an equation or proportion to answer the question. Lastly, the students were instructed to check their answers. The first six days of the study involved the teacher modeling problems by going through each step and visually displaying how to use the graphic organizer. An example of a modeled problem is included in Figure 2. The question stated, “Dave purchased a \$50 pair of jeans with a 40% off coupon. How much did the jeans cost after the 40% percent discount?” All students in the Intervention and control group were provided with a scientific calculator as well as explicit instruction before the study on how to use the different functions of the calculators.



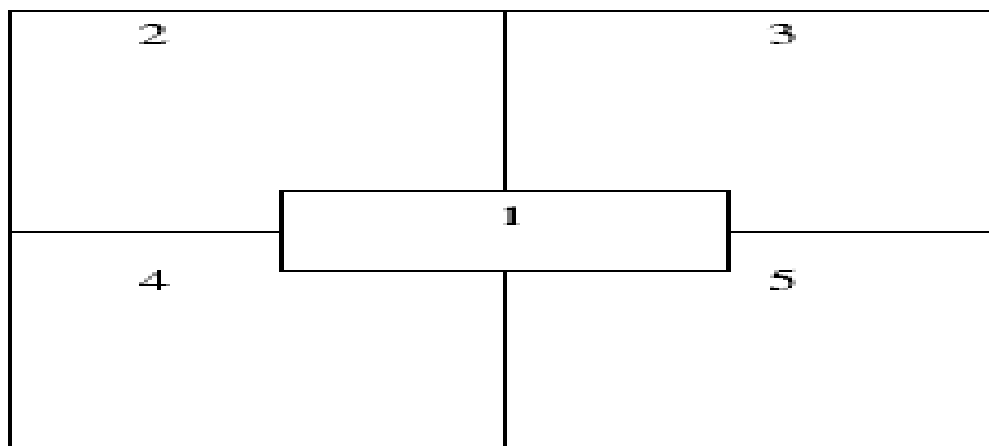


Figure 1. Graphic Organizer

1. Read the problem and identify key information.	\$50 jeans and 40% off coupon Coupon=Discount
2. Hypothesize	-Discount means saving money -Almost 50% -Roughly \$28
3. Identify operations/skills	-Percentages -Multiply cost of jeans by percent for discount -Subtract discount to amount of jeans
4. Create equation/proportion and solve	$\$50.00 \times 40\% = \$20.00$ (discount) $\$50.00 - \$20.00 = \$30.00$
5. Check answer with hypothesis	$\$30.00$ answer/ $\$28.00$ hypothesis

Figure 2. Modeled example

After six days of modeled instruction, students spent the first twenty minutes of the next twenty days completing problems using the Solve It! strategy. One-on-one instruction was provided when needed to complete a problem. At the end of the twenty minutes, the teacher would model the problems and provide the answer. Students participated in a pair-share during this time to check their classmates work and offer

suggestions to them if they got the problems wrong. Once a week for twenty five minutes, students worked on the ALEKs computer program. ALEKs is a mathematics based program that assists students in closing the achievement gap. It is an artificial intelligence program where no two students are on the same problem at one time. This program assists the teacher in tiering and differentiating instruction.

The control class conducted business as usual, but solved the same problems the intervention group did during the experiment. The teacher started each day with a guided warmup. She would then introduce the lesson using the Smartboard and students would take notes. After notes were completed, students were given a worksheet to complete independently. The teacher circulated the room answering any questions the students may have had. At the end of the period, the control teacher would give the students an exit ticket. On the exit ticket, the students would have to solve a problem based of the day's notes and explain in words how they came to their solution. The teacher would then collect the exit ticket as the students left the classroom and provide one-on-one instruction the following day based off of the results of the exit ticket. The control group also used the ALEKs computer program once a week for twenty five minutes to assist students in closing the achievement gap. The control group's afternoon class had to meet in a computer lab and not the daily class setting due to technology issues.

### **Variables**

The independent variable for this was study was a modified version of the program *Solve It!*. Students utilized a graphic organizer while going through five of the seven steps of *Solve It!*. The dependent variable for this study was a curriculum based

assessment created by both teachers involved in the study. The assessment was composed of ten open-ended mathematical problems. Teachers used KUTA software as well as a McDougall Littell Algebra 1 textbook to create the assessment.

## Chapter 4

### Results

#### Summary

In this study, the effects of cognitive strategy instruction in the high school mathematics classroom were analyzed. Four classes participated in the study, with two classes receiving the intervention and two classes acting as a control group, with the teacher conducting class as usual. The intervention implemented was the Solve It! strategy instruction model with a graphic organizer. The research questions to be answered were:

1. Do students who are provided with extensive cognitive based strategy instruction along with a graphic organizer to organize problem details instead of conventional instruction perform better on a curriculum - based measurement?
2. After solving problems on a post test, will students report that they understood the question, utilized an appropriate problem-solving strategy, and checked their answer?

The study began with students completing a baseline assessment created by the intervention and control group teachers using KUTA software, as well as a McDougall Littell Algebra 1 textbook by Larson, Boswell, Kanold & Stiff. The baseline contained ten problems that included mathematical concepts such as percentages, percent of change and proportions. The test had a time limit of forty-five minutes and all students were able to complete the assessment.

## Group Baseline Results

Table 1 shows the baseline scores for the control and intervention groups. The intervention and control group teachers graded their student's assessments but used the same rubric to do so.

Table 1

### *Baseline Assessment Data*

Intervention Group 1: 35%	Control Group 1: 40%
Intervention Group 2: 30%	Control Group 2: 20%
INTERVENTION TOTAL: 32.5%	CONTROL TOTAL: 30%

A t-test was run to determine the significance of the results. The difference between the pre-test scores of the two groups (32.5% v. 30%) yielded a t-score of .43 which was not statistically significant. This indicates that there was no statistical difference between the two groups at the start of the study.

## Intervention

After the baseline was given, the intervention teacher implemented Solve It! instruction for twenty - six days. Students were explicitly taught how to use Solve It! instruction while using a graphic organizer. The control teacher conducted her classroom as she had done in the past utilizing warmups, guided notes, group work and exit tickets. At the end of the twenty-six day trial, the students were given a post test to see what they have learned and retained. Table 2 shows the post test scores for the control and intervention groups.

Table 2

*Post Test Assessment Data*

Intervention Group 1: 70%	Control Group 1: 52%
Intervention Group 2: 66%	Control Group 2: 33%
INTERVENTION TOTAL: 68%	CONTROL TOTAL: 42.5%

A t-test was then run on the pre and post - test scores of each group. The intervention group had a difference (between 32.5% and 68%) which yielded a t score of 5.1, with a probability (p) of <.0001. For the control group the t score was 2.3 with a probability of p<.05. This indicates that both groups improved, although the improvement for the intervention group was greater.

The difference between the groups between the baseline assessments to the post assessment is presented in table 3. It appears that Solve It! instruction along with a graphic organizer assisted the students in gaining a better understanding of percentages, percent of change and proportions. The intervention group's percentage went from a 32.5% to a 68% while the control group's percentage went from a 30% to a 42.5%. While both groups displayed academic growth in the three areas assessed, the students who were exposed to Solve It! instruction scored higher on their post test.

Table 3

*Pre/Post Test Scores*

	Pre-Test Score	Post-Test Score	Difference
Intervention Group 1	35%	70%	+ 35
Intervention Group 2	30%	66%	+ 36
Control Group 1	40%	52%	+ 12
Control Group 2	20%	33%	+ 13

The difference in improvement between the experimental group (35.5%) and the control group (12.5%) yielded a t-score of 5.42 with a  $p < .0001$ . This shows that the difference in the amount of gain for the two groups was statistically significant, with the intervention group making significantly greater gains.

In Table 4 the results are presented for the intervention group and control group on their understanding of the question, utilization of an appropriate problem-solving strategy, and checking their answer on the post test. Students answered these three questions with “yes” or “no” responses after each question on the post test. Based off of the data collected, 91% of the students understood the question in the intervention group while only 61% understood it in the control group. When asked if they utilized an appropriate problem solving strategy, 90% of the intervention group reported they did while only 54% of the students reported they did in the control group. Finally, when asked if they checked their answer, 96% of the students in the intervention group reported that they did while only 45% of the students in the control group reported that they did.

Table 4

*Post Test Survey Data*

	Did you understand what the question was asking you?	Did you use a strategy or formula to solve the problem?	Did you check your answer?
Question 1	IG: 15/16 CG: 5/13	IG: 12/16 CG: 7/13	IG: 16/16 CG: 3/13
Question 2	IG: 15/16 CG: 9/13	IG: 16/16 CG: 7/13	IG: 16/16 CG: 5/13
Question 3	IG: 12/16 CG: 7/13	IG: 14/16 CG: 7/13	IG: 13/16 CG: 8/13
Question 4	IG: 15/16 CG: 8/13	IG: 10/16 CG: 3/13	IG: 15/16 CG: 9/13
Question 5	IG: 14/16 CG: 8/13	IG: 15/16 CG: 8/13	IG: 16/16 CG: 9/13
Question 6	IG: 15/16 CG: 12/13	IG: 16/16 CG: 6/13	IG: 15/16 CG: 5/13
Question 7	IG: 15/16 CG: 9/13	IG: 16/16 CG: 7/13	IG: 16/16 CG: 5/13
Question 8	IG: 15/16 CG: 5/13	IG: 13/16 CG: 10/13	IG: 14/16 CG: 5/13
Question 9	IG: 15/16 CG: 9/13	IG: 16/16 CG: 7/13	IG: 16/16 CG: 5/13
Question 10	IG: 15/16 CG: 7/13	IG: 16/16 CG: 8/13	IG: 16/16 CG: 4/13
Total Percentages	IG: 91% CG: 61%	IG: 90% CG: 54%	IG: 96% CG: 45%



## Chapter 5

### Discussion

The current study analyzed the effectiveness of cognitive strategy instruction in the high school mathematics classroom. Throughout the twenty-six day study, students were taught lessons on percentages, percent of change and proportions. There were two classes in the intervention group and two classes in the control group which both contained sixteen students. The intervention teacher implemented the Solve It! cognitive based strategy instruction method along with the assistance of a graphic organizer. Solve It! is a seven step process for solving mathematical problems, however in this study it was modified to five steps with the addition of a graphic organizer that was created by the intervention and control group teacher. The control group teacher conducted her classroom as she typically does presenting lessons via the Smartboard, giving guided practice worksheets and utilizing exit tickets to identify if the students understood the days lesson. Both groups supplemented the ALEKs mathematics computer program into their weekly plans to provide children with tiered assignments. Progress was monitored by students taking a pre and post assessment. On the post assessment, students had to identify if they understood the question, used a strategy or formula to solve the problem and if they checked their answer.

The results from the study were positive. They showed that students in the intervention group performed better on a post test then those students who were in the control group. The intervention group had an increase of 35.5 percentage points while the control group had an increase of 12.5 percentage points. These results showed that the intervention group made significant gains over the control group throughout the

study. When asked on a post test if the students understood the question that was being asked, the intervention group reported they did 91% of the time while the control group only reported they did 61% of the time. Students were also asked on the post - test if they used a formula or strategy to solve the problem. The intervention group reported they did 90% of the time while the control group only reported that they did 54% of the time. Finally, the students were asked if they checked their answer at the end of each problem. Students in the intervention group reported that they did check their answer 96% of the time while students in the control group only reported that they did 45% of the time.

The results from the study were consistent with previous research in that each time Solve It! instruction was used the group who was exposed to it saw significant gains. A study in 2011 conducted by Montague, Enders & Dietz showed results that indicated that students who received the Solve It! intervention showed significantly greater growth in math problem solving over the school year than students in the comparison group (Montague, Enders, & Dietz, 2011). A 2012 study conducted by Krawec, Huang, Montague, Kressler and Melia de Alba also looked at the effectiveness of Solve It! instruction and if students applied the strategy while taking assessments. Their results showed that students who took place in the intervention scored higher on a post test as well as identified that they used more strategies than students who did not take part in the intervention (Krawec, Huang, Montague, Kressler & Alba, 2012).

Throughout this study there were many implications. First, the intervention teacher taught the Solve It! strategy instruction to himself. It may have been more beneficial if he took a workshop on it or observed a teacher who was currently utilizing the program. Another limitation is that the sample size was small. With only sixteen

students in each group, the results could be skewed a little bit because of the lack of participation. A few students dropped out of the study because their placement was changed during the twenty-six day study. If I were to complete this study again in the future, I would look to add regular education students and identify if they make greater gains after learning Solve It! or if the focus should just be on children with special education needs.

Overall, this study was a success and received the results that were hypothesized. The intervention itself is very inexpensive and most educated people can teach themselves the Solve It! cognitive strategy instruction process. It has become apparent through many studies that the intervention works and needs to be put into place in more classrooms for further research and development. Currently, I would focus the instruction in the special education setting of schools to accommodate the needs of students who lack a lot of the strategies needed to be proficient problem solvers. Most general education students have a plethora of strategies at hand already and may not benefit as much from this instruction. They may find it to be too laborious and time consuming. However, for students with special needs the structured nature of Solve It! instruction can help them identify key parts in mathematical word problems and solve them using the process each time.

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