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USING COMPUTER-BASED MNEMONIC ILLUSTRATIONS TO TEACH ALGEBRA WORD-PROBLEM SOLVING SKILLS TO HIGH SCHOOL STUDENTS WITH LEARNING DISABILITIES

by
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Dedication

I would like to dedicate this manuscript to my three children,

Caitlin, Kelsey, and Robert

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Abstract

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It is clear that students with Learning Disabilities (LD) struggle with complex mathematical problems, particularly in learning algebra. Technology may provide a new way for math instruction, as well as use of a concrete instructional method such as a mnemonic device. Difficulty solving word problems in algebra can be attributed to a variety of deficits, thus it becomes difficult to choose an instructional method that will provide positive results for these students. To date, research on adolescent students in this area is limited. The present study was designed to examine the impact of a combination of two different approaches by using a mnemonic device and SMART board presentations to teach algebraic word problem solving skills to high school students with LD. It attempted to investigate whether these approaches would improve the performance of 2 groups of secondary students with LD in learning math skills. All 6 students involved in the study improved their individual performance, and both groups as a whole achieved 100% mastery during the last two weeks of the investigation.

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Chapter 1

Introduction

1.1 Statement of the Problem

Successful completion of algebra is required by many states for students to earn a high school diploma (Kortering, deBettencourt, & Braziel, 2005). Lack of success in or access to algebra may be part of the explanation for the low rate of post-secondary schooling among students with learning disabilities (LD) (Kortering et al., 2005). According to Hsieh and Lin (2008), students with LD tend to be skillful in solving calculation questions, but are deeply frustrated with and frightened of word problems. Solving algebraic word problems is among one of the most difficult academic skills for students to master (Maccini & Ruhl, 2000). When a string of numbers and words are encountered together, students tend to unconsciously refuse to comprehend and analyze the meaning of the question (Hseih & Lin, 2008). The National Assessment of Educational Progress (1992) reported that word problems in math present difficulty for students of all ages and ability levels, but more specifically for students with mild disabilities (Jittendra et al., 1998).

The fundamental criteria for learning disabilities are characterized as follows: (1) a psychological processing disorder that presents obstacles for some individuals to understand and interpret information they see or hear; (2) difficulty learning not brought on by another primary disability; and (3) problem resulting in a discrepancy between potential and actual performance, or underachievement in at least one academic area (Steele, 2002). In addition, such learners may have problems with oral language, visual processing, auditory processing, memory problems, and organization and attention deficits (Steele, 2010). Word problems present a challenge to students with LD due to multiple factors. These include trouble identifying and ignoring extraneous information in the problem, as well as completing all requisite steps to solve it. In addition, students have difficulty organizing an efficient strategy for approaching the problem, representing words within the math equation, and computing basic facts (Jittendra et al., 1998). Memory deficits may cause these students to have difficulty learning math facts or remembering the sequence necessary for problem solving. In algebra, generally a word problem consists of one or more sentences representing a situation or story, where the student needs to understand the elements and be able to generate a math model to represent it. Thus, the problem has two phases: problem representation and problem solution (Jacques et al., 2013).

According to Shellard (2004), the two most common math difficulties are basic operations and word problems. For word problems, many times the difficulty lies with the inability to read and comprehend the problem. Students with co-existing deficits in reading and or comprehension will struggle, and the gap appears to widen as students move from the elementary grades to the secondary (Jittendra et al., 1998). For students with LD, the difficulty in the elementary grades continues through secondary education (Maccini & Ruhl, 2000). Their limited understanding of abstract reasoning often causes these students to "shut down" mentally when they encounter a word problem (Maccini, McNaughton, & Ruhl, 1999). When taking into consideration the fact that there are two types of math disabilities: primary or nonverbal; and verbal or reading disorders (Fleischner & Manheimer, 1997), the combination of reading, writing, reasoning, and math skills makes the task of solving a word problem extremely complex.

Research on strategies for teaching algebraic word problems to students with disabilities has been identified as an area in need of further research (Test & Ellis, 2005). The small number of studies and the significant difficulty these students encounter indicate the need to further examine methods for instruction (Jittentra et al., 1998). According to Hsieh and Lin (2008), teachers consider that students will become more competent in solving word problems after learning more math skills. For students who can't decode text, teachers tend to adopt a passive attitude and believe that failure is a result of a mismatch of cognitive development or pre-requisite knowledge (Hsieh & Lin, 2008). Furthermore, many strategies have been designed and evaluated for students in lower grades, but most are not applicable to upper level math instruction. For example, a systematic approach using concrete representations, or manipulatives, followed by semi-concrete representations, followed by abstract representations (numbers only) has proven effective for learning basic math skills. This approach becomes problematic for higher levels of math such as algebra and calculus that don't lend themselves to concrete or semi-concrete representations (Miles & Forcht, 1995). Difficulty at the abstract level means that students with LD may need hands-on manipulatives and pictorial representations because they struggle to solve problems strictly using numbers (Witzel, Smith, & Brownell, 2001).

Research on teaching strategies concluded that adolescent students with LD can benefit from the planned use of mnemonic devices most often associated with elementary grades (Allsopp, 1999). This intervention is especially helpful for students with difficulty remembering the correct steps of a problem (Miller, Stringfellow, Kaffar, Ferreira, & Manci, 2011). A mnemonic strategy is defined as a word, sentence, or picture device or technique used for improving or strengthening memory (Lombardi & Butera, 1998). Mnemonic devices have been found to be successful in teaching a wide variety of math skills. It was shown that use of a mnemonic device helped students remember the steps for solving one-variable algebraic equations (Allsopp, 1999). For example, mnemonic illustrations such as LAP for teaching fractions (Test & Ellis, 2005) and STAR for solving word problems involving the subtraction of integers (Maccini & Ruhl, 2000) provided successful evidence in teaching math to high school students with LD.

In recent years, the use of technology to provide visual cues to support underachieving students has become an important tool for promoting math problem-solving, reasoning, and exploration (Pugalee, 2001). Technology is defined as a tool to support the exploration of math and to provide essential skills for advanced studies (Pugalee, 2001). It is found that students seem to be increasingly comfortable with graphics and a computer, a way of stressing links with algebra whenever possible (Lord & Barnard, 2003). Technology provides visual symbols for the purpose of increasing attending behavior necessary for learning mathematical relationships (Bailey & Downing, 1994) and highlights key words from equations on a computer screen during problem-solving to benefit students with LD (Trotter, 2008). In addition, teacher- created Power Point slides and multimedia presentations using the SMART board and projector can be recorded for later playback for students to review and practice (Hofmann & Hunter, 2003). The SMART board is an interactive whiteboard that uses touch detection for user input in the same way as a regular computer. A projector connected to the classroom computer displays the desktop image on the board that accepts touch input from a finger, pen, or other solid object. Various colors and highlighting features are available, as well as a “spot light” that focuses the students on important material. Images posted on the SMART board can be saved for future use on the desktop computer in the classroom.

1.2 Significance of Study

It is clear that students with LD struggle with complex mathematical problems, particularly in learning algebra. Technology may provide a new way for math instruction. Difficulty solving word problems in algebra can be attributed to a variety of deficits, thus it becomes difficult to choose an instructional method that will provide positive results for these students. To date, research on adolescent students in this area is limited. It is found that of the studies in math instruction, few were conducted for high school students, especially teaching algebra for those with LD. The present study is designed to examine the impact of a combination of two different approaches: using a mnemonic device and SMART board presentations to teach algebraic word problem solving skills to high school students with LD. It attempts to investigate whether these approaches would improve the performance of students with LD in learning math skills.

1.3 Statement of Purposes

The purposes of this study are to (a) investigate the effectiveness of using a mnemonic device called GUFSA (Given, Unknown, Formula, Solve, Answer) in math instruction on word problem solving and (b) evaluate the effects of using the SMART board in math instruction for students with LD.

1.4 Research Questions

1. Would students with LD increase their math scores on word problem-solving using a mnemonic device?
2. Would students with LD increase their math scores when SMART board presentations are provided?

1.5 Definition of Terms

1. SMART classroom: defined as one which includes:
    a. SMART board
    b. Projector
    c. Computer

d. Microphones

e. Speakers

f. VCR

The SMART classroom allows the teacher to take advantage of all available multi-media resources, such as Power Point, Excel, etc. (Hofmann & Hunter, 1997)

Chapter 2

Review of Literature

The study of algebra provides a systematic approach for solving problems applicable to a variety of jobs, and is considered a “gatekeeper” to educational and occupational opportunities. The reasons for this are two-fold: (a) most secondary schools require students to take higher-level mathematics such as algebra to graduate; and (b) students need higher-order reasoning and problem-solving skills to compete in a technological society (Maccini & Ruhl, 2000). Algebraic thinking involves the use of symbols to generalize certain kinds of arithmetic operations and the ability to represent relationships (Xin et al., 2011). Problem solving has been defined as a higher order cognitive process that requires detecting steps or processes necessary to arrive at an answer (Xin et al., 2011). When information about the problem is presented as text rather than in mathematical notation, the problem becomes a word problem. Successful performance in algebra requires mastery of many components, including basic skills, terminology, problem representations, problem solutions, and self-monitoring strategies (Xin et al., 2011). For students with LD, problems in these areas become more pronounced (Feigenbaum, 2000).

It was found that students with LD fail to automatize even the most basic skills that would allow them to concentrate on more conceptually difficult problems, such as word problems (Jittendra et al., 1998). Word-problem solving presents persistent difficulties for those students when they have coexisting deficits in either reading or computation, or both (Jittendra et al, 1998). Many students lack the ability to decode the meaning in the question and tend to think that all information given is useful, resulting in their incompetence in summarizing the task at hand. Some may understand the question incorrectly due to comprehension issues or inadequate knowledge of vocabulary and terminologies (Hsieh & Lin, 2008). Others demonstrate serious difficulty with problem application, including simple calculations and measurement problems, even though they know some of the basic facts necessary to carry out the required computations (Maccini et al., 1999).

In recent years, research has been conducted to investigate the best instructional strategies to address the complex problem of teaching algebraic problem solving skills to students with LD. This chapter reviews research on two specific approaches to algebraic problem-solving instruction for students with LD. One is using a mnemonic device; and another is using SMART board (interactive white board) technology with visual cues.

2.1 Mnemonic Device Approach

The mnemonic device approach focuses on teaching students a first-letter mnemonic for self-monitoring and problem-solving (Maccini & Ruhl, 2000). Students with LD have difficulty representing problems and distinguishing relevant from irrelevant information (Maccini & Ruhl, 2000). The mnemonic device offers one way to teach for understanding, offering students a method for making greater connections in their learning by using a concrete method. In Maccini and Ruhl's study (2000), a combination of strategies, including general problem-solving strategies and strategic instruction, was used to support students with LD. Three high-school males with LD, ages14 to15, who demonstrated functional deficits in the targeted task of solving algebraic word problems participated in the study. A mnemonic device termed "STAR" was used to cue students to the steps in word-problem solution. The "S" was for "search the problem"; "T" for "translate the words into an equation"; "A" for "answer the problem"; and "R" for "review the solution". A concrete, semi-concrete, and abstract instructional sequence; general problem-solving strategies; and self-monitoring strategies were provided in the instruction. Each lesson included advance organizers, modeling, guided practice, independent practice, post-test, and teacher's feedback. The experimental design was single-subject with the three subjects given four probes intermittently during baseline to determine current status and stability of the behavior under investigation to determine the need for intervention. Once stable baseline data was obtained for student one, treatment was introduced. When student one's performance increased, treatment was introduced to student two, etc. The participants were assessed after each instructional phase to determine their changes over time. Participants were observed for evidence of searching the word problem, translating the words to equations, answering the problem, and reviewing the solution. Accuracy on problem representation, problem solution, and percent of using the strategy was collected for each student. Generalization data was also collected to measure students' use of the strategy on other problems. Results indicated that adolescent students with LD could learn to represent and solve word problems. All students in the study increased their percentage of strategy use, accuracy of problem representation, and accuracy of problem solution. The mnemonic device, STAR, helped students attend to critical features of word problems and make solutions.

Similar results found another mnemonic device, LAP, to be useful in teaching algebraic concepts to 8^{th} grade students with LD. Test and Ellis (2005) examined the effects of teaching six students how to solve fraction problems using this strategy. The participants were divided into three pairs in a special education math class. LAP refers to: (a) L: look at the denominator; (b) A: ask yourself "will the smallest denominator divide into the largest denominator an even number of times; and (c) P: pick the correct fraction type. Students were taught the mnemonic device and, after mastering the strategy, students learned how to use the strategy to solve each fraction problem. Instruction continued with the same type of fraction until 89% accuracy was achieved for three consecutive days. The results indicated a functional relationship between implementation of a mnemonic device and student acquisition of both the strategy and their ability to apply it. Five out of six students mastered both skills and maintained performance over a six week period, while the sixth demonstrated mastery of the strategy, but not the application. This study adds to the previous conclusion that use of a mnemonic device and systematic instruction leads students with LD to acquire complex math skills.

Manalo et al. (2000)'s study differentiated the effects of two different types of mnemonics: Fact mnemonics (FM), the more commonly known form, to remember facts, typically with one letter associated with each item; and Process mnemonics (PM) to help remember rules, principles, and procedures. PM are especially useful for teaching subjects such as trigonometry, math, and science, but limited studies have been found for students with LD. Manalo et al. (2000)'s study investigated the effects of PM on the math skills of 13 and 14 year old students with LD. PM incorporates five basic principles of learning and memory: meaningfulness, organization, association, attention, and visualization. Specifically, PM is largely a verbal strategy but accompanied by visual aids such as illustrations and demonstrations on the board, thus fostering visualization. These components assist students with LD in identifying what parts of a problem are relevant and need to be remembered vs. what are incidental. The study involved 29, 8th graders who demonstrated math deficits. There were two control groups: Study Skills (SS) and No Instruction (NI). The SS group was instructed in reading, note-taking, and other study skills not directly related to the math skills being assessed. The NI group received no instruction at all. Each of the PM, DI, SS, and NI groups had 3-5 participants. Students in the DI group received only DI instruction, while students in the PM group received PM instruction which also employed the basic DI components of demonstrating steps necessary to arrive at a correct math solution. The most important result of this study showed that PM can be used to effectively teach computational skills to students with LD. Significant differences in scores were attributable to instruction received, with gains found in the PM group. Although the PM group showed greater improvement than the DI group, the difference was not always significant. Results indicated that both PM and DI address the needs of student with LD for "learning what to do". Both also seem to address the problem of remembering and retaining steps for the short-medium term. The significant difference between the two groups was found in the long-term results. The PM group demonstrated good maintenance while the DI group showed decreased performance. Although the findings were not as strong as the previous studies, the PM seems to be the effective component in long-term retention of mathematical steps.

In contrast, Jimenez et al, (2008) found somewhat different results from the previous studies. In their study, three students, ages 15-17, were observed to determine the effects of systematic instruction with a concrete representation on the acquisition of algebra skills for students with LD. Baseline data was collected after one instructional session on solving for "x". The interventions included: (a) concrete representations for solving linear equations; (b) task-analysis instruction on the steps necessary to solve the equation problems; and (c) prompting with fading. Students with LD were taught to solve beginning algebra problems using modeling, manipulatives, and mnemonics. Results showed that all three students were able to master the concrete representations of an algebra equation, but that they continued to rely on manipulatives to solve the linear equations. The ability to fade to symbols alone following prolonged instruction remains unknown. The results indicated that while students were able to learn the step-by-step process, they were not necessarily mastering algebraic reasoning. Thus these findings, while promising, are not as significant as those of the previous research.

Students with LD need additional coaching and visual cues to achieve academic success (Lombardi & Butera, 1998). Use of a mnemonic device assists students in remembering a particular strategy and its subsequent use for strengthening thinking skills. In the studies conducted by Maccini & Ruhl (2000) and Test & Ellis (2005), the results demonstrated that teaching a first-letter mnemonic to students with LD greatly improved their understanding of higher-level math concepts, as well as self-regulation of their own learning. In addition, these studies contribute to the sparse literature on teaching advanced math concepts to students with LD, as well as teaching math in a variety of ways to adolescent students. However, there were several limitations found in both studies. These include the time of the study (near the end of the school year) and the small sample size which limits the possibility to generalize the results. Manalo et al.'s study (2000) demonstrated that using mnemonics seemed to increase the performance of students with LD in choosing the correct procedures when solving algebraic equations and to retain those steps over time. This study, however, was limited for further investigation by the amount of teacher training required. Finally, research by Jiminez et al. (2008) indicated that manipulatives and mnemonics helped increase student knowledge of step-by-step procedures, but did not seem to increase algebraic reasoning skills. The contribution of each of the individual components of the intervention to its overall effectiveness is unknown. Further research is needed not only on the individual components of the intervention, but also on the application of this method to other advanced level of mathematics skills.

2.2 Technology-Based Approaches

Using technology has been shown to provide students with LD with the interaction and collaboration necessary for effective math instruction (Pugalee, 2001). This approach reinforces the idea that math curriculum should move away from basic memorization to acquisition of skills that emphasize conceptual understanding, multiple representations and connections, math modeling and problem-solving (Pugalee, 2001). Technology provides teachers with a tool for helping students establish links between math problems and symbolic representations. Furthermore, visual elements of technology promote critical thinking and a more dynamic learning environment than the traditional classroom situation (Hsieh & Lin, 2008). In addition, technology has the potential to capture and hold students' attention, enhancing student engagement and reducing negative behaviors (Allsopp et al., 2012).

In Pugalee's study (2001), 16 high school students at risk of math failure were involved. Graphic calculators were used to explore relevant algebraic ideas through constructivist methods; e.g. constructing math ideas about graphs of linear equations using hand-held graphics calculators. Qualitative data was collected by observations and anecdotal notes. The data showed that the instructional activities enabled students to generate their own concepts based on discourse between students and teachers and their experience in the use of graphic calculators. The results showed that using technology in teaching math increased student performance.

Similarly, Hsieh and Lin (2008) investigated whether integrating graphics associated with word problems into a computer-assisted learning environment would improve student achievement. The participants were 3, 5th grade low math achievers. Graphic representations of algebraic word problems were employed using the Excel computer program. Student performance was evaluated by pre- and post-tests. The results showed that students had significant improvement in successful decoding of textual information, so that they were able to choose correct formulas and operand symbols. Furthermore, multiple representations in math learning proved to promote greater understanding of target concepts and the representations became internal to support students successfully learning problem-solving skills.

In 2012, the use of Interactive Whiteboard Technology (IWBT) was examined for students with disabilities (Allsopp et al). IWBT provides research-supported practices, including: (a) modeling concepts, processes, and skills in multiple ways; (b) engaging students to respond actively to teacher questions and prompts; (c) providing immediate feedback to student responses using individual student whiteboard presentations; and (d) monitoring student progress. Six teachers with different experiences in teaching math participated in the study. All were first-time users of IWBT. Data was collected using observations, interviews, focus group activities, and field notes, and analyzed using coding methods according to teacher actions, student responses, and type of IWBT used during instruction. Data related to teacher actions included comments concerning actual instructional use of IWBT as well as hardware and software available in the classroom. Teacher actions were further coded in the following ways: (a) modeling; (b) providing students with response opportunities; (c) providing feedback; and (4) monitoring progress. Student responses were also collected and were coded in the following way: individual, small group, and whole class response. Students were able to respond to teacher prompts individually using the IWBT with an electronic pen or other tool. The results were overwhelmingly positive in demonstrating the potential for IWBT in teaching math. Data showed that students' performance was enhanced due to three major features of IWBT: (a) interactive nature; (b) immediate feedback; and (c) visual display to gain student interest and attention. In addition, it was shown that modeling with IWBT occurred when concepts and skills were shown visually via projection on the IWB using teacher-developed presentations such as Power Point, and the pen feature was used to highlight or circle an important word. Student performance was shown to be dramatically improved using IWBT modeling as compared to modeling without the IWBT.

In contrast, Reed's study (1985) presented different results. Although this study was 20 years ago, the results gave valid insight into exploring the conditions under which computer graphics could be used to improve students' math skills. In this study, non-interactive programs with simulations were used. The participants included four groups of 30 undergraduate students with an additional 30 as a control group. Student performance was evaluated by pre- and post-tests. Results indicated that students improved estimates of average speed on 50% of the questions on the post-test but gave low estimates on 17% of the questions, for a net gain of 33% improvement. Their estimates improved but were not significant. These results indicate that computer simulations require additional modifications to make them effective, and that simply viewing a simulation of an event is not always sufficient for improving students' performance. Further, replacing verbal information with only graphic simulations was unsuccessful. Visualization allowed the students to see concrete examples of events, but depended on the students' ability to perceive and correctly interpret the relevant information. This study should be viewed as an initial step in design of a technology-based environment, and it demonstrated that non-interactive instruction is unsuccessful.

Taylor's study (2008) provided similar results. The participants included 98 college freshmen taking an intermediate algebra class. The control group consisted of 39 students enrolled in a traditional lecture, while 59 were enrolled in a web-based technology course entitled Assessment and Learning in Knowledge Spaces (ALEKS). Student achievement in both groups, using ALEKS versus traditional lecture, was measured by pre- and post- tests. Results showed a positive relationship between the algebra pre- and post-test scores for the experimental group, however a statistically significant difference was shown on the algebra achievement for the experimental group as well as the control group. It was shown that the control group outperformed the experimental group in some areas. This indicated that for some students lecturing would be best, while others might achieve success with technology.

Using technology provides an interactive learning environment for students with LD (e.g., Pugalee 2001, Hseih & Lin 2008, and Allsopp et al. 2012). Incorporating technology and visual cues into math instruction to these students greatly improved their skills to understand complex math concepts, as well as self-regulation of their own learning. However, there were several limitations in the previous studies reviewed. These include the small number of participating students and the restrictions inherent in attempting to control complex classroom practice. In each of these studies, technology was readily availability, which might not always be the case in some classrooms. For example, the study by Allsopp et al. (2012) included a small group of teachers with different levels of expertise, thus the interpretation of the results may not represent the actual experiences of the teachers using IWBT. Furthermore, the results apply only to the group of teachers being studied and the individual concepts being taught. Research on experienced users of IWBT may have shown different results. Studies by Taylor (2008) and Reed (1985) showed non-significance on use of technology to teach math concepts. Taylor's study (2008) is limited by pre-existing knowledge of the participants as well as the availability of the ALEKS technology. Reed's study (1985) is limited by the participants' perceptions of the concept being taught. It is possible that the students cannot correctly perceive relevant information because it is inconsistent with their current beliefs. Thus, it is determined that the quality of feedback is impaired by students' misconceptions and lack of focus on the task at hand.

2.3 Summary

A review of the literature summarized the approaches to improving the performance of students with LD in solving mathematical word problems. Learning disabilities in math often derive from difficulty decoding the representations in the questions being asked (Hsieh & Lin, 2008). Technology is serving as a tool to motivate students in learning math with graphic representations and visual stimuli. Dynamic graphics on a computer screen better present variations of scientific phenomena and provide students with a profound learning experience (Hsieh & Lin, 2008). Using interactive white board technology (IWBT) enables teachers to incorporate a variety of multi-media resources, such as written text, pictures, videos, sound, diagrams, and on-line web sites into their instruction. In addition, the features of IWBT provide an opportunity to create and annotate materials to be saved and re-used to reinforce and extend learning over time. Incorporating a strategic instructional approach, such as a mnemonic device, with visual technology is supported by the research, but findings are mixed, especially the effect on improving student performance. This current study attempts to examine how direct instruction using a mnemonic device combined with systematic instruction using IWBT can be used to improve the performance of students with LD in solving algebraic word problems.

Chapter 3

Methods

3.1 Participants

9th grade students (n=6) between the ages of 14-15 in a high school in southern New Jersey participated in this study. All participants (4 boys and 2 girls) were diagnosed with a Specific Learning Disability (SLD) or Other Health Impaired (OHI) that entitled them to Special Education services and demonstrated a functional deficit in the targeted task (e.g., solving algebraic word problems). In addition, all participants scored Partially Proficient in both Language Arts Literacy (LAL) and Mathematics on the 8th Grade standard test, New Jersey Assessment of Skills and Knowledge (NJ ASK), as demonstrated by a score of below 200. Students with test scores between 200-250 are considered Proficient, and students with scores greater than 250 are considered Advanced Proficient. Six students met eligibility criteria. The category of exceptionality for 4 of the participants was Specific Learning Disability (SLD); the remaining 2 participants were classified as Other Health Impaired (OHI). All received instruction in a co-taught inclusive classroom. Participants' demographic information (e.g., gender, age, disabilities, ethnicity, and academic achievement scores) is presented in Table 1.

Student A is a 14 year-old Caucasian male in 9th grade with a classification of SLD. He is a quiet, polite student who is organized and motivated to learn. He eagerly participates in class and works well both independently and in a group. He gets along well with peers and teachers and demonstrates no behavior issues. Student A receives Speech and Language services as part of his IEP. In addition, he is permitted extra time for task completion and is required to us his agenda book for organizational issues. Student A has math skills that are stronger than his language skills. His 8th grade NJ ASK standardized test scores are 199 and 189 respectively for math and LAL. Both of these scores are in the Partially Proficient (PP) range. In class, Student A seems to grasp math skills readily, but lacks confidence and often fails to ask questions if something is unclear. Student A's weakness is in the area of reading comprehension. Student A reads well, but sometimes text needs to be explained to him to ensure understanding.

Table 1

Participants' Demographics

Students	Gender	Age	Classification	8th grade ASK score (math)*	8th grade ASK score (LAL)*	Ethnicity
A	Male	14	SLD	199 (PP)	189 (PP)	Caucasian
B	Male	15	OHI	150 (PP)	195 (PP)	African American
C	Female	14	SLD	199 (PP)	187 (PP)	Caucasian
D	Female	14	SLD	191 (PP)	196 (PP)	Caucasian
E	Male	14	SLD	188 (PP)	192 (PP)	Caucasian
F	Male	14	OHI	128 (PP)	186(PP)	Caucasian

Note: *PP = Partially Proficient (score <200)

Student B is a 15 year-old African-American male in 9th grade with a classification of OHI. He generally participates in class and works well with others. He is an organized student and comes to class prepared. Student B is respectful and there are no behavior issues. Student B is permitted to re-take failed assessments and receives extra time for completion of tasks according to his IEP. Students B's scores on the NJ ASK are 150 for math and 195 for LAL. In LAL, Student B struggles with expository reading comprehension as well as lengthy assignments. He often needs directions repeated several times. In math, Student B exhibits difficulty in discrete math, geometry, number operations, and patterns of algebra. This becomes evident during multi-step problems, where Student B lacks confidence in the basic skills required to accomplish preliminary steps. Student B often requires visual or concrete manipulatives to grasp complex or novel concepts. Multi-step equations and word problems pose specific difficulty.

Student C is a 14 year-old Caucasian female in 9th grade with a classification of SLD. She is a very focused and diligent student. She is polite and respectful and works well both independently and in a group setting. She receives no specific modifications as per her IEP. In LAL, Student C was enrolled in the Wilson Language Program as an 8th grader and she made tremendous progress in the areas of decoding and encoding. Her NJ ASK test scores were 199 and 187 respectively for math and LAL. Student C continues to demonstrate weakness in the areas of writing skills and answering open-ended questions. She continues to benefit from explicit, multi-sensory instruction in the area of LAL. Student C demonstrates stronger mathematics skills, with her major weakness being comprehension of word problems. Reading problems aloud and providing visual cues have been used to help Student C in math.

Student D is a 14 year-old Caucasian female in 9th grade with a classification of SLD. She is a model student in class, completing all assignments on time and with great effort. She is extremely focused and takes great pride in doing well. She receives additional time for reading assignments and is permitted to re-take failed tests as per her IEP. Student C received scores of 191 and 196 on the NJ ASK test. In the area of LAL, Student D demonstrates weaknesses in decoding, comprehension, and response to text. Since she works so diligently in class at all time, her testing scores are much lower than what is observed on a daily basis. In mathematics, Student D demonstrates deficits in the areas of numbers and operations, as well as patterns and algebra.

Student E is a 14 year-old Caucasian male in 9^{th} grade with a classification of SLD. Student E is generally organized, but is extremely quiet and often resistant to offers of help. He receives no specific modifications as part of his IEP. Student E received scores of 188 and 192 on the NJ ASK for math and LAL, respectively. In LAL, Student E is well organized, but struggles with fundamental math computation. He demonstrates deficits in basic math skills and has difficulty solving two-step equations and other multi-step problems. Student E benefits from systematic instruction. In the area of LAL, Student E is inconsistent with organization. His writing skills are below grade level standards and he struggles with fluency and reading comprehension.

Student F is a 14 year-old Caucasian male in 9^{th} grade with a classification of OHI. In general, Student F is polite and respectful, although he is very apathetic about school and his grades. He is often resistant to instruction, and gets easily frustrated. He is permitted to re-take failed assessments as per his IEP, but rarely utilizes this accommodation. His NJ ASK scores of 128 and 186 are indicative of Student F's academic struggles. In the area of LAL, Student F struggles with focus, and needs frequent re-direction to accomplish a task. These difficulties spill over into the area of math, where Student F struggles with word problems due to reading comprehension issues. In addition, he demonstrates deficits with number operations and mathematical processes as well as geometry, discrete math, and algebra. Student F has difficulty effectively communicating mathematical ideas in a written format, often failing to explain the mathematical concepts imbedded in open-ended questions. He is easily confused when solving multi-step problems.

3.2 Setting

The study was conducted in a public high school with an enrollment of approximately 1950 students. Data was collected during normal classroom instruction in an inclusive education science classroom during periods 1 and 2 of the school day. There were two teachers in the room, one special education science teacher and one general education science teacher. There were a total of 20 students in the class in period 1, 5 of which had Individualized Education Plans (IEP's). There were a total of 24 students in period 2, 6 of which had IEP's. All of the data in the study was collected at the same time each day, during 1st period, (7:44-8:24 a.m.), and during 2nd period (8:28-9:08 a.m.). All sessions including instruction, assessment, and generalization were conducted in the standard science classroom, which was equipped with a desktop computer connected to a projector with SMART Board technology.

3.3 Research Design

This study was single-subject multiple baseline design across two different groups. Data for this study was collected quantitatively by analyzing percent correct on baseline and post-treatment assessments. In addition, qualitative information was obtained using surveys that assessed students' attitudes about the treatment protocol. During the baseline (phase A1), students A, B, and C (group 1) were given three probes over the course of three weeks to determine their need for intervention. During the second baseline (phase A2), students D, E, and F (group 2) were given the same three probes over the course of three weeks, staggered one day behind group 1. Each probe consisted of five word problems and percent accuracy on problem solution was calculated for each student. Once baseline data was established for each group of students, treatment was introduced. In this design, replication of treatment effects is demonstrated if changes in performance occur only when treatment is introduced. During the first intervention (phase B1), the mnemonic (e.g., GUFSA) strategy was introduced. During this instructional phase, data on problem solution and percent strategy use was collected for each student. The first intervention phase for group 2 (phase B2) began one day following group 1, with data being collected in the same manner. During intervention two (phase C1), treatment using Interactive White Board Technology (IWBT) was introduced to group 1, with treatment then applied serially to group 2 (phase C2). After 5 weeks of treatment using both GUFSA and IWB technology, data on problem solution and percent strategy use was again collected for each student using the five-word problem assessment format.

3.4 Variables

The first independent variable for this study was use of a mnemonic device known as GUFSA as a strategy in solving algebraic word problems. The steps of GUFSA are: (1) GIVEN: What does the problem tell you? (2) UNKNOWN: What are you looking for in the problem? (3) FORMULA: Which formula will you use to solve the problem? (4) SOLVE: Use your calculator to solve the problem and (5) ANSWER: What is your answer? Don't forget the label! (see Table 2 in *Procedures*). The second independent variable was incorporation of Interactive White Board Technology (IWBT) using color-coding to enhance visual recognition of the necessary components of algebraic word problems.

The dependent variable in this study was twofold. Initially, students' mastery of and ability to apply the GUFSA mnemonic to solving word problems was measured using a five-question teacher-made quiz. Subsequently, the students' ability to visually recognize and color-code the five parts of the mnemonic using IWBT to solve algebraic word problems was tested using a similar teacher-made quiz with five algebraic word problems.

3.5 Instruments

Instructional materials. Multiple instructional materials were utilized for this study. Conceptual content was presented using Power Point presentations and students were provided with guided notes to fill in as instruction was being given. All guided notes were numbered in chronological order and placed in a student notebook, which was brought to class each day by the students. Once concepts were taught, students were then asked to solve the same scientific concepts mathematically using algebraic word problems. For example, students were taught the concept of density, and then were asked to solve for density mathematically. For the first intervention in this study, students were taught a mnemonic device, “GUFSA”, using guided notes and the completed GUFSA procedure was kept in the student notebook. For the second intervention, students were provided instruction using Interactive Whiteboard Technology (IWBT). The IWB was used by the teacher to highlight and color-code relevant information in the word problems that students were being asked to solve. Students were given colored pencils so that as the teacher modeled using the IWB, they could practice the same procedure on their worksheet of practice problems.

Measurement materials. Three baseline probes were given, each consisting of five word problems with content unfamiliar to the study participants. Baseline probe 1 consisted of density problems, probe 2 consisted of specific heat problems, and probe 3 consisted of problems using the equation for calculating speed. Following intervention one, use of the mnemonic device, students were given one quiz per week for 5 weeks with the same format as the baseline probes, i.e. five word problems per quiz (see Appendix A). All quizzes were teacher-made and all followed a consistent format. Following intervention two, instruction using IWBT, students were given an additional one quiz per week on the same content, but with different problems. All quizzes were teacher-made and each followed the same format as the first intervention quizzes.

Following the study, students were given a survey to assess their attitude on the following: (a) effectiveness of GUFSA strategy for learning to solve algebraic word problems (b) effectiveness of IWBT for highlighting relevant information to solve algebraic word problems and (c) efficiency of the interventions. Participants indicated a “1” if they strongly disagreed with a statement, “2” if they disagreed, “3” if they felt neutral, “4” if they agreed, or “5” if they strongly agreed (see Appendix B).

3.6 Procedures

GUFSA strategy instruction (5 weeks). The procedures used to teach GUFSA began by teaching the strategy and the meaning behind each letter using a Power Point presentation (see Table 2). Students completed guided notes on the GUFSA strategy and how to apply it to solving word problems. During the 5 week instructional period, the GUFSA strategy was applied to problems involving density, mass, and volume; specific heat; and calculating speed. After introducing the strategy, students kept the procedure in the guided notes section of their notebooks. During guided practice, students and teachers read aloud the steps together. Students were then asked to read aloud the steps individually. Afterwards, students worked individually to practice each letter of the GUFSA mnemonic using word problems designed to reinforce their learning for the remainder of the 40-minute period. Students who continued to struggle with mastery of the mnemonic strategy were given additional, individualized help by the teacher. Students who were still unable to master the information received after school help and/or and peer tutoring. A quiz was given after 5 days of instruction.

Table 2

Explanation of GUFSA Mnemonic Strategy

First Letter	Explanation
G	GIVEN: What does the problem tell you?
U	UNKNOWN: What are you looking for in the problem?
F	FORMULA: Which formula will you use to solve the problem?
S	SOLVE: Use your calculator to solve the problem
A	ANSWER: What is your answer? Don't forget the label!

Interactive White Board instruction (5 weeks). During the second phase of the study, IWBT was introduced to provide visual cues for selecting relevant information contained in the word problems being presented. The teacher used the color feature of the IWB to underline the "Givens", or necessary information needed to solve the problem. The "Unknown" was color-coded with a different color, followed by the "Formula", "Solve" and "Answer" steps all with different respective colors. Students used colored pencils to model their practice problems to match the colors on the IWB. The highlighter and "spotlight" features were also utilized for emphasis on key words in the problem as needed. After guided practice, students completed independent practice and a quiz was given after five days of instruction. Table 3 summarizes the procedures for week one; subsequent weeks followed the same procedure with different material being taught.

Table 3

Summary of Instructional Procedures

Day	Instructional Procedure
1	PowerPoint presentation: introduction; guided notes
2	Guided Practice
3	Independent Practice; Reinforcement; Individualized help
4	Review; Peer-tutoring; After School help as needed
5	Assessment

3.7 Data Analysis

Data analysis for this study involved visual inspection and quantitative analysis of results. Experimental significance was judged relative to whether students' mathematics performance improved and if the treatment caused the change. Percent correct on baseline probes and assessments were displayed graphically as data points and then judged relative to: a) stability of baseline conditions, (b) changes in instructional variables between conditions, and (c) changes in mean performance between phase conditions. Survey results on students' attitudes about the intervention strategies were organized using mean scores.

Chapter 4

Results

The results of this study indicate that adolescent students with LD can learn to successfully represent and solve word problems involving algebra. The result of individual participants' percent accuracy of problem solution following baseline, intervention one, and intervention two is presented in Table 4. The data indicates that each student increased their individual performance over the course of the study, with improvement shown after introducing GUFSA, and again after introducing IWBT (see Table 4). When comparing data collected from both groups 1 and 2, the results show that both groups performed in the same manner. Group 1 solved an average of 11% of baseline problems correctly, 61% following intervention 1, and 91% following intervention 2. Group 2 correctly solved an average of 4% of baseline problems, 57% following intervention 1, and 92% following intervention 2. The data is summarized in Table 5 below.

The percentage of word problems solved correctly by students in groups 1 and 2 following baseline, intervention 1, and intervention 2 can be found in Figure 1. Figure 1 displays results by week for each of the two groups, and shows that group 1 showed steady improvement in their performance following introduction of the mnemonic device until the 5th week, when the percent decreased. Group 2 showed steady improvement following introduction of the GUFSA strategy. Once IWBT was introduced, there was a general improvement in student achievement for both groups over the course of the 5-week intervention, with a decreased performance for both groups in week 3. All students achieved 100% accuracy by the fourth week of using SMARTboard technology and students were able to maintain 100% accuracy in week 5.

Table 4

Summary of Individual Student Performance; Percentage of Problems Solved Correctly

Student	Baseline %	Intervention 1 %	Intervention 2 %
A	27	60	92
B	0	44	80
C	0	80	100
D	13	76	96
E	0	40	88
F	13	60	92

Table 5

Comparison of Results for Groups 1 and 2

	Group 1	Group2
	Average % problems solved correctly	
Baseline	11%	4%
Intervention1	61%	57%
Intervention 2	91%	92%

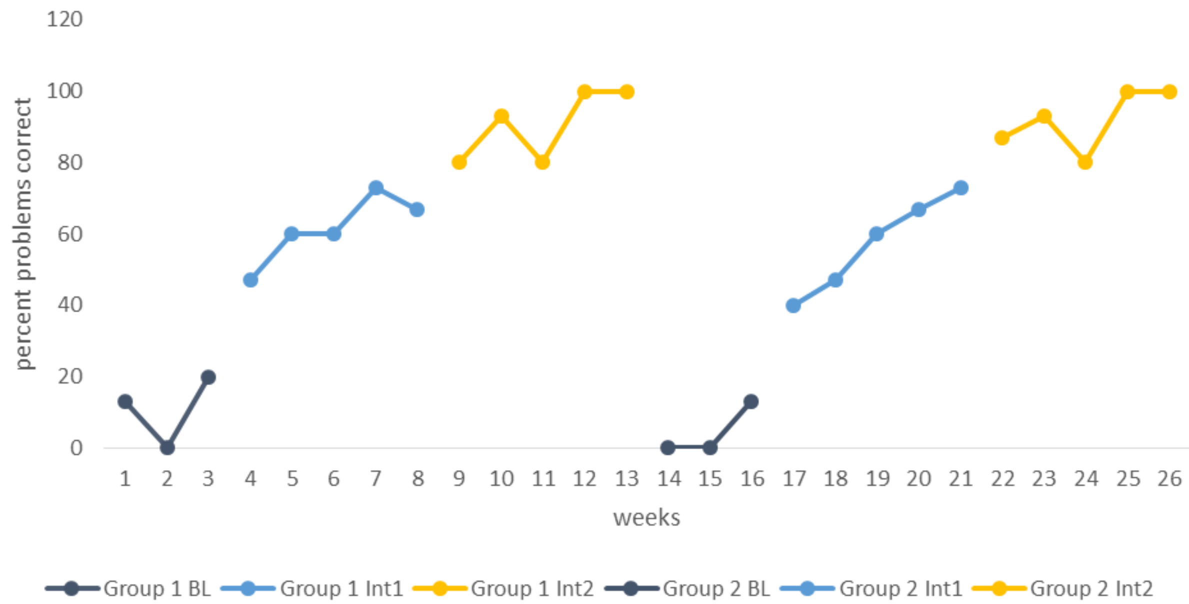

Figure 1. Percent correct following baseline, intervention 1, and intervention 2 for two study groups.

Chapter 5

Discussion

The purpose of this study was to examine the impact of a combination of two different approaches to teach algebraic word problem solving skills to high school students with LD: using a mnemonic device and using SMARTboard presentations with Interactive Whiteboard Technology (IWBT). Results indicate that: (a) students' abilities to represent and solve work problems involving algebra improved following strategic instruction using a mnemonic device and (b) students' performance increased to a greater extent when technology was utilized in the form of SMARTboard instruction and use of IWBT. All 6 students involved in the study improved their individual performance, and both groups as a whole achieved 100% mastery during the last two weeks of the investigation. Social validity data collected from students indicated that 5 out of 6 liked using the GUFSA mnemonic device and all 6 liked using the SMARTboard for instruction. All 6 participants felt that the combination of both strategies provided them with an efficient system to approach solving word problems.

The results of the present study add to the sparse literature on teaching math skills to high school students in a variety of ways. For the first intervention, the results provide additional support to the idea that mnemonics can help a student remember the steps to approaching a word problem (Test & Ellis, 2005). Second, this study included specific, detailed descriptions of the independent variable (GUFSA), which should increae the ability to replicate the procedures and enable collection of maintenance data over time. Third, the rsults add to the limited database of strategies for teaching students to solve algebraic word problems using this methodology. For the second intervention, the results provide support for the practice of integrating technology into the teaching of math to increase student performance. The results demonstrate that using technology provides an interactive learning environment for student with LD (e.g., Pugalee 2001, Hseih & Lin 2008, and Allsopp et al. 2012) and that incorporating technology and visual cues into math instruction for these students greatly improves their ability to understand complex math concepts, as well as assist in the self-regulation of their own learning.

5.1 Educational Implications

The GUFSA strategy helped students attend to critical features of word problems while eliminating unnecessary information. Though particpants demonstrated improvemnet, some experienced difficulty with the third step, "F" for "formula". While students were able to correctly choose the formula necessary to solve the problem, when the problem called for re-arranging the equation to solve for the correct variable, students still continued to struggle with the basic algebra skills necessary to do this. Hence, additional instruction or use of a structured worksheet to help them with this step may prove to be beneficial. Additionally, the GUFSA strategy addressed self-regulation strategies by encouraging students to ask questions to themselves while problem-solving. Verbal cueing is important as many student with LD experience problems monitoring their metacognitive processes (Maccini & Ruhl, 2000).

Overall use of IWBT as a method of increasing student engagement was shown to be consistent with results found in previous literature (e.g. Pugalee 2001, Hseih & Lin 2008, and Allsopp et al. 2012). The interactive nature of the IWBT as a powerful instructional tool should be noted. In addition, this study demonstrataed that the ability to provide explicit models and representations of concepts in differentiated ways can be closely linked to improved performance. Furthermore, use of the tools / actions that are available using the IWBT, such as the color-coded pens and highlight feature, can be viewed as a means to link presentation with student retention. The immediate feedback provided by the IWBT is also a tool for monitoring student progress and systematically correcting deficiencies in student achievement as they arise.

5.2 Limitations

The findings of the current study are limited by a number of factors. First, as with any single subject research design, the small number of students limits the generalizability of the results. Had data been collected with a larger group of students, one would be better able to generalize the effectiveness of the strategies employed. Second, the study was weakened by having the data collected over days that involved breaks in instruction due to school scheduling, holidays, and multiple school closings due to weather. Ideally, instruction should have been conducted and data collected over consecutive sessions, but this was not always the case. Furthermore, technological issues with the classroom SMARTboard between the 2nd and 3rd week of Intervention 2 caused the data to be skewed, as students did not receive consistent instruction using this instructional method. Finally, this study investigated the practices of two teachers in one classroom. Additional studies by different teachers using the same methodologies would provde other perspectives about the validity of the strategies described.

5.3 Future Direction

Readers should view this study as an initial attempt to ascertain the importance of implementing non-traditional methods in the instruction of students who are sometimes neglected in the area of math. Teachers of students with LD should consider alternative methods for teaching higher-level mathematical concepts if their students are to acquire skills necessary to succeed. Future research migh be designed to investigate the use of the GUFSA mnemonic strategy on the performance of an entire classroom of students, not just those with disabilities. In addition, increasing the length of time for data collection to include assessing the student’s ability to generalize the use of the strategy to other types of problems would be beneficial.

Access to technology must increase if students are to have opportunities to acquire skills for the appropriate use and application of higher-level math problem-solving. In conclusion, the present study provides convincing evidence that given systemative instruction and dynamic learning environment, students with learning disabiites can acquire complex math skills.

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Appendix A

Name____________________________________ Date_________ Period _____________

DENSITY PROBLEMS QUIZ

Use GUFSA to solve the following problems. D=M/V

1. Find the density of a Mr. La's foot that has a mass of 130 g and a volume of 3.2 cm^3.

2. Find the volume of Ashley Vail's stomach as she consumes tons of gummy bears in Mr. La's class if it has a density of 12.3 g/ cm^3 and mass of 0.008 kg.

3. Find the mass of Reagan's pet kangaroo if it has a volume of 0.90 cm^3 and a density of 4.01 g/ cm^3.

4. Briana Fiorenza and Tori Gallo are SOOOOO into science, so they design an experiment to figure out what fast food chain has denser burgers. A McDonalds beef patty has a mass of 68 g and a volume of 11 cm^3. A Burger King beef patty has a mass of 75 g and a volumes of 12 cm^3. Which is denser? (Show the density for both.)

5. Brandon Rota gets a Thanksgiving Turkey (and eats the whole thing) that has a mass of .5021 kg and has a density of 0.98 g/cm^3. How much space does the turkey take up?(volume)

Appendix B

MATHEMATICS AND SCIENCE ATTITUDE INVENTORY

The attached instrument is designed to measure attitude towards mathematics and science. Please respond to the questions on this page first, then follow the instructions below. Thank you for your assistance.

General Information:

Please place a check mark in the appropriate space next to each question:

DIRECTIONS

The following statements are about the study of mathematics and science. Please read each statement carefully and decide whether it describes the way you feel about mathematics or science. Then, find the number of the statement on the answer sheet, and put a circle around the appropriate response according to the following format:

If you **Strongly Disagree** with the statement, circle **number 1**

If you **Disagree** with the statement, circle **number 2**

If you have **no opinion** (neutral) about the statement, circle **number 3**

If you **Agree** with the statement, circle **number 4.**

If you **Strongly Agree** with the statement, circle **number 5**

Be sure to circle only one response for each statement. Please mark your answers only on the answer sheet.

Please respond to every statement.

Remember, this is not a test. Simply respond to each statement according to the way you feel right now.

MATHEMATICS AND SCIENCE ATTITUDE INVENTORY - ANSWER SHEET

Question	Strongly Disagree	Disagree	Neutral / No opinion	Agree	Strongly Agree
Science is useful for the problems of everyday life.	1	2	3	4	5
Mathematics is something which I enjoy very much.	1	2	3	4	5
I don't do very well in science.	1	2	3	4	5
Solving mathematics problems is fun.	1	2	3	4	5
I think that using the GUFSA strategy helps me solve word problems.	1	2	3	4	5
When I hear the word mathematics, I have a feeling of dislike.	1	2	3	4	5
I think that learning math is easier when we use the SMARTboard in class.	1	2	3	4	5
I think that when my teacher uses the SMARTboard to solve problems using GUFSA, it makes the problems easier.	1	2	3	4	5