EFFECTS OF SCHEMA-BASED INSTRUCTION DELIVERED THROUGH COMPUTER-BASED VIDEO INSTRUCTION ON MATHEMATICAL WORD PROBLEM SOLVING OF STUDENTS WITH AUTISM SPECTRUM DISORDER AND MODERATE INTELLECTUAL DISABILITY

by

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ABSTRACT

ALICIA FERN SAUNDERS. Effects of schema-based instruction delivered through computer-based video instruction on mathematical word problem solving of students with autism spectrum disorder and moderate intellectual disability. (Under the direction of DR. YA-YU LO)

The Common Core State Standards initiative calls for *all* students to be college and career ready with 21st century skills by high school graduation, yet the question remains how to prepare students with autism spectrum disorders (ASD) and moderate intellectual disability (ID) with higher order mathematical concepts. Mathematical problem solving is a critical, higher order skill that students need to have in order to solve real-world problems, but there is currently limited research on teaching problem solving to students with ASD and moderate ID. This study investigated the effects of schema-based instruction (SBI) delivered through computer-based video instruction (CBVI) on the acquisition of mathematical problem solving skills, as well as the ability to discriminate problem type, to three elementary-aged students with ASD and moderate ID using a single-case multiple probe across participants design. The study also examined participant's ability to generalize skills to a paper-and-pencil format. Results showed a functional relation between SBI delivered through CBVI and the participants' mathematical word problem solving skills, ability to discriminate problem type, and generalization to novel problems in paper-and-pencil format. The findings of this study provide several implications for practice for using CBVI to teach higher order mathematical content to students with ASD and moderate ID, and offers suggestions for future research in this area.

DEDICATION

First, I dedicate this dissertation to my parents who have always encouraged me to rise to the top. As the first person in my family to achieve this goal, I feel honored to say thank you for your support throughout the years. Second, I dedicate this dissertation to the individuals with disabilities and their families who have forever changed my life and made a huge imprint on my heart. Every child with whom I have worked has driven me and guided my path in some way. I hope my work impacts their lives positively and affords them opportunities they would have never had otherwise. Finally, I dedicate this dissertation to my daughter, Savannah, to whom I gave birth during my dissertation phase. Balancing work and being a new mom was difficult, but it was important for me to finish in order to show you that women can achieve great things. This is one of my greatest wishes for you.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

Standards-based reform that drove federal mandates requiring accountability of and access to the general curriculum for all students (NCLB Act of 2001; IDEA 2004) has promoted the importance of providing general curriculum access to students with severe disabilities[1], including those with Autism Spectrum Disorders (ASD) and moderate intellectual disability (moderate ID). The charge set forth by standards-based reform, linking academic achievement and accountability for all students, has greatly increased the expectations in educational programming for students with severe disabilities, including those with ASD and moderate ID. These students are now being educated on alternate achievement standards aligned to grade-level academic content standards. In the past decade, students with severe disabilities, including those with ASD and moderate ID, have risen to the challenge and surprised researchers and educators across the nation by showing that they are capable of learning academic concepts that were once thought improbable (Browder, Jimenez, & Trela, 2012; Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008; Browder, Trela, et al., 2012; Browder, Wakeman, Spooner, Ahlgrim-Delzell, Algozzine, 2006).

Now in 2013, the expectation for academic achievement is raised again. Most states have responded to the call by the Common Core State Standards Initiative (CCSSI, 2010), a state-led effort coordinated by the National Governors Association Center for

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[1] Students with severe disabilities include students with “mental retardation,” multiple disabilities, and some students with autism who also have a moderate to severe intellectual disability.

Best Practices and the Council of Chief State School Officers, which developed a common set of state standards for proficiency in English language arts and mathematics. The CCSS in mathematics (namely CCSSM) delineate the content expectations and standards for mathematical practices for K-12, and are a much more rigorous, focused, and coherent set of standards than the previously defined National Council of Teachers of Mathematics (NCTM) *Principles and Standards for School Mathematics* (2000) and traditional state standards. The intended outcome of the CCSSI is to prepare students in the 21st century to be college and career ready upon high school graduation. Although college and full-time careers may not be realistic goals for all students with ASD and moderate ID, all students deserve better post-secondary opportunities in the 21st century, such as gainful employment, compensatory education, and independent living.

Despite the assumption that the CCSSM are for *all* students, they do not specify intervention methods or materials that are needed to help students with ASD and moderate ID achieve the standards. Over the past decade, evidence-based and research-based practices have emerged on teaching academics to students with ASD and moderate ID in response to the standards-based reform. With the shift to the new CCSSM, it is important for teachers to incorporate effective instructional practices for lesson delivery, while using the new standards to drive instruction.

The shift to the new and more rigorous CCSSM has unveiled challenges in special education, especially for students with ASD and moderate ID. The first challenge relates to the quality of instruction. Most special education teachers are not qualified to teach academic content, and most personnel preparation programs do not explicitly teach future special educators how to provide access to the general curriculum for this student population (Browder, Trela, et al., 2012; Whetstone, Abell, Collins, & Kleinert, 2013). Although recommendations for how to provide access to and extend academic content standards for students with severe disabilities, including those with ASD and moderate ID, have been established (Browder, Ahlgrim-Delzell, Courtade-Little, & Snell, 2006; Browder, Trela, et al., 2012; Burdge, Clayton, Denham, & Hess, 2010; Saunders, Bethune, Spooner, & Browder, 2013), many teachers may not be aware of the recommendations because of the research-to-practice gap. Unlike their general education counterparts, special educators typically do not receive curricula they can use to teach students and must develop their own instructional materials. Without formal instruction on how to teach and access general curriculum content and without instructional materials, the quality of academic instruction for students with ASD and moderate ID is questionable. This in turn presents another challenge, which is accountability. The No Child Left Behind Act of 2001 (2006) mandates that states report proficiency in mathematics, English language arts, and science for students with significant cognitive disabilities on alternate assessments based on alternate academic achievement standards (AA-AAS), and their scores are counted in NCLB's adequate yearly progress (AYP) measure. Presently states are able to develop their own AA-AAS; however, most states will transition to a nationalized AA-AAS aligned to the CCSSM (and English language arts) in 2015. Without effective instruction delivered by a highly qualified teacher and with the increased level of academic expectations from the CCSSM, students with ASD and moderate ID are limited in their ability to show growth and progress on alternate assessments. Consequently, the question arises regarding how students with ASD and moderate ID can best access the CCSSM while receiving high quality instruction via effective practices so they can demonstrate growth and become equipped with 21st century skills.

Teaching mathematics to students with ASD and moderate/severe ID. With the growth and reliance on technology in recent years, there has been an emphasis on the importance of mathematics in order for students to graduate with the skills needed to thrive in the 21st century (Kilpatrick, Swafford, & Findell, 2001). The NCTM (2000) states that all students need to have mathematical competence and the ability to use mathematical skills in everyday life because these skills provide “significantly enhanced opportunities and options for shaping their [all students’] futures” (p. 1). This notion has not changed with the transition to the CCSSM.

The majority of research on grade-aligned mathematics for students with ASD and moderate ID has been based on the NCTM’s *Curriculum and Evaluation Standards for School Mathematics* (1989), as these were the first common set of standards published. Although the present focus is on the transition to the new CCSSM, it is important to point out that the CCSSM were built based on prior work by NCTM, and many NCTM experts were involved in the drafting and editing of the CCSSM. Therefore, it is helpful to consider the NCTM standards as guiding principles for the development of CCSSM. Briefly, both entities promote that all students should have the necessary supports to be able to learn mathematics with depth and understanding, with the CCSSM focusing on students gaining a deeper understanding of core mathematical concepts, which progress in a linear fashion across grade levels, and being able to apply these skills to new contexts. Both NCTM and CCSSM describe the fundamental principles of high-quality mathematics education to be with (a) equity with high expectations and strong supports for all students, (b) a coherent curriculum that progresses and deepens across grades, (c) effective teaching strategies that challenge all learners, (d) enhancement of student learning to help students gain new knowledge and connect with a priori knowledge, and (e) ongoing and informative assessment. The two entities vary in their organization of mathematical content. NCTM explicitly defines mathematical content across five core standards for grades pre-K through 12^{th}, including (a) numbers and operations, (b) algebra, (c) geometry, (d) measurement, and (e) data analysis and probability. The CCSSM includes specific, operationalized grade-level standards in the organization of their domains and conceptual categories as (a) numbers and quantities, (b) algebra, (c) functions, (d) modeling, (e) geometry, and (f) statistics and probability. In addition, NCTM delineates process standards for which students should learn and apply mathematics, including problem solving, reasoning and proof, communication, connections, and representations. The CCSSM also describes processes for students to engage in mathematics, called the *Standards for Mathematical Practice*, but differ because much more emphasis is placed on the relationship between these standards and the processes. Regardless of their differences, the principles and standards set forth by NCTM and now the CCSSM are to ensure high quality education in mathematics for *all* students, including those with ASD and moderate ID. A full description of both NCTM and CCSSM is provided in Chapter 2.

In response to the NCTM's *Principles and Standards*, Browder et al. (2008) conducted a meta-analysis of 68 studies, published between 1975 and 2005, on teaching mathematics to students with moderate and severe ID to determine effective practices for teaching the mathematics standards to this student population. Browder et al. evaluated these studies using the Horner et al. (2005) criteria for high quality single-subject research studies with sound research practices, and found that the majority of the reviewed studies that met the “high quality” standards incorporated systematic instructional techniques, often in the form of a treatment package. Specifically, these studies demonstrated that students with moderate and severe ID successfully learned the targeted mathematical content standards (Colyer & Collins, 1996; Gardill & Browder, 1995; Mackay, Soraci, Carlin, Dennis, & Strawbridge, 2002; Matson & Long, 1986; Test, Howell, Burkhart, & Beroth, 1993 as cited in Browder et al., 2008). Browder et al. (2008) also concluded that the following instructional strategies were evidence-based practices for teaching mathematics to students with moderate and severe ID, including (a) massed trials or distributed trials with systematic prompting and corrective feedback, (b) in vivo instruction paired with systematic prompting and corrective feedback, and (c) repeated opportunities for student responding. The majority of studies addressed content on measurement (e.g., money, purchasing, and time) and numbers and operations (e.g., calculations, number identification, and counting). Four studies focused on data analysis (e.g., graphing) and geometry (e.g., shape identification), and only one study targeted algebra, specifically problem solving (Neef, Nelles, Iwata, & Page, 2003). In addition, only 24 of the 493 participants were students with ASD and moderate or severe ID. The authors stressed the need for future research to investigate additional strategies to teach mathematics to students with moderate and severe ID that: (a) targets other mathematics standards, such as algebra; (b) focuses on skills that required higher level thinking, such as problem solving; (c) includes specific subgroups of students with moderate/severe ID, such as students with ASD; and (d) is consistent with the preferences and needs of students with moderate and severe ID.

Problem solving. Problem solving is a pivotal skill that is used across most standards in mathematics, and is needed for generalization to solving mathematical real-world problems. Although it is arguably one of the most functional mathematics skills, it requires a high level of cognitive processes. Successfully solving word problems requires understanding the relations and goals in the problem (Jitendra, Dupuis, et al., 2013; Jitendra et al., 2007). Students must comprehend the text of the word problem, put the information in their working memory, create a mathematical representation of the problem, develop a plan to solve, and then find a solution (Hegarty, Mayer, & Monk, 1995; Jitendra, Peterson-Brown, et al., 2013). Despite its importance as a foundational skill in mathematics, there is very limited research in the area of problem solving with students with ASD and moderate ID. The limited research in problem solving is likely because this population has many challenges that make solving word problems very difficult, such as working memory and conceptual difficulties, deficits in background knowledge, weak early numeracy skills, linguistic and vocabulary difficulties, difficulty selecting and using strategies, and self-regulation difficulties (Jitendra, 2008).

One method that has been effective at ameliorating these difficulties in students with learning disabilities and students who are at risk for mathematics failure is schema-based instruction (SBI; Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004; Jitendra, Dupuis, et al., 2013; Jitendra, Peterson-Brown, et al., 2013; Powell, 2011; Xin & Zhang, 2009). A *schema* provides a framework for solving a problem (Marshall, 1995). SBI systematically and explicitly teaches a number of strategies to scaffold students' learning (Jitendra &

Star, 2011). SBI is composed of four critical elements: (a) identifying the underlying problem structure to determine problem type (e.g., change, group, or compare); (b) use of visual representations (e.g., schematic diagrams) to organize the information from the problem that represents the underlying structure of the problem type; (c) explicit instruction on the schema-based problem-solving heuristic (problem schema identification, representation, planning, and solution); and (d) metacognitive strategy knowledge instruction, which includes activities like analyzing the problem, self-monitoring of strategy use, and checking the outcome (Jitendra, Dupuis, et al., 2013; Powell, 2011). SBI relieves the dependency on working memory and helps students visually map out the problem structure in order to solve problems successfully. In addition, it offers students strategies to solve a variety of problems with an appropriate amount of flexibility, while monitoring the process of problem solving (Jitendra, Peterson-Brown, et al., 2013).

The SBI approach to problem solving has been shown to be much more effective than the direct-translation strategy, commonly known as the “key word strategy.” The key word strategy, where students find the numbers, key words, and solve, often misleads students and results in systematic errors (Hegarty et al., 1995; Jitendra & Star, 2011; Jitendra & Xin, 1997). The conceptual understanding of word problem solving, which requires comprehending the action language and referential meaning, especially as problems get more complex, shows the need for SBI over traditional approaches, such as the key word strategy.

Only one study to date has used SBI to teach problem solving to a student with moderate ID. Neef and colleagues (2003) used a multiple baseline across behaviors design to teach a 19-year-old man with an IQ of 46 to solve change-addition and change-subtraction problems by teaching precurrent behaviors, which included teaching the student to identify component parts of the word problem, including the initial set, the change set, key words to identify the operation, and the resulting set. In addition to identifying the components, the student learned to fill out a schematic diagram with the information from the problem. Teaching precurrent behaviors was successful in yielding accurate current behaviors (correct solutions) as the student increased the number of correct solutions from a mean of 1.2 to 8.0 out of 10 possible points. This study only included one participant with a moderate ID and only addressed one problem type.

One pivotal study by Rockwell, Griffin, and Jones (2011) directly influenced the development of the present study. The study investigated the effects of SBI on word problem solving of three problem types (i.e., group, change, and compare) on a fourth grade female student with autism and mild ID using a multiple probe across behaviors (problem types) design. The student was explicitly taught to discriminate problem types using schematic diagrams and to solve the addition and subtraction word problems using the mnemonic "RUNS" (i.e., "Read the problem," "Use a Diagram," "Number sentence," and "State the answer"). Scripted lessons, based on a direct instruction approach, were used for each instructional session. Two dependent variables were measured, including practice sheets which were used as a formative assessment during training phases to guide the pace of instruction, and problem-solving probes which were used to measure treatment effects. For all practice sheets and probes, the problem situations had unknowns in the final position and no extraneous information was included. Generalization probes measured the student's ability to solve problems with unknowns in the initial and medial position. Results showed that the student was able to achieve perfect scores (6 out of 6 possible points) across all three problem types. She met mastery during generalization for two of three problem types, but failed to reach mastery in one change problem probe due to a calculation error. She was able to maintain the skill with perfect scores for group and change problems and averaged 5 out of 6 possible points for compare problems. Rockwell (2012) replicated her 2011 study with one 7-year-old male student and one 12-year-old male student with ASD. Findings were similar. Both students achieved perfect scores (6 out of 6 possible points) for all three problem types. One student continued to have perfect scores in both generalization and maintenance phases, and the other student continued to have a perfect score during generalization, but fell slightly during the 8-week follow-up period. Clearly, more research on problem solving is needed to include students with ASD and moderate ID.

Computer-assisted instruction. One possible method for addressing the recommendations for future research by Browder et al. (2008), as well as to accommodate for special educators' deficits in mathematics content knowledge, is to teach problem solving to students with ASD and moderate or severe ID by using computer-assisted instruction (CAI). CAI has been deemed an evidence-based practice for teaching communication skills to students with ASD (Odom, Collet-Klingenberg, Rogers, & Hatton, 2010) and has recently been shown to be effective in teaching academic content to students with moderate and severe ID (Blischak & Schlosser, 2003; Mechling, 2005; Pennington, 2010; Ramdoss et al., 2011). CAI is defined as the inclusion of some format of multimedia (e.g., text, graphics, animation, voice, music, and slides) in a single system that is delivered via a computer program. CAI has the benefit of customizability by the developer to meet individual students' needs. Three examples of programs often used for creating CAI are Hyperstudio 4.0, Microsoft PowerPoint®, and Illuminatus (Mechling, 2005; Ramdoss et al., 2011). Other commercial programs are also available, such as Baldi/Timo, Delta Messages, Alpha program, and Teach Town: Basics (Ramdoss et al., 2011).

Pennington (2010) conducted a literature review of empirical research that used CAI to teach academic skills to students with ASD and found 15 articles with a total of 52 participants with ASD ranging from ages 3 to 17. All studies targeted literacy skills, with eight targeting reading instruction (e.g., identifying nouns, letters, numbers, and food words; acquisition of target vocabulary; decoding skills), and seven targeting written expression (e.g., sentence construction; Japanese character construction; and essay writing skills). Additionally, Pennington found that only two of the 15 studies involved using CAI to teach more complex skills (i.e., decoding skills [Coleman-Martin, Heller, Cihak, & Irvine, 2005] and essay writing skills [Delano, 2007], as cited in Pennington, 2010).

Knight, McKissick, and Saunders (2013) expanded the findings by Blischak and Schlosser (2003) and Pennington (2010) by evaluating the reviewed studies and additional studies through 2012 using the Horner et al. (2005) or Gersten et al. (2005) criteria for determining evidence-based practices in single-subject or group experimental/quasi-experimental designs, respectively. Their findings revealed 29 studies with a total of 142 participants with a diagnosis of ASD. All 29 studies focused on the content area of English language arts and three of the 29 studies also included a mathematics component. Only four of the 17 single-subject studies met acceptable quality according to Horner et al.'s (2005) criteria (i.e., Hetzroni, Rubin, & Konkol, 2002; Hetzroni & Shalem, 2005; Mechling, Gast, & Langone, 2002; Pennington, Stenoff, Gibson, & Ballou, 2012) and no group design studies were of acceptable or high quality. Clearly, more research using CAI with strong empirical support is needed for teaching more complex academic skills and for teaching mathematics to students with ASD and moderate ID.

In addition to positive academic outcomes, research also suggests positive collateral effects of CAI in academics on social behavior. The positive collateral effects are likely due to the fact that CAI often embeds explicit instruction, feedback, modeling, prompting, repetition of instruction, and positive reinforcement (Mechling, 2005; Ota & DuPaul, 2002; Pennington, 2010). It also requires students to actively respond (e.g., touch a screen, click on a mouse to advance slide) to specific stimuli (Mechling, 2005). Active student response or engagement has been shown to reduce students' problem behaviors and increase academic-related behaviors (e.g., on-task behaviors, answering questions) in the classrooms (Carnine, 1976; Greenwood, Terry, Marquis, & Walker, 1994; Sutherland, Alder, & Gunter, 2003; West & Sloane, 1986). For example, Soares et al. (2009) demonstrated that CAI in academic instruction, which was provided with individualized, embedded opportunities for self-monitoring, feedback, and praise, effectively increased student productivity and resulted in a reduction of problem behaviors. These collateral benefits are important factors to consider when selecting instructional strategies to use with students with ASD and moderate/severe ID based on the social and behavioral needs of these students.

Computer-based video instruction. One form of CAI interventions specifically embed videos within the intervention package, also commonly referred to as computer-based video instruction (CBVI). The video instruction, rather than the teacher, provides students with explicit instructions and visual demonstrations of the targeted skills. CBVI combines the evidence-based practice of video modeling (Bellini & Akullian, 2007; Odom et al., 2010) within CAI. The video model, performed by any model type, is embedded within a program, such as Microsoft PowerPoint®, in order to provide a multimedia, interactive learning opportunity (Mechling, 2005).

There are many benefits to using CBVI in mathematics instruction for students with ASD and moderate ID. First, CBVI allows the developer to embed evidence-based practices for teaching mathematics to students with ASD and moderate ID, including systematic instruction with error correction and feedback and repeated opportunities to view videos and practice skills (Mechling, 2005). Second, the mathematical content can be validated by a content expert to ensure accuracy of content, which addresses the challenge that special educators are not content experts. Third, CBVI incorporates the principles of programmed instruction (Lockee, Larson, Burton, & Moore, 2008), where instructional decision making based on student responding can be incorporated into the development of the program. For example, when a student watches a short video, advances to the next screen involving a question, and answers it incorrectly, the program can link the student immediately back to the video, where the student will watch it again (Mechling, 2005). This built-in feature provides error correction and repetitive practice until the student masters the skill. In addition, CBVI provides the developer with the opportunity to familiarize students with AA-AAS type questions and train students to answer in a testing format so students are better prepared for the AA-AAS. Fourth, CBVI offers advantages over face-to-face instruction. The videos can be individualized according to students' interests, be personalized for specific students' needs, and be culturally sensitive to learners (Mechling, 2005; Ramdoss et al., 2011). Additionally, CBVI is likely to promote better generalized outcomes than traditional face-to-face instruction because it can include a wide variety of stimulus and response examples in natural, real-life environments in which the student will be performing the skill. Teachers and researchers have the ability to program common stimuli, such as familiar sights and sounds in which the student may experience in the natural setting (Mechling, 2005). CBVI also limits the amount of social interaction required by the student when acquiring a new skill; whereas in traditional face-to-face instruction, social interactions between the teacher and other students and among students can present as distraction for students with ASD (Ramdoss et al., 2011). Finally, Charlop-Christy, Le, and Freeman (2000) found that CBVI led to faster skill acquisition.

Despite its numerous benefits, research on using CBVI to teach academic content to students with ASD and moderate ID is very limited. Currently, there are only three studies with this student population that have integrated CBVI to teach academic skills; of which, all focused on the acquisition of literacy skills (Heimann, Nelson, Tjus, & Gillberg, 1995; Kinney, Vedora, & Sromer, 2003; Mechling et al., 2002).

CAI and CBVI for teaching mathematics. Research addressing the effects of CAI or CBVI on mathematics skills is very scarce with only three studies published to date (i.e., Burton, Anderson, Prater, & Dyches, 2013; Chen & Bernard-Opitz, 1993; Whalen et al., 2010). Chen and Bernard-Opitz (1993) compared CAI with a one-to-one personal instruction condition using an adapted alternating treatments design to teach the mathematical concepts of addition, the concept of more or less, and recall of object position to four participants with autism. This study also examined the effects of CAI on the labeling of pictures. The two conditions included a researcher-made CAI program condition, which included changing the proximity of the trained stimulus, massed trials, and within-stimulus prompting, and a one-to-one personal instruction condition. The researchers measured the learning rate in terms of average percentage in both conditions. Results showed that only one student's learning rate was higher in the CAI condition, whereas motivation and appropriate behavior were higher in the CAI condition for all four participants. Little information was provided about the specifics of the CAI program. According to the authors, the mixed results could have been related to some students' difficulty in operating the computer. It is important to note that this study occurred in the early 1990s and computer technology has significantly advanced since its publication. Students are more familiar with using computers and technology, so the results may not be as applicable now.

In the second study, Whalen et al. (2010) taught the mathematical concepts of shape and number identification, most and fewest, one-to-one correspondence with number matching, addition, subtraction, number lines, and fractions using CAI via the computer software program *Teach Town: Basics*. This study also involved teaching several other academic/cognitive domain concepts (e.g., reading, categorization, and problem solving) and social/communicative/adaptive skills (e.g., receptive language-comprehension skills, social-emotional skills, independence and life skills). Fifteen of the 22 students in the treatment group mastered lessons across the four domains in a 3-month time period. Although mathematics was not the primary content area taught, the study did show effectiveness in mathematical content acquisition.

In the most recent study, Burton et al. (2013) taught functional mathematics problem solving (i.e., purchasing skills) via video self-modeling (VSM) on an iPad® using a multiple baseline across participants design to four students with middle school students with ASD and ID (IQ ranges 61-85). Students were given pictures of five items with price tags and were asked to estimate the amount of money needed to purchase the item using the smallest number of bills possible and to calculate the amount they would receive in change. Participants used a seven-step task analysis for problem solving in all conditions (baseline, video development, intervention, post-intervention, and follow-up). During intervention, participants could watch the video of themselves performing the steps to solve the problems as many times as they needed to solve the problem correctly. Results demonstrated a functional relation between VSM and functional mathematics problem solving across all four participants. Three participants were able to maintain mastery criterion once VSM was withdrawn, and the other participant dropped slightly below mastery criterion but remained well above baseline. The study showed CBVI can be used to teach functional mathematics problem solving.

Limitations of Current Research

There are several limitations to the current research. First, additional research is needed to determine effective instructional procedures for teaching grade-aligned mathematics content, especially aligned to the CCSSM. Second, there is a need to teach the pivotal skill of problem solving in mathematics to students with ASD and moderate ID, moving beyond basic *numbers and operations* and *measurement* skills of time and money. There is also a need to investigate whether the use of effective strategies for teaching problem solving to high incidence disabilities, such as SBI, in combination with effective strategies for teaching mathematics to students with moderate/severe ID can be used to successfully teach problem solving to students with ASD and moderate ID. Finally, there is a need for more empirical studies using CBVI to teach important mathematics skills that are designed to address the quality indicators set forth by Horner et al. (2005).

Purpose of the Study and Research Questions

This study extended the limited research on using CBVI to teach mathematical problem solving by investigating the effects of CBVI, embedding SBI, on acquisition and generalization of mathematical problem solving skills for elementary level students with ASD and moderate ID. There were four research questions.

1. What were the effects of SBI delivered through CBVI on the acquisition of mathematical problem solving skills in students with ASD and moderate ID?
2. What were the effects of SBI delivered through CBVI on students' discrimination between problem types (i.e., group and change) in students with ASD and moderate ID?
3. What were the effects of SBI delivered through CBVI on the generalization of the learned mathematics skills to novel problems presented in paper-and-pencil format in students with ASD and moderate ID?
4. What were the perceptions of participants and their teachers on the effectiveness and/or feasibility of learning word problem solving through CBVI in students with ASD and moderate ID?

Significance of the Study

This study contributed to the growing body of CAI and CBVI research in several ways. First, it added to the limited literature on using CBVI to teach mathematics content as the primary dependent variable to students with ASD and moderate ID. Second, it focused on teaching a more complex mathematical skill of problem solving through SBI which has very limited research for students with ASD and moderate ID (Neef et al., 2003; Rockwell, 2012; Rockwell et al., 2011). The inclusion of problem solving skills in this study was to prepare students with ASD and moderate ID with 21st century mathematical concepts. Third, it addressed the need for effective instructional strategies for teaching higher level mathematical skills to students with ASD and moderate ID. CBVI was used as a support to help students acquire skills by embedding evidence-based practices, such as explicit instruction, corrective feedback, modeling, systematic prompting, repetition of instruction, and positive reinforcement. Fourth, the CBVI was content-validated and used as the method of delivering grade-aligned mathematics content, thus ameliorating the challenge of special educators having deficits in content knowledge and in how to provide access. Fifth, the study included generalization measure of the newly acquired mathematics skills in paper-and-pencil format, which is similar to the alternate assessment format.

Delimitations

There are several delimitations in this study. First, this study was conducted in a large, urban school district, which has received a grant for all self-contained classrooms to be equipped with SMART Boards™. Some school districts and classrooms may not have the same technology available. Second, this study did not address the inclusion of students with ASD and moderate ID in the general education setting. This may have limited students' direct access to general education mathematics content. Third, because the research with this student population is so new, the researcher chose to target the two initial problem types of group and change in this investigation. The more complex problem type of compare was not addressed in this study. Finally, students in this study were selected because they had already mastered early numeracy skills, such as identifying numbers to 10, counting with 1:1 correspondence, creating sets to 10, and early addition skills. Results may not be applicable to students who have not yet mastered these prerequisite skills.

Definitions

The following terms are critical for the understanding of the related literature and methodology used in this study.

Autism spectrum disorders. The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) which was released in May 2013, has proposed a new definition for autism spectrum disorder (ASD), which includes autistic disorder (i.e., currently DSM-IV definition of autism), Asperger's disorder, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified. The proposed revision to the definition of autism, which appears in the Diagnostic Statistics Manual, 5th edition, is:

"Must meet criteria A, B, C, and D:

A. Persistent deficits in social communication and social interaction across contexts, not accounted for by general developmental delays, and manifest by all 3 of the following:

1. Deficits in social-emotional reciprocity; ranging from abnormal social approach and failure of normal back and forth conversation through reduced sharing of interests, emotions, and affect and response to total lack of initiation of social interaction.
2. Deficits in nonverbal communicative behaviors used for social interaction; ranging from poorly integrated-verbal and nonverbal communication, through abnormalities in eye contact and body-language, or deficits in understanding and use of nonverbal communication, to total lack of facial expression or gestures.
3. Deficits in developing and maintaining relationships, appropriate to developmental level (beyond those with caregivers); ranging from difficulties adjusting behavior to suit different social contexts through difficulties in sharing imaginative play and in making friends to an apparent absence of interest in people.

B. Restricted, repetitive patterns of behavior, interests, or activities as manifested by at least two of the following:

   1. Stereotyped or repetitive speech, motor movements, or use of objects; (such as simple motor stereotypies, echolalia, repetitive use of objects, or idiosyncratic phrases).
   2. Excessive adherence to routines, ritualized patterns of verbal or nonverbal behavior, or excessive resistance to change; (such as motoric rituals, insistence on same route or food, repetitive questioning or extreme distress at small changes).

3. Highly restricted, fixated interests that are abnormal in intensity or focus; (such as strong attachment to or preoccupation with unusual objects, excessively circumscribed or perseverative interests).
4. Hyper-or hypo-reactivity to sensory input or unusual interest in sensory aspects of environment; (such as apparent indifference to pain/heat/cold, adverse response to specific sounds or textures, excessive smelling or touching of objects, fascination with lights or spinning objects).

C. Symptoms must be present in early childhood (but may not become fully manifest until social demands exceed limited capacities)

D. Symptoms together limit and impair everyday functioning." (American Psychiatric Association, 2010).

Common Core State Standards Initiative (CCSSI). The CCSSI (http://www.corestandards.org) is a state-led effort coordinated by the National Governors Association Center for Best Practices and the Council of Chief State School Officers to create a shared set of content standards that frame instruction and assessment for all students, including students with disabilities. The goal of the CCSSI is to prepare students who are college and career ready upon completion of high school. The standards are clear and concise, and include rigorous content and application of knowledge through critical thinking. Currently, 45 states and 3 territories have adopted the CCSS. The CCSSI released the Common Core State Standards in English language arts (CCSSE) and the Common Core State Standards in mathematics (CCSSM) on June 2, 2010. The purpose of the CCSSM is to delineate the knowledge and skills that students should gain in a progressive fashion from kindergarten through grade 12.

Computer-assisted instruction (CAI). CAI is an evidence-based practice for students with ASD and includes the use of computers for teaching students academic skills and promoting communication and language development (Odom et al., 2010).

Computer-based video instruction (CBVI). CBVI is a term used to describe some type of video technology, such as instructor-created video recordings, embedded within a computer-based program used for the purpose of delivering instruction in an interactive learning environment (Mechling, 2005). CBVI is defined as a “nonlinear or nonsequential presentation of text, graphics, animation, voice, music, slides, movies, or motion video in a single system that involves the user as an active participant” (Wissick, 1996, p. 494).

Curricular adaptations. This term refers to “modifications that change the way content is represented or presented to students to promote student engagement, either through pedagogical means (e.g., advance organizers) or through the use of technology” (Soukup, Wehmeyer, Bashinski, & Bovaird, 2007, p. 102). For the purposes of this study, the computer-based video instruction was considered a curricular adaptation.

Curriculum augmentations. The term refers to “the addition of content to general education curriculum to enable students to learn skills and strategies to perform more effectively in the general education curriculum” (Soukup et al., 2007, p. 102). Examples of these include direct instructional strategies, explicit instruction, constant time delay, and student-directed learning, all of which were embedded within the instruction delivered via the computer in the current study.

General curriculum access. This term refers to providing students with disabilities meaningful access to the same curriculum as age- and grade-equivalent students without disabilities in the core academic domains of math, English/language arts, science, and social studies. This is a federal requirement of IDEA (2004). The purpose of general curriculum access is not to teach all standards to mastery, but to provide: (a) equality in education; (b) increased educational opportunities, which lead to greater competence in adult living; and (c) increased opportunities for self-determination (Browder & Spooner, 2011). Inclusion does not guarantee access to the general curriculum, although it is often mistakenly interpreted that way (Soukup et al., 2007).

Intellectual disability. "Intellectual disability is characterized by significant limitations both in intellectual functioning and in adaptive behavior as expressed in conceptual, social, and practical adaptive skills. This disability originates before age 18" (Schalock et al., 2007, p. 118). This term is replacing the antiquated term "mental retardation," although the term "mental retardation" is still used in some areas, such as federal law. This umbrella term includes individuals with mild, moderate, and severe/profound cognitive disabilities. Individuals with an intellectual disability (ID) may or may not have co-morbid disabilities, such as ASD, Down's syndrome, Fragile X syndrome, or Angelman's syndrome (Browder & Spooner, 2011). Moderate ID refers to a specific subset of students with an intellectual disability as described above with an IQ in the range of 35-40 to 50-55 (DSM V), and severe ID refers to students with an IQ of 20-25 to 35-40.

National Council of Teachers of Mathematics (NCTM). The NCTM was the first national organization to establish standards in mathematics in 1989, which were further updated in 2000.

Schema-based instruction (SBI). Schema-based instruction is a process in which the mathematical structure of a problem is used to solve the problem. A schema provides the framework, or organizing structure, for solving a problem because it shows the relationships among elements specific to each problem (Marshall, 1995). SBI is composed of four critical elements (Jitendra, Dupuis, et al., 2013; Powell, 2011). The first element includes identifying the underlying problem structure to determine problem type (e.g., change, group, or compare). The second element includes using visual representations (e.g., schematic diagrams) to organize the information from the problem to represent the underlying structure of the problem type. The third element includes the use of explicit instruction to teach problem schema identification, representation of the problem, planning to solve, and the solution. The final element includes metacognitive strategy knowledge instruction, including analyzing the problem, self-monitoring of strategy use, and checking the outcome.

Severe disabilities. Students with severe disabilities include students with profound ID, “mental retardation,” multiple disabilities, and some students with ASD who also have moderate to severe ID. The term “severe disabilities” is used throughout this dissertation when the topic being discussed encompasses more than individuals with moderate/severe ID, such as when students with profound ID or co-morbid disabilities are being included.

Students with significant cognitive disabilities. This term refers specifically to students who are assessed using alternate assessments which align with alternate achievement standards. This term does not indicate the severity of the individual's disability, but refers to an individual who "(1) requires substantial modifications, adaptations, or supports to meaningfully access the grade-level content, (2) requires intensive individualized instruction in order to acquire and generalize knowledge, and (3) is worked toward alternate achievement standards for grade-level content" (Browder & Spooner, 2006, p. xviii). Students in this study were or are on track to be assessed using the NCEXTEND1, an alternate assessment designed for the 1% of the student population with a significant cognitive disability, and therefore were considered students with significant cognitive disabilities.

Systematic instruction. This term refers to a clearly defined, replicable process that is designed with best practices, collects ongoing performance data and uses data to make instructional decisions, and progresses from acquisition to proficiency in learning (Snell, 1983). It incorporates principles of applied behavior analysis to promote the transfer of stimulus control, such as prompt fading procedures, reinforcement, and training for generalization (Spooner, Knight, Browder, & Smith, 2012).

Word problem solving. Mathematical word problems present information in some type of narrative format, such as a story problem, instead of mathematical notation. Word problem solving is defined as the ability to comprehend the story problem and the underlying semantic structure, understand the quantitative relationships among numbers or actions in the story problem, develop a plan for solving, apply previously learned mathematical skills such as basic operations and arithmetic to solve the problem, and interpret the solution (Jaspers & Van Lieshout, 1994; Jitendra, Dupuis, et al., 2013; Van de Walle, Karp, & Bay-Williams, 2010). Word problem solving requires executive functioning skills such as working memory, organization, and mental flexibility in order to complete the tasks (Schaefer Whitby, 2012).

CHAPTER 2: REVIEW OF LITERATURE

Standards-based reform has transformed special education over the past decade by emphasizing the need for all students to participate in the general curriculum and to be held to high academic expectations. Two pieces of federal legislation strongly influenced standards-based reform for students with disabilities. First, the 1997 Amendments to the Individuals with Disabilities Education Act (IDEA) mandated that students with disabilities have access to the general curriculum and participate in state-wide assessments. Second, the No Child Left Behind Act of 2001 (NCLB) required that all students must be assessed in the content areas of reading/language arts, math, and science, and that schools must report adequate yearly progress (AYP) on student achievement. Students who are unable to participate in these assessments with appropriate accommodations are given alternate assessments aligned to alternate achievement academic standards (Browder & Spooner, 2003), and these students are included in the reports on AYP. Although research is emerging on teaching academic skills to students with moderate/severe ID, including those with ASD and moderate ID, the primary focus has been on literacy (Bouck, Satsangi, Taber Doughty, & Courtney, 2014; Browder, Trela, et al., 2012). Little exists on how to teach academic mathematics to students with moderate/severe ID beyond the skills of time, money, and purchasing (Collins, 2007; Ryndak & Alper, 2003; Snell & Brown, 2011; Westling & Fox, 2009).

In addition to the federal requirements, another important reason for educating students with moderate/severe ID, including those with ASD and moderate ID, in the field of mathematics is that mastery of mathematics skills can improve students' overall quality of life. Quality mathematics instruction can afford students with moderate/severe ID with an increased number of opportunities that these students may have never had before and will greatly increase their independence as well as employability advantages. Mathematical problem solving is a pivotal skill that directly affects an individual's ability to apply mathematical skills to everyday life.

Van de Walle (2004) suggested that learning to solve story problems is the basis for learning to solve real-world mathematical problems. Unfortunately, problem solving is very difficult for students with moderate/severe ID, including those with ASD and moderate ID, because of numerous challenges that are characteristics of their disability, such as working memory deficits, attention deficits, difficulty with language comprehension, early numeracy deficits, and difficulty with self-regulation (Donlan, 2007). This is not to say that students with disabilities cannot learn problem solving; instead, they simply need sound instructional practices based on empirical research to do so. Schema-based instruction (SBI) is one method that has shown to decrease cognitive load requirements and improve problem solving in students with high incidence disabilities by teaching students to identify the underlying problem solving structure before solving the problem (Fuchs et al., 2006; Jitendra & Hoff, 1996).

SBI includes a four-step problem solving approach, including schema identification, visual representation, planning, and finding a solution (Xin & Jitendra, 2006). Although SBI has been quite successful with students with high incidence disabilities and students at risk for failure in mathematics, it requires higher level cognitive and metacognitive processes that may be difficult for students with moderate/severe ID, including those with ASD and moderate ID. Additional adaptations are necessary for this population. As shown in Figure 1, by combining SBI with evidence-based practices for teaching mathematics to students with moderate/severe ID, such as systematic instruction (Browder et al., 2008) and computer-assisted instruction (CAI; Knight et al., 2013; Pennington, 2010) with video modeling, known as computer-based video instruction (CBVI; Mechling, 2005) for teaching academics to students with ASD, it may be possible to teach mathematical problem solving to students with ASD and moderate ID.

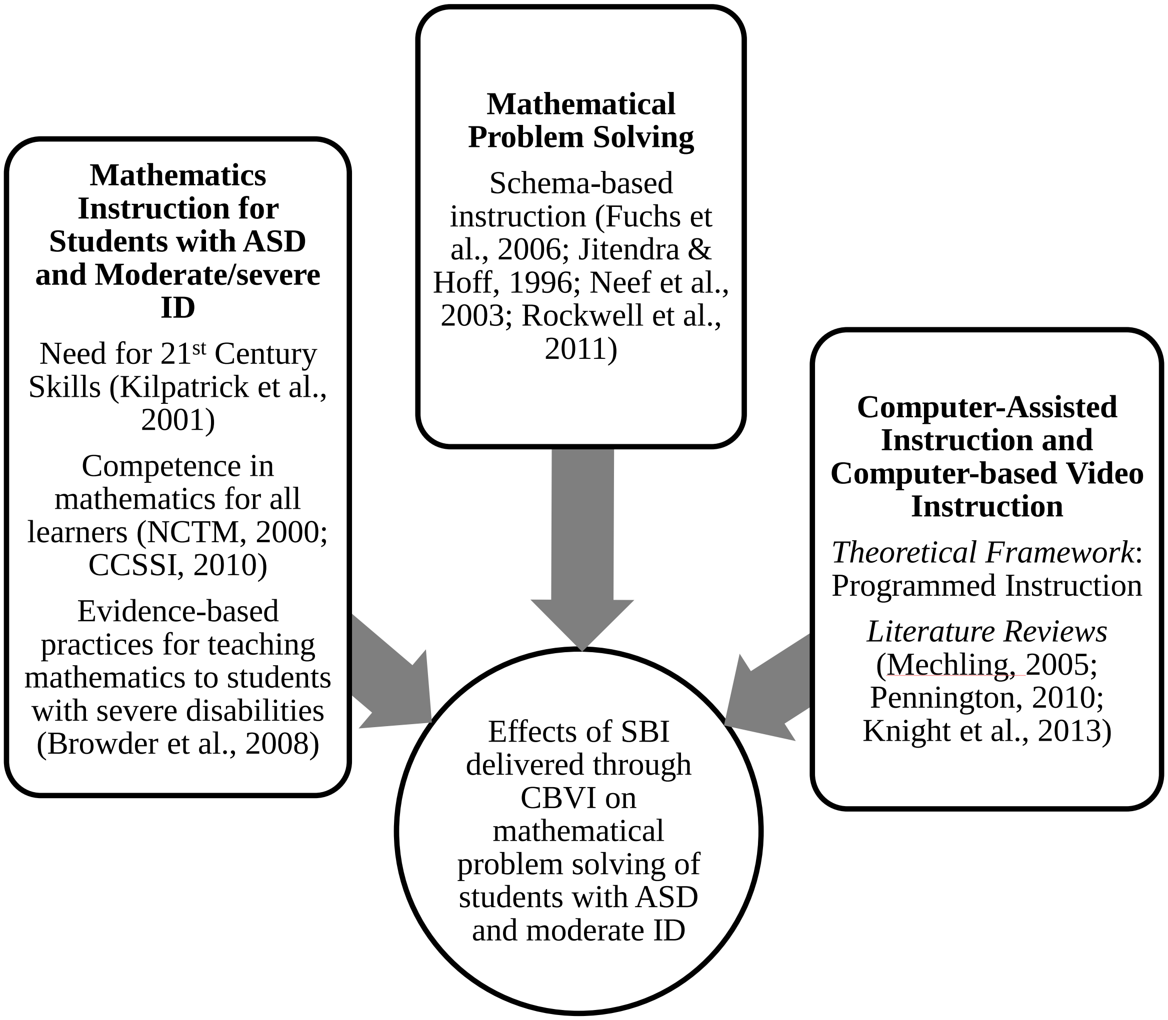

Figure 1: Theory of change for teaching mathematical problem solving to students with ASD and moderate ID.

This chapter includes an overview of mathematical standards for all students, a review of evidence- and research-based strategies for teaching mathematics to students with moderate/severe ID, and a discussion on research for teaching problem solving to students with high incidence disabilities, as well as those with ASD and moderate ID. In addition, this chapter will include a review of the literature for using CAI and CBVI to teach academics to students with ASD and ID. The last section will examine the literature on using CAI to teach problem solving to students with high incidence disabilities to provide recommendations that will guide the development of the intervention for this study.

High Quality Mathematics Instruction

Two organizations that have established standards for mathematics include the National Council of Teachers of Mathematics (NCTM, 2000) and the Common Core State Standards Initiative (CCSSI, 2010). The NCTM was the first national organization to establish standards in mathematics in 1989, which were further updated in 2000. These standards, along with each state's individualized state standards, were used to developed grade-aligned skills in mathematics for students with moderate/severe ID. The CCSSI, a state-led effort, released the Common Core State Standards (CCSS) in mathematics on June 2, 2010. The purpose of the CCSS in mathematics (CCSSM) was to delineate the knowledge and skills that students should gain in a progressive fashion from kindergarten through grade 12. Although NCTM and CCSSI are two separate entities, the NCTM was actively involved in the state-led effort to develop a nationalized set of mathematical standards, with the goal that students would be college and career ready upon the completion of high school. Because the NCTM standards were used to develop grade-aligned mathematics content prior to the release of the CCSSM, and because the CCSSM will be the direction in which future grade-aligned mathematics is focused, both are described below.

The NCTM established essential components of high-quality school mathematics programs, which included five content standards that students should know and five processes for how students should acquire and apply the content knowledge. The five *content standards* are Numbers and Operations, Algebra, Geometry, Measurement, and Data Analysis/Probability (NCTM, 2000). The Numbers and Operations standard includes an understanding of numbers and number systems, operations, and computation with fluency. The Algebra standard includes an understanding of patterns, relations among numbers, functions, and the ability to represent quantitative relationships using algebraic symbols. The Geometry standard includes the understanding and analysis of geometric shapes through visualizations, spatial reasoning, and geometric modeling. The Measurement standard includes not only the understanding of measureable attributes, units, systems, and processes of measurement, but also skills in applying techniques, tools, and formulas to determine measurements. The Data Analysis and Probability standard consists of the ability to formulate questions, gather data, organize data, represent data, analyze and interpret data, and develop an understanding of the principles of probability.

The five *process standards* include problem solving, reasoning and proof, communication, connections, and representations. Problem solving is one of the most integral parts of mathematics. It requires students to reflect on their thinking and apply and adapt strategies to solve problems that extend beyond the classroom. Reasoning and proof are components of analytical thinking and reflect on how students develop, justify, and express insights on phenomena. Communication is essential to the understanding of mathematics. When students communicate their mathematical thinking and reasoning orally or in writing, they are able to increase their understanding of the content. The same is true when students listen to others explain their reasoning. Connections between mathematical ideas and other subjects, interests, and personal experiences help students create a deeper understanding of mathematical ideas. Representations, whether it be graphics, manipulatives, tables, graphs, symbols, or charts, are essential to students' understanding of mathematical concepts and relationships.

The CCSSM (http://www.corestandards.org) are a cohesive set of standards adopted by 45 states and 3 territories that frame instruction and assessment for *all* students, including students with ASD and moderate ID, in order to prepare them for college and career readiness. The standards progress across grade levels in a sequential manner; they emphasize not only the conceptual understanding of key ideas, but also the organizing principles of mathematics, such as place value and arithmetic. The CCSSM describe the *what*, or the content to teach, but leave the *how* up to the teachers in their instructional planning. There are no prescribed set of interventions, materials, or supports for students. The CCSSM vary from the NCTM standards by narrowing the content covered but go more in-depth for a deeper understanding.

The content of the CCSSM is broken into domains (similar to the strands of the NCTM) for grades kindergarten through eighth grade: counting and cardinality (kindergarten only), operations and algebraic thinking (kindergarten through fifth grade), number and operations in base ten (kindergarten through fifth grade), number and operations – fractions (third through fifth grade), measurement and data (kindergarten through fifth grade), geometry (kindergarten through eighth grade), ratios and proportional relationships (sixth and seventh grade only), the number system (sixth through eighth grade), expressions and equations (sixth through eighth grade), functions (eighth grade only), and statistics and probability (sixth through eighth grade). In high school (ninth through 12th grade), the standards are broken into six conceptual categories to form a set of high school standards, including number and quantity, algebra, functions, modeling, geometry, and statistics and probability. The CCSSM also delineates eight *Standards for Mathematical Practice,* the first three of which are derived from the NCTM process standards, including (a) making sense of problems and persevering to solve them, (b) reasoning abstractly and quantitatively, (c) constructing viable arguments and critiquing the reasoning of others, (d) modeling with mathematics, (e) using appropriate tools strategically, (f) attending to precision, (g) looking for and making use of structure, and (h) looking for and expressing regularity in repeated reasoning. These standards of mathematical practice describe what “mathematically proficient students” should be able to do across grades K-12. It is expected that curricular developers, assessment designers, and professional development organizers connect these standards with the mathematical content.

Although there is a heavy emphasis on teaching academics to students with ASD and moderate ID because of high-stakes testing, it is important to teach the academic content in meaningful ways, such as in context with relevant applications to real-world activities or situations, rather than teaching skills in isolation, which provides no reasoning as to when or why to apply the skills (Browder, Trela, et al., 2012; Collins, Hager, & Creech-Galloway, 2011). Furthermore, mathematical learning activities should also incorporate literary development and opportunities for communication to maximize learning so it is as personally relevant as possible (Hunt, McDonnell, & Crockett, 2012). One method is to address functional skills within core content instruction and gather data on both skill sets (Falkenstine, Collins, Schuster, & Kleinert, 2009); however, this may not always be necessary. Within all NCTM and CCSSM, practical applications are an integral part and, therefore, students are often exposed to functional skills embedded in the mathematical learning (National Mathematics Advisory Panel, 2008). For example, the NCTM's process standards of problem solving and reasoning (also included in the CCSSM *Standards for Mathematical Practice*) require students to complete practical application problems, which further encourage students' independence and self-determination skills.

Despite the benefit of incorporating content standards when designing mathematics instruction for students with ASD and moderate/severe ID, existing research on how to go about doing so is limited. Browder et al. (2008) conducted a meta-analysis of 68 studies, published between 1975 and 2005, which taught mathematics to 493 students with significant cognitive disabilities. Studies were conducted in a variety of settings, with some being conducted in more than one setting (e.g., special education classroom: 56.7% or the community: 26.9%; general education classrooms: 35.8% or home settings: 13.4%; employment settings: 4.5% and residential settings: 4.5%). The authors examined what NCTM components of mathematics were included, what skills from these NCTM components had been taught, and what instructional practices were considered evidence based in effectively teaching students with significant cognitive disabilities. Browder et al. found that most studies focused on Numbers and Operations (n = 37, 40.3%) and Measurement (n = 36, 53.7%); whereas only six studies focused on Algebra (n = 2, 3.0%), Geometry (n = 2, 3.0%), or Data Analysis/Probability (n = 2, 3.0%). The skills taught within each standard included: (a) Numbers and Operations: counting, calculating, and matching numbers; (b) Measurement: money and telling time; (c) Algebra: word problems, determining equivalence, and quantifying sets; (d)

Geometry: shape identification; and (e) Data Analysis: graphing as a self-monitoring skill. The authors evaluated the quality of the studies using the Gersten et al. (2005) criteria for group designs and the Horner et al. (2005) criteria for single-subject designs. Of the 68 studies, none of the 14 group design studies met all of the evaluation criteria and 19 of the 54 single-subject studies met all evaluation criteria. The 19 single-subject studies that met all of the quality indicators addressed the NCTM components of Measurement (*n*=13), specifically the skills of money, purchasing, and time, and Numbers and Operations (*n*=6), specifically the skills of calculations, number identification, and counting. Results of the meta-analysis also showed that systematic instruction with prompt fading procedures, such as constant time delay and least intrusive prompts, and in vivo instruction were found to be evidence-based practices for teaching mathematics to students with significant cognitive disabilities.

Several key ideas emerged from the meta-analysis conducted by Browder et al. (2008). First, there is a great need to expand on the mathematical content taught to students with ASD and moderate/severe ID. There is a plethora of research on teaching functional mathematics to this student population (Browder & Grasso, 1999; Mastropieri, Bakken, & Scruggs, 1991; Xin, Grasso, DiPipi-Hoy, & Jitendra, 2005), but information on teaching academic mathematics directly related to NCTM's five content standards is very limited, and there is currently no research on teaching the CCSSM. There is also a great need to investigate the NCTM standards of Geometry, Data Analysis/Probability, and Algebra. Second, the scope and sequence within *all* five of the content standards needs to be addressed and the magnitude of mathematical learning needs to be considered. Most studies addressing mathematics instructions with students with ASD and moderate/severe ID focused on basic skills and targeted only a few surface-level skills within each NCTM standard. Although students with moderate/severe ID should not be expected to master all of the skills within a standard, skills should be prioritized to ensure the scope and sequence are covered. It is possible to teach more complex problem solving skills, which still have personal relevance, through applications to real-world problems. Finally, there is a need for more instructional methods to teach students with significant cognitive disabilities in the area of mathematics. Although systematic instruction is effective, Browder et al. (2008) noted that some mathematical concepts may require more explicit conceptual demonstrations. In the following sections, instructional practices for teaching mathematics to students with moderate/severe ID are discussed, including systematic instruction and explicit instruction.

Systematic Instruction to Teach Mathematical Content Standards

Systematic instruction with response prompting procedures has been identified as an evidence-based practice for teaching mathematics content to students with moderate/severe ID and has been used in numerous studies teaching functional mathematics skills with an emerging base of research teaching NCTM's content standards (Browder et al., 2008). Systematic instruction can be used to teach both discrete skills and chained tasks (Snell & Brown, 2011). A discrete skill is composed of one response that has a definite beginning and ending and can be counted as correct or incorrect. Mathematical examples of discrete skills include identifying a symbol, labeling a numeral, or matching a numeral to a quantity. A chained task is a series of discrete behaviors that are joined together sequentially to create one task (Gollub, 1977). Mathematical examples of chained tasks include solving an algebraic equation, analyzing a bar graph, and solving a word problem. Three types of systematic instruction that are used to teach mathematics to students with moderate/severe ID include time delay, simultaneous prompting, and the system of least prompts, also called least intrusive prompts.

Time delay is an effective strategy to teach both discrete skills and chained tasks (Collins, 2007; Schuster et al., 1998; Wolery, Ault, & Doyle, 1992). Time delay is a method for transferring stimulus control by systematically increasing the delay interval that students have to make a correct response before the controlling prompt is provided (Snell & Gast, 1981; Terrace, 1963; Touchette, 1971). There are two types of time delay found in the literature, progressive time delay (PTD) and constant time delay (CTD). PTD gradually increases the delay interval by a specified number of seconds (e.g., 0 s, 1 s, 2 s, 3 s, and so on) over subsequent trials; whereas CTD always begins with a 0 s delay for a specified number of trials (i.e., typically one or two) and then increases the delay interval to a specified number of seconds for subsequent instructional trials (Collins, 2007).

Simultaneous prompting also can be used to teach both discrete skills and chained tasks (Morse & Schuster, 2004). In simultaneous prompting, the instructional cue is delivered and the controlling prompt immediately follows, often in the form of a model prompt (Morse & Schuster, 2004; Snell & Brown, 2011). Both prompted and independent correct responses are reinforced. One difference between simultaneous prompting and the other types of systematic instructional strategies is that a probe session is conducted prior to every training session in simultaneous prompting to help determine when to fade prompts (Schuster, Griffen, & Wolery, 1992).

The system of least prompts also has been used to teach discrete skills and chained tasks in mathematics (Ault, Wolery, Doyle, & Gast, 1989; Collins, 2007; Doyle, Wolery, Ault, Gast, & Wiley, 1988). System of least prompts is a method where the instructor delivers the instructional cue and waits for the student to independently respond during the predetermined response interval (e.g., 3 s, 4 s, or 5 s) before providing prompts according to a prompt hierarchy. If no response occurs after the response interval, the instructor delivers the least intrusive prompt from the hierarchy (e.g., verbal prompt). The instructor continues to move through the prompting hierarchy in this manner until the student responds independently (Collins, 2007).

Systematic instruction to teach discrete skills in mathematics. Several studies have demonstrated the effectiveness of systematic instruction on teaching discrete skills in mathematics to students with moderate/severe ID and students with ASD. Skibo, Mims, and Spooner (2011) used a multiple probe across participants design to teach three elementary students with moderate and severe ID to identify numbers 1-5 using the system of least prompts (i.e., verbal, model, physical) and response cards. In this study, the response cards were preprinted cards with numerals and symbols to represent the numerals for students to hold up in order to display their answer to a question presented by the teacher. All three students met mastery (i.e., 11/15 independent correct responses) and were able to maintain the skill for at least one additional probe upon discontinuation of the instruction.

Akmanoglu and Batu (2004) used a multiple probe across behaviors (e.g., three sets of three numerals) replicated across participants design to teach three students with autism, ranging in ages from 6 to 17 years old, to point to numerals using simultaneous prompting. Results showed that all three students acquired the skills of identifying numerals 1-9, maintained the skill for 4 weeks, and generalized to calendar pages with numerals.

Rao and Mallow (2009) used a multiple probe across behaviors (e.g., sets of multiplication facts) replicated across participants design to teach two middle school students with mild and moderate ID to recall multiplication facts using simultaneous prompting. Both students mastered the targeted multiplication facts with 100% accuracy and were able to maintain the skills for a minimum of four additional weekly probes. Students also generalized the skills to a timed paper-and-pencil test. The student with moderate ID required six more training sessions to acquire the 30 multiplication facts and averaged 22 correct facts per 2 min during the timed multiplication test, whereas the students with mild ID averaged 47 correct facts in 2 min.

These three studies demonstrate that systematic instruction can be used to teach discrete mathematics skills with students with ASD or moderate/severe ID. The skills taught were number identification (Akmanoglu & Batu, 2004; Skibo et al., 2011) and recall of multiplication facts (Rao & Mallow, 2009). Although the results of these studies were promising, showing that all participants met mastery and maintained the skills, these skills taught were basic mathematical skills and did not address NCTM or CCSSM standards.

Systematic instruction to teach chained tasks in mathematics. A relatively limited number of studies investigated the effects of systematic instruction on teaching chained tasks in mathematics to students with moderate ID. Jimenez, Browder, and Courtade (2008) used a multiple probe across participants design to teach three high school students with moderate ID to solve algebraic equations using a nine-step task analysis. Students used a concrete representation (i.e., graphic organizer), which included an equation template and a number line, and manipulatives to help solve the problems. The researchers used a 0-s and a 4-s constant time delay to teach students to complete each step of the task analysis. Two students were able to acquire all nine steps to solve the equations independently, and one student was able to master eight out of nine steps when she completed the problems while following the actual task analysis. Additionally, two of the three students generalized the skills to novel materials and to the general education mathematics classroom.

More recently, Collins et al. (2011) used a multiple probe across mathematics tasks replicated across participants design to teach three middle school students with moderate ID how to compute sales tax using an eight-step task analysis for the two students who could not write and an 11-step task analysis for the student who could write. This study focused on teaching skills in three different content areas: language arts, science, and math; however, the specific mathematical skill addressed was teaching order of operations using multiplication and division through computation of sales tax. The researchers used 0-s and a 3-s constant time delay to teach the students to complete each step of the task analysis. The student who could write met the mastery criterion of performing all the steps correctly, whereas the two students who could not write did not meet mastery due to time constraints and the school year ending. This study demonstrated that a student with a moderate ID can learn core mathematics content (e.g., order of operations) while applying it to a functional skill (e.g., computation of sales tax).

Both studies demonstrate that task analytic instruction combined with constant time delay can be used to teach chained skills, such as solving algebraic problems; however, three of the six participants in the studies were not able to master solving the entire chained task (Collins et al., 2011; Jimenez et al., 2008). When problem solving, performing the entire chain to attain correct answers is critical to being successful. On an alternate assessment, students are not given partial credit for steps performed correctly, but are scored on a dichotomous scale of correct or incorrect. More importantly, if the goal is for the student to generalize the skill to real-world settings, it holds little value if the student cannot perform the skill completely with accuracy. Another limitation of these two studies is that the participants were taught how to solve but not necessarily when or how to apply the strategies to real-world situations.

Explicit Instructional Strategies to Teach Mathematical Content Standards

As Browder et al. (2008) noted, some mathematical concepts may require more explicit conceptual demonstrations than can be taught using systematic instruction alone. Explicit instructional strategies, also called direct instruction, have been found effective for teaching mathematics to students who are at risk for academic failure and for students with learning disabilities (Baker, Gersten, & Lee, 2002; Darch, Carnine, & Gersten, 1984; Gersten et al., 2009; Stein, Kinder, Silbert & Carnine, 2006). Explicit instructional strategies consist of the instructor's modeling the targeted behavior(s), guided practice, independent practice, and continuous feedback on skill performance (Stein et al., 2006). This is sometimes referred to as a "model-lead-test" procedure with reinforcement and immediate error correction. Discrimination training may be a component of the instruction, where the student is taught to decide when to and when not to apply the strategy.

Explicit instructional strategies must be well designed and generalizable (Stein et al., 2006). Stein and colleagues (2006) provided several recommendations for designing high quality interventions using explicit instruction, including (a) instruction should link to prior knowledge, (b) skills should be sequenced from easiest to hardest, (c) examples should be carefully selected to represent a wide range of what the student may encounter, and (d) students should be provided with sufficient opportunities for practice to master the content. Despite the moderate to strong effect sizes seen in teaching mathematics using explicit instruction to students who are at risk or those with learning disabilities, explicit instruction has not been widely used to teach students with ASD and moderate/severe ID (Baker et al., 2002; Gersten et al., 2009).

Neef and colleagues (2003) used a multiple baseline across behaviors design to teach one student with moderate ID and one student with mild ID overt precurrent behaviors (e.g., to identify the component parts of story problems, including initial value, change value, operation, and final value) to solve addition and subtraction word problems using explicit instruction. A model-lead-test approach was used. During training (i.e., model), the primary researcher described and modeled five practice problems. During the lead component, the participant was given one completed problem as a model and asked to complete 10 trials. If the student made an error, the researcher modeled and retested the skill. When a participant received 100% correct responses under prompted conditions for two consecutive sessions, he moved to the "probe" phase. During probes (i.e., "test"), the student was given 10 problems and was asked to solve them without additional feedback. Results showed that both students were able to acquire the precurrent behaviors; and once learned, they increased the number of correct solutions found for untrained problems.

More recently, Rockwell et al. (2011) used a multiple probe across behaviors design to teach one female student with autism to solve addition and subtraction word problems using schema-based instruction (SBI) similar to that described by Jitendra, Griffin, Haria, et al. (2007) with students with mild disabilities or those at risk for mathematics failure. SBI consisted of using visual representations (e.g., diagrams), heuristics, and direct instruction. Direct instruction was based off the practices of Gersten, Woodward, and Darch (1986) and included teacher modeling, guided practice, independent practice, and continuous teacher feedback. A heuristic is a problem solving strategy that teaches students steps to approach a variety of word problems. In Rockwell et al. study, the heuristic was the mnemonic "RUNS," which stood for (a) read the problem, (b) use a diagram, (c) number sentence, and (d) state the answer. Discrimination training was also used to help the participant discern among three problem types, including change (e.g., an initial quantity that is increased or decreased to obtain a different ending quantity), group (e.g., two or more smaller quantities that are combined to create a larger ending quantity), and compare (e.g., a larger and smaller quantity that are compared to obtain a difference). The participant met mastery of 100% accuracy for all three problem types. She made two calculation errors in one generalization probe (i.e., word problems with unknowns in initial or medial position) and one maintenance probe, resulting in slightly lower scores during these phases (e.g., average of 5 out of 6 in generalization and 5.67 out of 6 in maintenance); however, the results still showed that she was able to maintain the skills and generalize to novel problems at a relatively high level after the SBI implementation.

Finally, Cihak and colleagues (2006) used a slightly different approach by combining explicit instruction and systematic instruction. The authors used an adapted alternating treatments design to train two groups of three middle school students with moderate ID to withdraw money from an ATM and make purchases using a 12-step task analysis and explicit instruction. The authors compared static picture prompts with video prompts. Students were taught in a small group instruction format using an adapted model-lead-test procedure. During the model component, the teacher acquired students' attention by saying "everybody look" and either displayed the static picture prompt or the video prompt of each step of the task analysis. Then, she verbally stated the behavior seen in the task (e.g., "insert debit card"). During the lead component, the teacher administered the salient cue, "now all," and students repeated the step of the task analysis just observed. The teacher provided specific praise and continued the process through all steps of the task analysis. During the test component, the teacher acquired students' attention by saying "everybody look" and called on one student. She showed either the static picture prompt or video prompt and asked, "What do you do?" She continued through all 12 steps of the task analysis with one student before assessing the other students. During community-based instruction (i.e., generalization probes), least intrusive prompting was used until students made a correct response when completing each step of the task analysis. All students met mastery and maintained the skills at a 2-week follow up. No difference was observed between static picture prompts and video prompts, in that students acquired the skills at the same level and rates. Although this study focused on functional mathematical skills, it adds to the literature by showing that explicit instruction and systematic instruction can be used to teach chained tasks to students with moderate ID.

The three studies described above show that explicit instruction can be effective in teaching more complex, chained mathematics skills to students with mild to moderate ID or ASD; however, these three studies only included one student with ASD and four students with moderate ID. More research is needed before any conclusions can be drawn about using explicit instruction to teach mathematics, especially chained skills, to students with ASD and moderate ID.

Summary

Research on teaching grade-aligned mathematics skills to students with moderate/severe ID, including students who also have a diagnosis of ASD, is emerging as a result of federal legislation requirements; however, more research is still needed, especially with stronger links to teaching the NCTM and CCSSM. As the majority of the nation transitions to the more rigorous CCSSM, there is a greater need to conduct research in mathematics for students with ASD and those with moderate/severe ID in order to see *what* and *how much* this population can learn. There is an even greater need to see if students with ASD and moderate ID can learn higher level mathematics, such as problem solving, which can be applied across standards. Systematic instruction has been used to effectively teach basic mathematical skills to students with moderate/severe ID, but there is still a need for research to address how to teach more complex mathematical skills. Explicit instruction has also shown promises in teaching chained mathematics skills to students with ASD or moderate ID. Combining systematic instruction with explicit instruction is one possibility for teaching more complex mathematical skills, such as word problem solving, with sustained skill demonstration to students with ASD and moderate/severe ID.

Mathematical Word Problem Solving

The National Council of Teachers of Mathematics (2000) states that “problem solving is the cornerstone of mathematical learning” and emphasizes the importance of mathematical competence for all students, as well as the ability to apply mathematical skills to everyday life. The CCSSM continues to place high value on problem solving as a critical mathematical skill and have included it as one of their *Standards for Mathematical Practice*. For students with ASD and moderate ID, problem solving can open up a world of opportunities and can enhance their overall quality of life. Yet, the majority of research for students with ASD and moderate ID to this point has focused on computation versus higher level thinking skills, such as problem solving (Browder et al., 2008). Teaching calculation without problem solving only shows students *how* to solve, but teaching students how to apply these skills prepares them to determine *when* and *where*, which is an important life skill for all students, including students with ASD and moderate ID. There is a great need for development of a curricula to teach higher order mathematics, particularly problem solving, to students with ASD and moderate ID.

Successful problem solving relies on two types of knowledge: conceptual knowledge and procedural knowledge (Jitendra, 2008). Conceptual knowledge entails comprehending the text and modeling the problem situation. Procedural knowledge denotes finding the solution. There are many cognitive processes occurring when solving word problems, such as comprehending the problem text, creating a mathematical representation of the problem, developing a plan to solve, executing the plan, and interpreting the solution. These can be challenging for students with ASD and moderate ID who have working memory, language, and attentive behavior deficits (Jitendra, Dupuis, et al., 2013).

The linguistic requirements of mathematical word problems create difficulties for many students, particularly students with ASD as language impairment is one of the defining characteristics of autism (Rockwell et al., 2011). The linguistic difficulty of word problems are related to the way in which the problems are worded such as length, the grammatical and semantic complexity, mathematical vocabulary, and the order key information appears in the text (Fuchs & Fuchs, 2007). The linguistic aspect of problem solving is especially challenging for students with ASD and moderate ID, who tend to have poor reading comprehension skills and may have difficult reading with fluency or who may be nonreaders.

Problem solving also relies heavily on executive functioning, such as planning, organizing, switching between tasks or strategies (i.e., cognitive sets), and working memory (Hughes, Russell, & Robbins, 1994). Research shows that students with ASD have difficulty with executive functioning tasks that require flexibility and planning, both of which are essential to problem solving (Bull & Scerif, 2001). Students with ASD and moderate ID have difficulty taking information from word problems and putting it into their working memory, which leads to ineffective problem solving. They tend to have difficulty retaining mathematical strategies in their long-term memory and knowing when to use them to solve problems. These deficits also prevent students with ASD and moderate ID from identifying relevant and irrelevant information in word problems.

Both linguistic requirements and executive functioning can negatively impact mathematical functioning (Donlan, 2007). For students with ASD and moderate ID, challenges such as limited background knowledge and experiences, weak early numeracy skills and lack of fluency in mathematics, and difficulty with self-regulation further complicate problem solving (Donlan, 2007). Students with disabilities in general, but especially students with ASD and moderate ID, need high quality, explicit instruction with repeated opportunities for practice in order to be effective mathematical problem solvers (Darch et al., 1984; Jaspers & Van Lieshout, 1994). Traditional instructional strategies commonly found in mathematical textbooks do not provide the necessary level of support for students with ASD and moderate ID.

Two traditional approaches to problem solving that appear frequently in textbooks are: George Pólya's four-step model, or a derivative of it, and the key word strategy. George Pólya (1945) developed one of the first heuristic approaches to problem solving using a four-step model (i.e., understand the question, devise a plan, carry out the plan, and look back and reflect). This approach is still commonly used in textbooks today; however, it does not lead to improvement in students' word problem solving for students with learning disabilities or students who are at risk for mathematics failure (Jitendra & Star, 2011). According to Jitendra and Star (2011), these steps are too general, and students with disabilities often need a much more systematic strategy and explicit approach to aid in solving word problems. Another common approach to teaching students how to solve word problems is the key word approach. In this approach, students are taught to identify superficial cues or key words (e.g., *in all*, *altogether*, *total* indicate an addition problem; *left*, *remain*, *difference* indicate subtraction) in a word problem in order to select the correct operation and solve. Jitendra and Star discussed three main problems with using this strategy. First, it does not teach conceptual understanding of the word problem and its underlying structure, so students are less likely to be able to generalize the strategy to novel problems. Second, it leads to systematic errors, where the key word may lead the student to solve the problem using the wrong operation. Finally, key words are not always included in word problems, so students are unable to solve the problems.

Despite the traditional instructional approaches still being used widespread in classrooms today, a plethora of research exists on more effectively teaching problem solving to students with learning disabilities and those who are at risk for mathematical difficulties (Case, Harris, & Graham, 1992; Gersten et al., 2009; Xin & Jitendra, 1999). Gersten et al. (2009) conducted a meta-analysis to synthesize the findings from 42 interventions which improved mathematics performance of students with learning disabilities. Word problem interventions which included general problem solving heuristics, multiple-strategy instruction, peer-assisted instruction, direct instruction, and instruction using visual representations were found to be effective. Among the interventions, those that used visual representations produced the largest effect sizes, particularly those that included visual representations paired with heuristics and direct instruction. Other research has also provided recommendations for improving problem solving in students with disabilities, including using self-instructional strategies, aiding with the reading requirements and reading comprehension needs when problem solving, making problems concrete, and removing extraneous information (Hickson et al., 1995; Mastropieri, Scruggs, & Shiah, 1997; Polloway, Patton, Epstein, & Smith, 1989). One effective strategy that addresses the weaknesses of traditional approaches is schema-based instruction, which is discussed in detailed in the following section.

Schema-based Instruction

Schema-based instruction (SBI) uses a conceptual teaching approach which combines mathematical problem solving and reading comprehension strategies (Jitendra, 2008). SBI focuses on conceptual knowledge by enhancing comprehension to ensure students can effectively create representations of the problem situation, thus developing an understanding of the underlying problem structure. This step is imperative to successful problem solving because most errors in word problem solving are actually a result of students misunderstanding the problem situation, rather than computation errors (De Corte & Verschaffel, 1981). In SBI, students learn to understand the semantic structure of word problems through text analysis in order to identify quantitative relations between sets or actions between sets, and then learn to create a visual model of these relationships (Jaspers & Van Lieshout, 1994). From this mathematical representation, or model, students can select the correct operation to solve. The procedural rules for solving problem types are directly related to the underlying concepts. For example, rather than just teaching students to add when the total is unknown (i.e., the procedural rule), SBI would teach a rule that relates the concept to the algorithmic procedure (e.g., two small parts are combined to create a whole, or "part-part-whole;" Jitendra, 2008).

Problem type and schematic diagrams. There are three main types of arithmetic word problem situations (i.e., schemata) that have been identified; these are *group*, *change*, and *compare* (Marshall, 1995). In SBI, students are explicitly taught to identify the structural features of the problem (e.g., part-part-whole) in order to identify the problem schemata (e.g., group problem). Visual representations go far beyond simply a pictorial representation of the information in the word problem. These representations, called schematic diagrams, provide students with a way to visually organize and summarize the information from the word problem so that it is concrete and shows the relationship among numbers in the problem. Schematic diagrams help students develop a deep understanding of the problem and aid in the transfer of learning to novel problems (Zahner & Corter, 2010). Known values in the word problem are written into their corresponding parts of the selected schematic diagram, and the unknown value are either left blank or a question mark is placed in the diagram to indicate the unknown.

Group schema (Figure 2) involves two or more small groups combined to make a larger group, emphasizing the part-part-whole relationship. For example, *Sarah earned 3 tickets at the carnival. Jose earned 5 tickets. How many tickets did they earn?* Three and five tickets represent the “part” relationships and the unknown quantity (i.e., tickets in all) represents the “whole.”

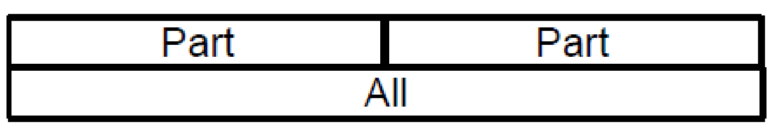

Figure 2: Group diagram adapted from Willis and Fuson (1988).

Change schema (Figure 3) involves a dynamic process, where an initial quantity is either increased or decreased over time to result in a final quantity. An example of a change increase problem is shown below: *Marcus earned $2 for sweeping the kitchen. He earned $5 more for mowing the lawn. How much money did Marcus earn?* An example of a change decrease problem is shown below: *Marcus raked 5 piles of leaves. He bagged 2 piles of leaves. How many more bags does he have left to bag?* In both examples, Marcus starts with an initial set ($2 and 5 piles). The initial set was changed by adding more or taking away from the set ($5 and 2 piles), resulting in a final amount which is unknown. The change decrease problem also illustrates one issue that can result in incorrect operation when using the key word strategy. Specifically, the question uses both key words “more” and “left,” which usually denote addition and subtraction, respectively; however, the problem requires the student to subtract to solve.

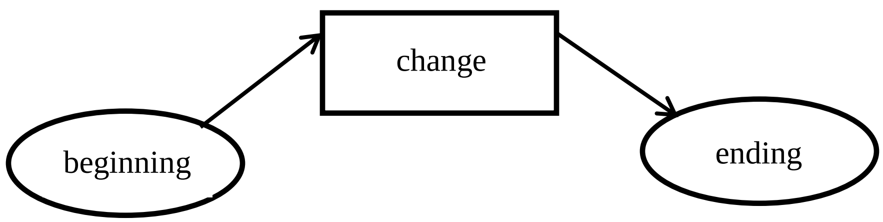

Figure 3: Change diagram adapted from Jitendra and Hoff (1996).

The compare schema (Figure 4) involves comparing two differing sets that are related in some way, and requires finding the difference between the sets, regardless of whether the question is asking “how many more” or “how many fewer.” Here is an example: *Sam ordered 5 chicken nuggets. His brother, Drew, ordered 10 chicken nuggets. How many more nuggets did Drew order than Sam?* The two numbers being compared are the number of chicken nuggets Sam ordered (5) and Drew ordered (10) and the relation between these two sets is the difference of 5.

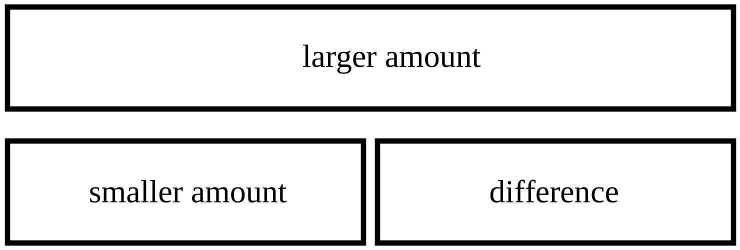

Figure 4: Compare diagram adapted from Willis and Fuson (1998).

All of these examples displayed the unknown quantity in the final position of a number sentence. More complex problems may place the unknown in the initial or medial position, or include extraneous information (e.g., information that is irrelevant to the development of the number sentence or to the problem solving) in the word problem.

Key components of SBI. SBI has four main components, including: (a) identifying the underlying problem structure, using visual representations known as schematic diagrams; (b) explicitly teaching problem solving through the use of a heuristic (often taught through the use of a mnemonic); (c) using explicit instruction to teach the four-step problem-solving heuristic (i.e., problem schema identification, representation, planning, and solution); and (d) delivering metacognitive strategy knowledge instruction, which includes activities such as analyzing the problem, self-monitoring of strategy use, and checking the outcome for accuracy. Visual representations help students organize key information from the problem. Students can be taught to organize information using a schematic diagram and show their solution using a mathematical equation (Griffin & Jitendra, 2009). Heuristics are explained at the end of the paragraph as they serve a dual purpose as a metacognitive strategy. Explicit, teacher-delivered instruction is essential to SBI. Specifically, teachers initially model problem solving by demonstrating how to analyze text in the word problem to find key information and represent it in schematic diagrams. Rules and procedures are explicitly explained. According to Jitendra (2008), in SBI, students are taught to identify the problem type first and fill in the corresponding schematic diagram, using story situations with all known values. This is known as schema induction. The purpose of doing so is to teach students explicitly to analyze the story situation structure rather than acting impulsively, selecting numbers, and computing (Jitendra, 2008). Schema induction reduces the working memory demands and cognitive load required when problem solving (Rockwell et al., 2011). Once students have shown mastery identifying the problem type, selecting the corresponding schematic diagram, and filling in the known and unknown values, they are taught to solve the problem. They are also taught to represent the schema in an equation (also referred to frequently as a number sentence in SBI). Students practice these skills repeatedly within each problem type, as well as with mixed problem types once they have learned all types. For metacognitive strategy knowledge, students are taught to use think-alouds to explain their reasoning (e.g., “Why is this a *change* problem?” It is a *change* problem because there was an initial set, a change set, and an ending set.). In addition, students are given a four-step strategy checklist with the heuristic to help transition from teacher-led instruction to student-led instruction. Jitendra et al. (2009) uses a specific heuristic of *FOPS* (e.g., F: Find the problem type, O: Organize the information in the problem using the schematic diagram, P: Plan to solve the problem, and S: Solve the problem). Rockwell et al. (2011) used a shortened version of Jitendra’s heuristic, namely *RUNS* (e.g., R: Read the problem, U: Use a diagram, N: Number sentence, and S: State the answer) with a student with autism and mild ID.

Effectiveness of SBI

Numerous studies have shown that students with learning disabilities can be taught problem solving using SBI both at the elementary level and at the middle school level (Jitendra, DiPipi, & Perron-Jones, 2002; Jitendra, Hoff, & Beck, 1999; Xin, Jitendra, & Deatline-Buchman, 2005; Xin & Zhang, 2009). Some research has also shown that the use of schematic diagrams can be faded, so students gradually transfer their skills of using a schematic diagram to using mathematical equations to represent the structure of a word problem, known as schema-broadening instruction (Fuchs et al., 2009; Fuchs et al., 2008). Xin, Wiles, and Lin (2008) further built on SBI by using word problem story grammar to enhance problem solving in elementary students with mathematics difficulties.

Although the research on SBI is very promising for students with learning disabilities and students who are at risk for mathematical disabilities, very little research exists on using SBI with students with ASD, and even less exists on students with moderate ID. The following sections will provide reviews of the available literature on SBI for students with ASD and students with moderate ID.

SBI for students with ASD. Rockwell and colleagues (2011) examined the effects of SBI to teach all three types of addition and subtraction word problems (i.e., combine, change, and group) to one female student with autism and mild ID using a multiple probe across behaviors (problem type) design. Two dependent variables were measured, including practice sheets which were used as a formative assessment during training phases, and problem-solving probes which were used to measure treatment effects. Scripted lessons were used for each instructional session. First, students were taught a four-step heuristic for problem solving, *RUNS* (e.g., R: Read the problem, U: Use a diagram, N: Number sentence, and S: State the answer). Next, each problem type was introduced one by one. The student was shown a story problem with all quantities filled-in to facilitate schema induction. Direct instruction (i.e., teacher modeling, guided practice, independent practice, and continual feedback) was used to teach the salient features of problem types. Then the student was asked to sort the problems into categories as belonging or not belonging to the problem type being taught. Once the student was able to discriminate problem type, she was taught to solve the problems of that type where the final quantity was the unknown. During generalization, an instructional session was given on using algebraic reasoning to solve problems of any problem type with unknown quantities in the initial or medial position. The student achieved perfect scores (6 out of 6 possible points) for all three problem types. During generalization, she achieved perfect scores for all three sessions of each problem type with the exception of the change problem type, in which she made a computation error which resulted in her earning 3 out of 6 possible points for the session. At a 6-week follow-up data collection session, the student was able to maintain perfect scores for the group and change problem types, and averaged 5 out of 6 possible points for the compare problem type.

Rockwell (2012) replicated her 2011 study (Rockwell et al., 2011) with one 7-year-old male and one 12-year-old male with ASD using a multiple baseline across behaviors (problem types) design replicated across students. Neither student had a reported IQ score; however, both students attended general education mathematics classes with the support of a paraprofessional. In this study, Rockwell added one generalization measure, which included irrelevant information in the generalization probe word problems. Both students achieved perfect scores for all three problem types. One student continued to receive perfect scores during generalization and maintenance probes. The other student received perfect scores during generalization but at the 8-week follow-up probe, his data dropped slightly but still remained above pre-generalization training performance.

Both studies expanded the SBI research by including students with ASD and showed that students with ASD can master problem solving, maintain it, and generalize to novel problem types through SBI. However, the students with ASD in both studies all had relatively higher intellectual abilities.

SBI for students with moderate ID. Only one study to date has used SBI to teach problem solving to a student with moderate ID. Neef and colleagues (2003) taught a 19-year-old man with an IQ of 46 to solve change problem type problems by teaching precurrent behaviors. Four different training phases were conducted in which the student was taught to identify precurrent behaviors (i.e., component parts of the word problem) including the initial set, the change set, key words to identify the operation, and the resulting set. The unknown for each problem could be in any location (i.e., the initial set, the change set, or the resulting set). Within each training phase, supports and prompts were strategically faded. First, the targeted component was always known and the researcher prompted student responses. Next, the targeted component was randomly known in approximately half of the problems and the researcher continued to prompt responses. Finally, the targeted component was randomly unknown and no prompts were provided. One schematic diagram was used for all problems. Probes consisted of 10 word problems and were given after the student reached 100% correct responses for two consecutive sessions under the unprompted condition. The results showed that teaching precurrent behaviors was successful in yielding accurate problem solving. There are several important aspects to note in this study that offer implications and needed adaptations in SBI for students with moderate ID. First, in this study, traditional SBI was broken into much smaller steps by teaching precurrent behaviors to a student with moderate ID across four training phases. Second, it took the student many sessions to learn to solve one problem type (i.e., 26 for initial set, 35 for change set, 17 for operation, and 2 for resulting set). Third, a strategic prompt fading procedure was used in each phase to aid in the transfer from teacher-led instruction to student-led instruction. Finally, all problems were read aloud to the student.

The study by Neef et al. (2003) offers some directions in teaching word problem solving through SBI with adaptations to students with moderate ID. Additional strategies may be needed to support students with ASD and moderate ID. First, problems need to be simplified in reading level and extraneous information needs to be removed to accommodate the difficulty in reading comprehension of students with ASD and moderate ID. Read alouds offer necessary support for students with ASD and moderate ID, especially those who are nonreaders (Browder, Trela, et al., 2012; Neef et al., 2003). Story grammar instruction and story mapping are needed to support comprehension (Xin et al., 2008). Second, some precurrent skills may need to be taught to students with ASD and moderate ID, such as common vocabulary, symbol use, and problem structure (Neef et al., 2003). Third, manipulatives may be needed to represent the problem for students who lack fact recall (Bouck et al., 2014). Task analytic instruction with system of least prompts has been found to be effective at teaching mathematics to students with ASD and moderate ID and can be incorporated into SBI (Browder et al., 2008). Rockwell et al. (2011, 2013) and Neef et al. (2003) paved the way for teaching problem solving to students with ASD and moderate ID, but much more research is needed with this population.

Summary

SBI teaches students to analyze and identify the word problem structure and type prior to solving. Because it teaches conceptual understanding of problem solving, it is more effective than traditional approaches such as using keywords which are often found in textbooks and used in general education mathematics classrooms. SBI incorporates several instructional strategies which have shown promise for students with disabilities, including: (a) explicit, teacher-delivered instruction; (b) reading comprehension strategies such as read alouds, story grammar instruction, and story mapping; (c) visual diagrams known as schemata; and (d) metacognitive strategies, such as heuristics (also known as mnemonics), and self-monitoring strategies, such as checklists. Because SBI reduces working memory demands and cognitive load and incorporates many research-based strategies effective for teaching students with ASD and moderate ID, it is a promising strategy to use to teach problem solving to this population with some adaptions (e.g., embedding systematic instruction).

Computer-Assisted Instruction and Computer-Based Video Instruction

Federal mandates requiring students with disabilities to receive access to the general curriculum create a great need to ensure student learning in academic content for all students with disabilities (Ramdoss et al., 2011). Limited information, however, is available on effective strategies for teaching academic content to students with ASD and moderate/severe ID (Pennington, 2010). Research suggests that computer-based technologies may enhance access to the general curriculum by removing barriers that students with disabilities face when interacting with traditional materials (Ketterlin-Geller & Tindal, 2007). Students with ASD especially may benefit from the use of computer-based video technologies because it augments students' visual strengths (Quill, 2000). Research also shows that students prefer computer instruction over conventional teacher instruction (Moore & Calvert, 2000). This section will include a review of the theoretical framework behind computer-assisted instruction (CAI) by discussing B. F. Skinner's conceptualization of programmed instruction (Skinner, 1954). In addition, it will include a review of the existing literature on using CAI and CBVI, which utilizes the evidence-based practice of video modeling, to teach academics to students with ASD and ID. Finally, it will include discussion of present CAI literature with embedded SBI for teaching students with high incidence disabilities to find recommendations to guide the development of the intervention in this study.

Programmed Instruction as the Foundation of CAI

Computer-assisted instruction (CAI) is a form of instructional technology, also called instructional design and technology (Lockee et al., 2008). According to Lockee et al. (2008), the terms of CAI, instructional technology, and instructional design and technology are perhaps better labeled as "programmed technologies," which they defined as "process-based methods and approaches to support learning and instruction, often represented in the form of algorithms and implemented in computer software " (p. 188). The term, "programmed technologies," is based on B. F. Skinner's conceptualization of programmed instruction (PI) for which he developed the Teaching Machine, a mechanical device, in response to the decline in the quality of education in American schools in the 1950s (Lockee et al., 2008). Skinner felt that schools relied heavily on aversive stimulation, that students were presented with too much information at once, and that teachers had little understanding of the contingencies of reinforcement (McDonald, Yanchar, & Osguthorpe, 2005). In response, Skinner proposed a systematic plan for learning which presented information in small steps, with high rates of reinforcement, and fewer learning errors (Lockee et al., 2008).

Programmed instruction was based on Skinner's principle of operant conditioning, in which successive approximations to a target behavior are reinforced (Lockee et al., 2008; McDonald et al., 2005; Skinner, 1954, 1986). Skinner incorporated the principles of behavior into the design of the Teaching Machine to increase efficiency in teaching (i.e., teach more in less time). For example, the Teaching Machine was designed to shape responses by reinforcing correct responses immediately and to only advance slides following correct answers, which led to near perfect performances. He also incorporated priming, prompting (e.g., stimulus-context cues), and transfer of stimulus control by fading and delaying the prompts into his Teaching Machine (Lockee et al., 2008). In addition, Skinner felt it was critical to sequence the material in small steps, which were presented in a progressive fashion so that subsequent frames built on previous learning (McDonald et al., 2005; Skinner, 1986). By using the aforementioned strategies within the Teaching Machine, students were able to progress through the material at their own rate and with a high degree of success.

According to McDonald and colleagues (2005), PI was highly desired in the mid to late 1950s and early 1960s; however, there was a decline in the use of PI in the 1960s due to several factors. First, teachers were afraid that PI was being implemented to replace them, which was never Skinner's intention (McDonald et al., 2005; Skinner, 1986). Skinner developed PI to be used in conjunction with other teaching methods so teachers would be free to teach more content. Second, many critics felt PI was too rigid and could not be easily adapted or modified for individual needs (McDonald et al., 2005). Unlike the computers of today, these machines were bulky, expensive, and had to be reprogrammed entirely to make changes. Finally, in the early stages of PI, the use of overprompting (i.e., leading students to the correct answer every time) resulted in a loss of motivation and interest for students because they knew the machine would ultimately give them the answer. Many years later and after much research on prompting in the field of behaviorism, Skinner (1986) suggested reinforcement of student responses on a variable ratio schedule as a solution to increase motivation. Despite the demise of PI, the principles learned from PI have shaped the development of programmed technologies today (Lockee et al., 2008).

Today's CAI incorporated many of the same principles of PI, including presenting materials in small and sequenced steps, providing immediate feedback, using conditioned reinforcers, autonomy of instruction, and minimizing the rate of error in responses (Lockee et al., 2008; McDonald et al., 2005). In addition, much improvement has also been suggested to avoid the problems encountered in PI. First and foremost, CAI should be integrated with other empirically-based teaching strategies within the overall design of the technology in order for learning to occur (Babbitt & Miller, 1996; Seo & Bryant, 2009). Simply adding technology, which delivers the instruction, is not sufficient for learning to take place. Second, CAI has emerged to address individual learning needs, especially by using authoring software or programs which serve as templates that teachers or researchers can adapt and design specifically for individual learning needs (Higgins & Boone, 1996; McDonald et al., 2005). Third, principles of self-determination must be embedded within the instructional design, such as active student participation, decision making, and appropriate feedback to provide support, rather than controlling student responses, and to improve motivation and maintain student interest (Lockee et al., 2008; Seo & Bryant, 2009). Finally, the success of the CAI program should be evaluated throughout implementation (Lockee et al., 2008). The findings from Skinner's pivotal work in PI and the aforementioned recommendations provide the basis in the design of the current study.

Computer-Assisted Instruction

Computer-assisted instruction (CAI) has been shown to be effective at teaching academics, specifically in the content area of English and language arts (e.g., reading, writing, and spelling), to children with ASD (Bosseler & Massaro, 2003; Knight et al., 2013; Pennington, 2010; Whalen, Liden, Ingersoll, Dallaire, & Liden, 2006). CAI is defined as using the computer with multimedia (e.g., text based processes combined with graphics, animation, sound, voice, music) to deliver instruction (Higgins & Boone, 1996; Seo & Woo, 2010). There are numerous benefits to using CAI with children with ASD and ID. Some comparative studies have shown that students with ASD and ID learn better through computer-delivered instruction than via teacher-delivered instruction (Heimann, Nelson, Tjus, & Gillberg, 1995; Hitchcock & Noonan, 2000; Moore &

Calvert, 2000; Williams, Wright, Callaghan, & Coughlan, 2002). In addition, children with ASD are less disruptive, more attentive to the task at hand, have higher response rates and motivation, exhibit more intentionality and problem solving, and are more communicative when interacting with computer software (Chen & Bernard-Opitz, 1993; Hitchcock & Noonan, 2000; Moore & Calvert, 2000; Soares, Vannest, & Harrison, 2009; Tjus, Heimann, & Nelson, 2001; Whalen et al., 2006; Williams et al., 2002). CAI also ensures correct implementation of instructional strategies, such as prompting strategies (Kodak, Fisher, Clements, & Bouxsein, 2011; Whalen et al., 2006), which is not always the case with teacher-delivered instruction. For example, Kodak and colleagues (2011) found that therapists delivering instruction using a 5-s constant time delay prompting procedure had poor procedural integrity (<60%), whereas procedural integrity with CAI was 100%. Further, CAI was done with minimal training that only required no more than 5 min of reading a written protocol. Kodak and colleagues suggested additional benefits to CAI in that the instruction: (a) could be delivered in one setting and generalized to another; (b) can reduce the amount of time needed for organization and presentation of materials because everything is stored in a database; (c) can reduce the number of staff needed to implement instructional strategies; (d) allows teachers to randomize the order and position of content presentation; (e) can increase the number of instructional opportunities for students; and (f) can be implemented by personnel other than teachers, such as paraprofessionals. Although CAI is not intended to replace teacher-delivered instruction entirely, these collateral effects may make CAI an optimal choice of instruction for teaching mathematical skills, such as problem solving, to students with ASD and ID.

Commercially available CAI programs. There are numerous commercially available programs for students with ASD (e.g., *Discrete Trial Trainer*, *TeachTown Basics*, *Team Up with Timo*). Many of these programs are built upon principles of applied behavior analysis (ABA) and consist of drill-and-practice techniques. Most programs address receptive identification, matching, and sorting, all of which are simple, discrete skills (Whalen, Massaro, & Franke, 2009). Two companies, Animated Speech Corporation and TeachTown have developed empirically supported CAI programs, *Team Up with Timo* and *TeachTown: Basics*, respectively, which have been used with children with autism. The *Team Up with Timo* CAI programs use an animated tutor with synthesized speech, Baldi, to teach vocabulary and grammar using pictures. Timo greets each child by name and provides feedback and reinforcement. This program can be individualized by selecting the exercises to include the reward selection and captioning. There are three products of Timo: *Team Up with Timo: Vocabulary*, *Team Up with Timo: Lesson Creator*, and *Team Up with Timo: Stories*. The effects of *Team Up with Timo: Vocabulary* have been evaluated with students with ASD and showed that students learned new vocabulary, grammatical constructs, and concepts, and they retained the skills over time (Bosseler & Massaro, 2003; Massaro & Bossler, 2006). The *Team Up with Timo: Lesson Creator* allows teachers and parents to develop personalized vocabulary lessons using their own pictures. The *Team Up with Timo: Stories* promotes comprehension through story-based activities, such as retelling a story and answering comprehension questions. To date, *Lesson Creator* and *Stories* have not been empirically evaluated with students with ASD.

TeachTown: Basics incorporates the principles of ABA, and is designed specifically for students with ASD. Students are taught skills from four domains (i.e., receptive language, social understanding, life skills, and academic/cognitive skills) in a discrete trial format with a within-stimulus prompting procedure, where distracters fade in and out to help students respond correctly. Two different concepts are taught within each trial and multiple exemplars are used for each concept to promote generalization. Instructions vary slightly from trial to trial so students have to attend. Correct responses are reinforced immediately with verbal praise and graphics and on a variable ratio 3 schedule with a 15- to 45-s animated reward game. The pace of instruction is individualized based on the student's needs. One study using *TeachTown: Basics* showed that students made significant gains from pretest to posttest; however, 7 out of 22 students in the treatment group never met mastery (Whalen et al., 2010).

These commercially available programs demonstrate that there are some customizability options, such as pacing, exercise selection, and rewards; however, they are limited in teaching core academic content, especially areas other than English language arts. Furthermore, these programs are not linked to the CCSSM, and they do not teach higher order thinking skills such as problem solving.

Authoring software CAI programs. An alternative to commercially available CAI programs are authoring software CAI programs where teachers can individualize the instructional programming for specific student's needs using software that serves as a template for designing the instruction (Higgins & Boone, 1996). Authoring software CAI programs have many benefits, such as giving teachers and researchers the flexibility to individually design lessons for their students, select the content, and embed evidence-based and research-based strategies to teach the content. There are many types of authoring software available, ranging from those that are widely available to the public such as Microsoft PowerPoint® to programs available with a contract or license (e.g., Hyperstudio®, Vizzle®, SMART Notebook®). There are pros and cons to both types of programs. The widely available programs that come with most PC or Macintosh computers have wide accessibility and compatibility but require users to create the program from scratch, embedding their own instructional strategies, and can be very time consuming. On the contrary, the authoring software programs that have been created by developers often are costly, but already have templates with the instructional strategies included so users can simply create lessons by inputting desired materials in the templates. Regardless of the specific authoring program selected, users can control the content that goes into the authoring software, as well as the instructional strategies that are important for individualization to meet each student's need (e.g., reinforcers and reinforcement schedule). These benefits are not available when using commercially available software programs.

To ensure the adequacy of CAI programs for students with disabilities, Higgins and Boone (1996) established the following guidelines for creating individualized CAI programs. First, the individualization must consider the child's language needs (i.e., amount of verbal language incorporated into the program) and academic needs (i.e., incorporating skills the student has not yet mastered). Additional modalities that may enhance students' academic learning, such as video, sound, and graphics must be considered. Second, the individualized CAI program needs to include maintenance of new information (i.e., opportunities for repeated practice and embedding mastered tasks within new learning tasks), plans to promote generalization (e.g., training multiple exemplars and settings), and incorporate strategies to increase independent responding (i.e., making it very clear that the child's behavior directly correlates with the consequence on the computer screen). Third, the CAI program should embed components to maintain student motivation (e.g., selecting types of reinforcement, using schedules of reinforcement), should be age appropriate (e.g., selecting age-appropriate pictures and other stimulus materials), and embed social skill development when appropriate. Finally, teachers or researchers must predict and control for any idiosyncratic learning habits that may interfere with the student's learning (e.g., varying sounds and pictures so the student cannot perseverate on particular items).

Research on CAI with academics. Many of the studies using CAI have focused on teaching discrete skills, such as picture, object, and symbol identification (Bosseler & Massaro, 2003; Chen & Bernard-Opitz, 1993; Clark & Green, 2004; Hetzroni, Rubin, & Konkol, 2002; Hetzroni & Shalem, 2005; Kelly, Green, & Sidman, 1998; Reagon, Higbee, & Endicott, 2007; Simpson & Keen, 2010; Sugasawara & Yamamoto, 2007; Whalen et al., 2010). In these studies, the computer presented targeted skills via some form of interactive multimedia. For example, Simpson and Keen (2010) successfully taught three preschool-aged students with ASD, using Microsoft PowerPoint®, which incorporated Boardmaker® symbols projected on an interactive whiteboard, to identify graphic symbols in order to communicate during interactive songs. Although these studies suggest positive effects of CAI programs for most students with ASD, only a few studies have focused on teaching students with ASD and ID more complex academic skills using CAI.

A review of the literature shows that recent studies on CAI have targeted more complex literacy skills such as reading comprehension (Basil & Reyes, 2003; Chen, Wu, Lin, Tasi, & Chen, 2009), sight word identification (Bosseler & Massaro, 2003; Coleman-Martin, Heller, Cihak, & Irvine, 2005; Hetzroni & Shalem, 2005; Mechling, Gast, & Langone, 2002), and decoding and categorization (Whalen et al., 2010). Four CAI studies have focused on spelling (Kinney, Vedora, & Stromer, 2003; Schlosser, Blischak, Belfiore, Bartley, & Barnett, 1998; Schlosser & Blischak, 2004; Whalen et al., 2010), and only two studies have focused on more complex writing skills, including constructing and writing sentences (Basil & Reyes, 2003; Yamamoto & Miya, 1999).

In a literature review of 29 studies using CAI to teach academic skills to 142 individuals with ASD, Knight et al. (2013) found a variety of instructional strategies incorporated into the design of CAI including differential reinforcement (n = 10), error correction and feedback procedures (n = 15), delayed prompting procedure (n = 5), stimulus prompting and/or stimulus fading (n = 15), response prompting procedures (n = 4), simultaneous prompting (n = 1), reinforcement for correct responses (n = 11), and generalization training (n = 3). One study (i.e., Chen et al., 2009) did not describe any component of the CAI intervention. Despite the integration of instructional strategies with sound empirical bases in these studies, only four of the 29 studies (i.e., Hetzroni & Shalem, 2005; Hetzroni et al., 2002; Mechling et al., 2002; Pennington et al., 2012) met the acceptable quality indicators according to the Horner et al. (2005) criteria for single-subject designs and the National Secondary Transition Technical Assistance Center (NSTTAC) criteria (Test et al., 2009). No group design studies met the Gersten et al. (2005) criteria for group and quasi-experimental designs. This finding suggests that there was a moderate level of evidence for considering CAI as an evidence-based practice for teaching academics, specifically reading skills, to students with ASD. Knight et al. (2013) note that more research with sound research designs is needed to evaluate the effectiveness of CAI on teaching academic skills, especially in content areas other than reading. Further, this literature review indicates that there is not a clear set of research-based instructional strategies emerged from the 29 reviewed studies to be essential components for the design of CAI, which also is an area for future research.

Some studies included in Knight and colleagues' (2013) literature review examined the use of commercially-available software programs (Basil & Reyes, 2003; Bosselor & Massaro, 2003; Whalen et al., 2010), whereas other researchers and teachers were able to use readily available authoring software programs available on the computer (Coleman-Martin et al., 2005; Kinney et al., 2003; Yamamoto & Miya, 1999) and authoring software programs created by developers (Hetzroni & Shalem, 2005; Mechling et al., 2002) to achieve the same results. For example, Bosseler and Massaro (2003) used the commercially-available software program, namely *Baldi*, to target receptive identification of vocabulary words. This software used a 3D animated character to provide a smile or frown as feedback for students' correct or incorrect responses. Coleman-Martin et al. (2005) taught the same skill (i.e., receptive identification of vocabulary words) but used the Microsoft PowerPoint® program, which followed a model-lead-test approach and provided embedded feedback in the form of colorful pictures and audio praise. In another example, Basil and Reyes (2003) used the software, *Delta Messages*, delivered via a Macintosh computer, which used animations with digitized speech to teach two students with ASD to create sentences about the animations observed. Likewise, Yamamoto and Miya (1999) used a complex matrix training approach delivered via a researcher-developed program on a Macintosh computer to teach three elementary students with ASD to use trained stimuli (e.g., three subjects, three objects, three verbs) to compose sentences. The students were assessed on their ability to generalize to untrained stimuli (e.g., 24 words) and compose sentences with correct sentence structure (e.g., appropriate particle placement in the Japanese language). All students showed growth in their ability to create sentences, using the untrained stimuli, with correct sentence structure. Findings from these studies provide important implications for practitioners in that expensive, commercially available CAI software is not always required in order to teach academic skills and that software widely available in classrooms can be used to provide positive academic outcomes in students.

Computer-Based Video Instruction

CAI interventions that embed actual videos within the intervention are referred to as computer-based video instruction (CBVI). CBVI uses the evidence-based practice of video modeling (VM) within the computer program to explicitly demonstrate and teach targeted skills (Bellini & Akullian, 2007). VM has been shown to be an effective median for making positive behavior changes in individuals with ASD, and it has been shown to result in rapid skill acquisition, maintenance of skills over time, and generalization of skills (Bellini & Akullian, 2007). CBVI includes the principles of programmed technologies (Lockee et al., 2008) and has all of the advantages of CAI, such as the ability to include evidence-based and research-based instructional practices, to individualize, to promote independent responding, and to maintain motivation (Higgins & Boone, 1996; Mechling, 2005; Ramdoss et al., 2011). CBVI also has the ability to model targeted behaviors through the VM component. It incorporates observational learning and imitation, the basis of which roots from Bandura's social learning theory (Bandura, 1977; Rayner, Denholm, & Sigafoos, 2009). Many researchers believe that CBVI and VM are effective because they pair learning a new targeted skill or behavior with the highly preferred activity of watching videos (Bellini & Akullian, 2007; Delano, 2007; McCoy & Hermansen, 2007; Shukla-Mehta, Miller, & Callahan, 2010). CBVI and VM also provide learners with the opportunity to acquire skills through social models, but without the face-to-face interaction which may cause increased anxiety in some individuals with ASD (Sherer et al., 2001). Finally, CBVI and VM have the ability to reduce attention to irrelevant stimuli, to focus on the most pertinent aspects of the behavior being modeled, and to reduce the amount of verbal language to essential language only (Bellini & Akullian, 2007; Delano, 2007; McCoy & Hermansen, 2007; Sherer et al., 2001; Shukla-Mehta et al., 2010).

One of CBVI's greatest features is the ability to promote generalization by programming common stimuli and training multiple exemplars (Mechling, 2005; Stokes & Baer, 1977). Although plans for promoting generalization can be included in CAI, the VM component of CBVI provides teachers or researchers with the ability to portray real-world scenarios, making instruction much more meaningful for individuals with ASD who tend to be visual learners and have difficulty with generalizing skills to new settings, materials, and people. CBVI designers can: (a) program common physical stimuli (e.g., replicate actual objects or scenarios that may be used in real-world mathematical problems, as opposed to drawings on a worksheet) and social stimuli (e.g., use specific phrases and verbiage related to the problem); (b) provide multiple exemplars (e.g., provide many examples of applying and solving the problem at little cost, multiple exemplars of correct responses to the same problem); and (c) demonstrate natural contingencies of reinforcement. For example, consider a common division problem requiring a child to divide a pizza amongst friends so each person has an equal amount. In CBVI, the video component may include a scene with four friends standing around a pizza that has been divided into eight equal parts, demonstrating the actual division of the pizza amongst the friends, so the student viewing the video can see the real life situation. On the contrary, in CAI this may be done using a representative graphic without real objects and in the traditional classroom this may be done using a stick drawing on a worksheet. In this example of CBVI, students would be able to hear the language of the peers, see the problem being solved with actual objects (e.g., two pieces of pizza), and see the peers happily eating the pizza (i.e., natural contingency). On another day, students may view a similar division problem, but using a different situation or scenario (e.g., dividing a group of people into two teams to play kickball). Whereas the actual portrayal of problems can hardly be done in a traditional classroom, or even in some CAI programs, CBVI allows for a greater degree of generalizability, especially to real-world applications.

Another added benefit of CBVI is the ability to use the videos as a form of error correction. The program can re-loop students back to the video, where the students can view the video in the event that an error is made when answering a question (Mechling, 2005). The videos can be viewed as many times as needed by the individual students. This level of repetition for error correction and re-learning through concrete examples is largely impractical in traditional classroom instruction and some CAI programs.

Research on CBVI with academics. The majority of CBVI studies have targeted functional skills for instruction with students with ASD and moderate ID (Ayres, Langone, Boon, & Norman, 2006; Ayres, Maguire, & McClimon, 2009; Cihak & Schrader, 2008; Hansen & Morgan, 2008; Mechling & Cronin, 2006; Mechling, Gast, & Barthold, 2003; Van Laarhoven & Van Laarhoven-Myers, 2006). A few CBVI studies have focused on teaching academic skills. For example, Heimann et al. (1995) successfully used the multimedia software, *The Alpha Program* (Nelson & Prinz, 1991), with voice, animation, and videos to teach reading, imitation, verbal expression, and phonological awareness to 11 students with ASD. Results showed higher motivation with the CBVI implementation and increases in verbal behavior; however, the *Alpha Program* was a mass-produced software and was not tailored to address individuals' needs. Mechling et al. (2002) used a multimedia program, with digital photographs and videotapes imported into Hyperstudio 3.1 (Roger Wagner Publishing, Inc.), to teach vocabulary acquisition of words found on grocery store aisle signs to four students with moderate ID, one of whom had autism. All students generalized the learned skills to three different grocery store locations and were able to read the grocery aisle signs and find the location of grocery items within the corresponding aisles. This study showed the importance of teaching multiple exemplars and including "life-like" scenarios in promoting generalization through CBVI. Kinney et al. (2003) also used Microsoft PowerPoint® with embedded video models and video rewards to teach generative spelling to one student with autism. Not only was this student able to learn to spell 55 new words, but she was also able to generalize to novel words with similar beginning consonants and word endings that had been used in the matrix training. The studies by Mechling et al.

(2002) and Kinney et al. (2003) used researchers-designed CBVI to address specific academic deficits of individuals with autism and demonstrated the importance of planning for generalization within CBVI.

CAI and CBVI for Teaching Mathematics to Students with ASD or ID

Despite the positive effects of CAI and CBVI in teaching language and literacy to individuals with ASD or ID as reviewed previously, research addressing mathematical skills is very limited. Only three studies have been published to date that taught mathematics skills to students with ASD (i.e., Burton et al., 2013; Chen & Bernard-Opitz, 1993; Whalen et al., 2010).

Chen and Bernard-Opitz (1993) used an adapted alternating treatments design to compare CAI and one-to-one personal instruction in four students with ASD, ages 4 to 7. The study examined learning rates on concepts such as labeling pictures (i.e., reading) and addition, recall of object position, and more and less. The researchers also targeted motivation and appropriate behaviors as dependent variables. One-to-one personal instruction consisted of a teacher working with the student on tasks similar to those presented in CAI. The CAI used in the study incorporated strategies that included changing the proximity of the trained stimulus, massed trials, and within-stimulus prompting. Although motivation and appropriate behaviors were higher in the CAI condition, only one student's learning rate was higher in the CAI condition compared to the personal instruction condition. The study did not specify the CAI program used; however, all tasks were individualized for each student and appeared to be a researcher-created program. Although this study is older, it was one of the first studies to use computer technology to teach academic mathematical skills to students with ASD. The authors foreshadowed that CAI would be very beneficial to students with ASD in the future.

In a more recent study, Whalen and colleagues (2010) used a group design to examine the effects of the *TeachTown: Basics* software on the acquisition of concepts in four domains (i.e., receptive language, social understanding, life skills, and academic/cognitive skills) in 47 participants with ASD, ages 3 to 6 years, over a 3-month period. *TeachTown: Basics* is a commercially available software program developed using principles of ABA for students with developmental ages of 2 to 7. Students were reinforced for correct answers using a variable ratio 3 reinforcement schedule with animated reward games. Students were taught in a discrete trial format using a within-stimulus prompting procedure. Multiple exemplars were used to promote generalization and maintenance trials were embedded throughout the program. The skills specifically related to mathematics included identification of shapes, numbers, most and fewest concepts, numeral-quantity matching, mathematical symbols, addition, subtraction, number lines, and fractions. Students had to achieve 80% of trials correct during the training exercise to take the posttest. When students completed a posttest with 80% accuracy or better, they could advance to the next lesson. Results showed significant differences from pretests to posttests across concepts for students in the experimental group ($n = 22$, $F(1,13) = 77.18$, $p < .001$), and these students outperformed students in the control group ($n = 25$). Fifteen of the 22 students in the experimental group showed mastery of some lessons, whereas seven students did not master any lessons. The authors noted that the students who did not show mastery were either in a classroom where the teacher did not implement the program regularly, or they did make some progress (i.e., decrease in prompting levels) but not enough to master an entire lesson. Because this was a group design study, individual scores were not available. In addition, scores were not disaggregated by domain type, so no results were specifically reported for the acquisition of the mathematical concepts. The authors pointed out that the *TeachTown: Basics* is unique in that it does not allow the student to click through the program without performance-based contingencies (i.e., the screen will only advance once a correct answer is clicked with or without prompting), which is a common problem in some CAI programs.

Most recently, Burton et al. (2013) implemented a multiple baseline across participants design to evaluate the effects of CBVI with embedded video self-modeling (VSM) on functional mathematics problem solving skills in 4 middle school students with ASD and ID with IQ ranges from 61 to 85. All students attended a self-contained life skills mathematics classroom for students with ID, and one student also was included in a general education mathematics classroom. Story problems consisted of five items with five price tags presented on a worksheet. Students were given a cash register containing simulated money. Students were asked to estimate the amount needed to purchase the item using the smallest number of bills, hand the money to the teacher, then estimate, calculate, and provide exact change. The skill was linked to the CCSSM 7.EE, "solve real life and mathematical problems using numerical and algebraic expressions and equations." During all phases (baseline, video development, intervention, post-intervention, and follow-up), students had a seven-step task analysis with the steps listed for solving the problem. In baseline, students were given five story problems to solve with no error correction or feedback. In video development, the teacher videotaped the student solving five problems using the task analysis and provided as many prompts as needed for the student to read the step from the task analysis and solve the problem correctly. Then the teacher edited the video to remove all teacher prompts in order to produce five 3-5 min videorecordings of each student solving each story problem (i.e., VSM). During the intervention phase (math instruction via VSM), students were given an iPad® to view the video models in order to solve each story problem. The student could fast forward, pause, and rewind as much as needed to solve the problems. Once a student was able to solve the problems with 80% accuracy for three consecutive sessions, the student moved to the next phase. Post-intervention was divided into six phases. During the first phase, the student was required to solve four previously trained problems using the VSM and one novel problem with no VSM. During each subsequent phase, the number of previously trained problems decreased by one and the number of novel problems with no video model increased by one until the student reached phase 6, in which all problems were previously trained problems but students were required to solve them without VSM. During follow-up, students were given weekly probes where they were required to solve the same five problems that had previously been trained but without VSM. Verbal reinforcement and a token economy were used to encourage appropriate behaviors during all phases. In order to test the effects of VSM alone, no praise on academic performance, error correction, or prompts were provided during any phase. Results showed a functional relation as all students increased their story problem solving skills from baseline (mean range: 0% to 24%) to post-intervention (mean range: 85.8% to 100%). During follow-up, three of the four participants maintained mastery criteria (100%, 92.3%, and 88%, respectively), but one student dropped slightly below the 80% criteria (79.6%). Anecdotal information also showed that students in this study with aggressive behaviors and attention issues were less aggressive and remained on task more when the iPad® was present. This study shows promise that VSM delivered via an iPad® can be used to improve problem solving skills in students with ASD and ID. The technology allowed students to independently prompt themselves while problem solving, thus increasing independence and decreasing teacher dependency, an important self-determination skill. One major limitation of this study is the absence of observing whether students could generalize to novel problems once VSM was no longer implemented. Practice effects were also a confounding variable in this study. It is possible that marked improvement in problem solving was a result of memorization rather than skill acquisition since the students performed the same five problems that had been trained repeatedly.

CAI and Problem Solving

Presently no studies have involved CAI or CBVI to teach mathematical word problem solving with students with ASD and ID. Burton et al. (2013) taught “story problems,” but these problems consisted of pictures of items with a price tag and no linguistic information. This section will include recommendations from the CAI literature on teaching mathematical word problem solving to students with high incidence disabilities and students at risk for failure in mathematics. It will also include reviews of studies that have used SBI within CAI to teach mathematical word problem solving.

When developing CAI to teach problem solving, the curricular and instructional design features are most critical because the computer is merely a medium for delivering instruction (Babbitt & Miller, 1996; Seo & Bryant, 2009). One benefit to using CAI to teach problem solving is the ability to anchor the instruction using a video to contextualize the problem (Bottge, Rueda, Grant, Stephens, & Laroque, 2010). Bottge and Hasselbring (1993) conducted a comparative study of teaching standard word problems and word problems with anchored instruction on a videodisc. Although both groups showed improvement in problem solving, the anchored instruction group performed better on the posttest and transfer tasks than the control group (i.e., standard word problems group). Anchoring instruction when teaching problem solving through CAI is likely to benefit students with ASD and ID because it provides a context-rich learning environment to a population who has difficulty in reading and mathematics, and it makes the problem more concrete (Bottge et al., 2010). Another benefit for using CAI to teach problem solving is the ability to add prompts and to cue cognitive processes (Babbitt & Miller, 1996). Stimulus prompts can be embedded within the software to prompt students to perform the cognitive and metacognitive strategies required when problem solving. For example, if step 1 in the problem solving task analysis is to read the problem, the words “Read the problem” could be highlighted to cue students what to do, and when the problem is touched by the students, the words could be read aloud. This feature in CAI permits students who have poor reading abilities to develop mathematical problem solving skills without being dependent on a teacher to read for them. Direct instruction procedures can be incorporated into the design. Response prompts can be added, such as the system of least prompts to cue students what to do next in a progressive fashion when steps are not under stimulus control. Moreover, CAI permits fading of the prompts in a strategic manner to transfer stimulus control as students become more proficient in problem solving (Babbitt & Miller, 1996). Virtual manipulatives can be used for students who do not have fact recall, like many students with ASD and moderate ID. The concrete-to-representational-to-abstract teaching sequence of computation can be embedded within CAI for this population. For example, when solving a word problem about pets in a pet store, digital pictures of cats and dogs can be used initially. Then, the manipulatives can progress to more representational objects, such as circular counters. Finally, students may progress to using a number line or a counting strategy which are more efficient. Virtual manipulatives also limit the distractibility of students physically having to hold and manipulate concrete objects. In a recent comparative study between concrete and virtual manipulatives with three elementary-aged students with ASD, Bouck et al. (2014) found that the participants achieved greater accuracy and faster independence when solving subtraction problems with virtual manipulatives as opposed to concrete manipulatives. The flexibility of CAI to incorporate many research-based strategies, as described above, for teaching problem solving in a consistent, systematic manner makes it an ideal method of instruction.

In a recent study, Fede, Pierce, Matthews, and Wells (2013) examined the effects of SBI delivered through CAI on mathematical problem solving on 32 fifth-grade students struggling with word problems using a 2x2 mixed design. Children with severe developmental disabilities, including ASD and ID were excluded. The intervention was the *GO Solve Word Problems* CAI program (Synder, 2005), and included many research-based word problem strategies such as general strategy instruction, teacher modeling using worked examples, schematic diagrams, anchored instruction, and problem personalization. The instruction consisted of three modules: Addition and Subtraction, Multiplication and Division, Advanced Multiplication and Division, and focused on teaching students to solve word problems using nine different graphic organizers. Four dependent variables were measured: (a) a subset of word problem derived from the state assessment; (b) researcher-made probes that were similar to the problems in the *GO Solve Word Problems* CAI program; (c) the Process and Applications subtest from the Group Mathematics Assessment and Diagnostic Evaluation (GMADE; Williams, 2004), which measures a student's ability to understand language and concepts of mathematics and to apply in selecting an operation and computing to solve word problems; and (d) a social validity questionnaire for the *GO Solve Word Problems* CAI program. Results showed that the students in the experimental group made significantly greater gains from pretest to posttest when compared to the control group who received traditional instruction on probes consisting of problems selected from the state assessment and researcher-made probes. Although students in the experimental group made greater gains on the GMADE subtest, the results were not significant. Further, students in the experimental group reported that they learned "a great deal" from the intervention and they enjoyed using the computer to learn to solve word problems. Because the study did not address teaching word problems to students with ASD or moderate/severe ID, the generalizability of the results to students with ASD and moderate ID are questionable. In addition, the *GO Solve Word Problems* CAI program was designed for typically developing students who are struggling with mathematical word problem solving. Adaptations will be important to incorporate evidence- and research-based practices in instruction in order for the *GO Solve Word Problems* CAI program to be suitable for teaching mathematical word problem solving to students with ASD and moderate ID.

Summary

Computer-assisted instruction is based on B. F. Skinner's work on PI and incorporates many principles of ABA. Because of the sound instructional practices that can be incorporated into the design of CAI, along with its ability to be adapted and individualized for students with disabilities, and its efficiency and effectiveness, CAI is an ideal delivery method for academic instruction. The majority of research on using CAI to teach academics to students with ASD and ID has focused on English language arts or other non-academic domains, such as social or functional skills. There is a need for research on CAI to teach mathematics to students with ASD and moderate ID, especially moving beyond discrete skills into higher level thinking skills, such as problem solving. Although research on using CAI to teach mathematical problem solving is available to show its effectiveness with students with high incidence disabilities, no research exists on using CAI to teach mathematical problem solving to students with ASD and moderate ID. Findings from the research on using CAI and CBVI to teach academics to students with ASD and ID, combined with the lessons learned from the literature on using CAI to teach problem solving to students with high incidence disabilities, provide promise for developing a sound CBVI program for teaching mathematical problem solving to students with ASD and moderate ID.

Summary of Review of the Literature

Mathematical competence is a goal for all students, including those with ASD and moderate ID. Both the NCTM standards and the CCSSM emphasize the importance of teaching mathematical problem solving to *all* students, as this is a pivotal skill that directly influences a student's ability to solve real-world mathematical problems. When prioritizing mathematical content to teach students with ASD and moderate ID, mathematical problem solving should be at the forefront because it addresses the need to teach academic content in a personally relevant context (Courtade, Spooner, Browder & Jimenez, 2011). Mathematical problem solving is a functional life skill and has the potential to afford more opportunities to students with ASD and moderate ID. In addition to being an important life skill, mathematical problem solving is a foundational skill that can be applied across all standards of mathematics.

Research shows that students with moderate/severe ID, including students who also have a diagnosis of ASD, can learn mathematics, but more research is needed that links to the NCTM standards and the CCSSM (Browder et al., 2008). Systematic instruction with prompt fading procedures, such as constant time delay and least intrusive prompts, and in vivo instruction have been identified as evidence-based practices for teaching mathematics to students with moderate/severe ID (Browder et al., 2008). The majority of mathematical research for students with moderate/severe ID has focused on functional mathematical skills, such as time and money, or on simple skills, like number identification. Few studies have addressed higher level mathematical thinking, such as problem solving.

Several strategies have been used to teach problem solving to students with high incidence disabilities. One such strategy is SBI, which has a strong literature base (Gersten et al., 2009). Only one study to date has examined the effects of SBI on teaching problem solving to one student with moderate ID (Neef et al., 2003), and two additional studies have examined the effects of SBI on teaching problem solving to students with

ASD (Rockwell, 2012; Rockwell et al., 2011). More high quality research is needed in this area.

Computer-assisted instruction is an evidence-based practice for teaching communication skills to students with ASD (Odom et al., 2010); although the literature on using CAI to teach academics is growing, it has primarily been limited to English language arts (Knight et al., 2013; Pennington, 2010). Only three studies have used CAI or CBVI to teach mathematics (Burton et al., 2013; Chen & Bernard-Opitz, 1993; Whalen et al., 2010), and only one of those three focused on mathematics problem solving but did not include linguistic information commonly found in word problems (Burton et al., 2013). Additionally, there are no studies to date on teaching mathematical word problem solving to students with ASD and moderate ID using CAI or CBVI. Problem solving has been widely researched with students who have high incidence disabilities and recommendations from this literature have been incorporated into the design of the present study.

With a growing emphasis on developing 21st century skills, such as technology and mathematics, because they lead to greater post-school opportunities, it is important to consider integrating the two in research. Technology has been shown to reduce anxiety and motivate student learning. It also is a cost-effective way to engage students in real-world applications of problem solving (Leh & Jitendra, 2013). In an effort to address the major limitations and suggestions for future research within the reviewed literature, the current study examined the effects of CAI on teaching mathematical problem solving to students with ASD and moderate ID. This study used CBVI, a form of CAI, which incorporated the use of video modeling, an evidence-based practice for teaching students with ASD. Using CBVI as a delivery method for instruction has potential to address the barrier of special educators not being content experts, and result in a solution to provide high quality instruction and increased access to the general curriculum for students with ASD and moderate ID. The CBVI in the current study incorporated principles of SBI, such as explicit instruction and visual representations (graphic organizers), and combined these strategies with evidence-based practices for teaching mathematics to students with moderate/severe ID, such as task analytic instruction and least intrusive prompting.

CHAPTER 3: METHOD

The purpose of this study was to investigate (a) the effects of SBI delivered through CBVI on the acquisition of mathematical problem solving, (b) the effects of SBI delivered through CBVI on students' ability to discriminate mathematical problem type, (c) the degree to which these skills generalized to novel problems in a pencil-and-paper test format, and (d) the perceptions of participants and their teachers on the feasibility, appropriateness, and/or effectiveness of using CBVI to teach mathematical problem solving in students with ASD and moderate ID. This chapter addresses participants, setting, materials, dependent variables and data collection, procedures associated with experimental conditions, and measures for social validity and procedural fidelity.

Participants

Three students with ASD and moderate ID in an elementary school participated in this study. Participants were selected by convenience sampling via nomination by the special education teacher, based on the following initial inclusion criteria: (a) had a diagnosis of ASD; (b) had an IQ of 55 or below; (c) were assessed by a state's alternate assessment (e.g., NCEXTEND 1) if eligible by age; (d) could manipulate a computer and SMART Board™ (e.g., advancing a program and touching the screen); (e) demonstrated attending and imitating skills; and (f) had required prerequisite early numeracy skills, including identifying numerals 1-10 in random order, counting with one-to-one correspondence, and creating sets up to 10 objects. All inclusion criteria were verified by the primary experimenter by reviewing each student's educational records (for criteria a-c), observing him or her during at least one mathematics instructional session (for criteria d-e), and by administering a prescreening tool to select participants once parental consent has been obtained (for criterion f).

Legal guardians of targeted students signed parental consent forms permitting their child to participate in the study, allowing researchers to access educational records, and verifying that results may be usable for publication as long as anonymity of the participation is assured (see Appendix A). Targeted students also signed student assent form (Appendix B) to agree to participate in the study.

Students were given a prescreening to determine if they had adequate prerequisite skills for eligibility to participate in the study (see Appendix C). The following skills were assessed and were required to participate in the study, including identifying numerals 1-10 in random order, counting with one-to-one correspondence, and creating sets of up to 10 objects. The following skills were assessed, but were not required for participation in the study, to determine if the student had the skills in his or her repertoire, including receptively and expressively identifying the set that has “more” or “less,” representing a number sentence with sets and adding to solve, identifying pictures that were the same and different, identifying addition and subtraction symbols, and using a calculator to solve two-digit addition and subtraction problems. Students also were assessed to determine if they already could solve group and change word problems independently. Students who were able to solve these problems independently were excluded from the study. Student descriptions including age, grade, gender, diagnosis/disability, evaluation test scores, strengths and weaknesses, and prescreening results are included below.

Caleb. Caleb was a 7-year-old Caucasian male with ASD and moderate ID. According to his most recent evaluation data, Caleb had a cognitive scale of 55 on the Developmental Profile-3 (DP-3; Alpern, 2007) and full scale IQ of 64 on the Leiter International Performance Scale (Roid & Miller, 1997); however, it was noted the latter score may be inflated because he performed poorest on subtests requiring executive functioning, analysis, and synthesis, but scored within normal range of his peers on tasks that required automatic matching and automatic recognition. His adaptive behavior scores were 64 (Adaptive Behavior Assessment Scale-II [ABAS-II]; Harrison & Oakland, 2003) and <57 according to the Brigance Inventory of Early Development – II (Glascoe, 2003). He had a diagnosis of ASD according to the Gilliam Autism Rating Scale, 2nd edition (GARS-2; Gilliam, 2006). Caleb also was given two tests to assess mathematics ability and scored <57 on the Brigance (Glascoe, 2003) and 70 on the Test of Early Mathematics Ability- 3rd edition (TEMA-3; Ginsburg & Baroody, 2003). Caleb received all instruction in a self-contained classroom for students with ASD. He frequently engaged in stereotypy (e.g., flapping) and echolalia (e.g., scripted speech). He was extremely routine-oriented and needed to know his schedule in detail. He did not handle sudden changes well, but would adapt if provided with a written schedule. If his routine was interrupted, he would kick the table or stomp his feet, but these behaviors were mild when exhibited. Caleb's attending skills were limited in the beginning (e.g., attended to VM less than 1 min and struggled to do a work session longer than 10 min without frequent redirecting), but he showed great improvement over the course of the study (e.g., attended to VM 3 min long and completed 30-40 min work sessions). Caleb's oral reading skills were on grade level; however, his comprehension was low. His verbal abilities were one of his greatest strengths. Although many of his responses were scripted speech, he used them in appropriate contexts. The prescreening test results showed that Caleb could identify numerals 1-10, count with one-to-one correspondence, create sets of up to 10 objects, receptively and expressively identify more, identify addition and subtraction symbols, and identify pictures that were same or different. Caleb was not able to receptively or expressively identify less, represent a number sentence with sets and add to solve, use a calculator to solve two-digit addition or subtraction problems, or solve group or change word problems independently.

Anthony. Anthony was an 11-year-old Caucasian male with ASD and moderate ID. Anthony attended a private school for students with ASD until fourth grade. According to his most recent evaluation data, Anthony had a full scale IQ of 40 (Reynolds Intellectual Assessment Scale [RIAS]; Reynolds & Kamphaus, 2003) with a verbal intelligence index of 41 and nonverbal intelligence index of 46. His adaptive behavior score was 40 (ABAS-II; Harrison & Oakland, 2003) and had a diagnosis of ASD according to the Autism Diagnostic Observation Schedule (ADOS; Lord & Rutter, 2000). According to the Woodcock Johnson-III (Woodcock, Shrank, McGrew, & Mather, 2007), Anthony's mathematics calculation standard score was 59 (grade equivalence = 1.9) and mathematical reasoning score was 44 (grade equivalence = K.4). These scores do not correspond with his ability to perform tasks in the classroom when motivated. Anthony received all academic instruction in a self-contained classroom for students with ASD, but attended special area classes and lunch with same-age peers. Anthony was very bright, but it was not reflected in his performance because he was so prompt dependent, unmotivated, and easily frustrated by tasks that required independence or multiple motor or verbal responses. This was evident throughout his day in school. For example, Anthony had to be prompted to start a task, to complete steps in a task, and to have his wants/needs met (e.g., using restroom and eating each item in his lunchbox during lunch). Anthony frequently shouted “I want my mommy” throughout the school day and needed to know what time she was coming to pick him up. He left school 1-2 hr early daily for outside therapies. A token economy was added after the first baseline data point for Anthony to provide him with an opportunity to earn Starfall mathematics on the computer following the completion of four problems. In Phase I, Anthony quickly figured out how to get through the four problems with the least amount of effort possible (e.g., saying the “whats” were the same in step 3 so he could cross it off and move to the next problem). The token economy was modified several times throughout the study to encourage Anthony to complete problems using all 12 steps in the task analysis. Anthony’s strengths included his reading ability and his expressive language skills. The prescreening test results showed that Anthony could identify numerals 1-10, count with one-to-one correspondence, create sets of up to 10 objects, receptively identify more and less, identify addition and subtraction symbols, represent a number sentence with sets and add to solve, and identify pictures that were same or different. Anthony was not able to expressively identify more/less, use a calculator to solve two-digit addition or subtraction problems, or solve group or change word problems independently.

Neal. Neal was an 8-year-old Hispanic second grade male with ASD and moderate ID. According to his kindergarten evaluation, Neal had an IQ of 46 (Standford-Binet Intelligence Scale, Fifth edition; Roid, 2003) and adaptive behavior scores of 57 (teacher rating form) and 53 (parent rating form; ABAS-II; Harrison & Oakland, 2003).

Neal was given a diagnosis of autism according to the Childhood Autism Rating Scale, Second edition (CARS; Schopler, Peichler, & Rochen Renner, 1993); however, no score or range was provided. Neal was given the TEMA – 3 (Ginsburg & Baroody, 2003) and his mathematics ability score fell in the very poor range (<55); however, it was noted this score did not accurately reflect his ability to perform mathematics tasks in the classroom and was likely a result of a language barrier to receptively understand directions and Neal's expressive language deficits. English was Neal's second language. Both of Neal's parents were Hispanic, and his teenage sisters reported that Spanish was spoken in the home. Neal received all academic instruction in a self-contained classroom for students with ASD, but participated in special area classes with typically developing peers. Neal had limited verbal language. He did not initiate conversation, reciprocate conversation, or communicate his wants/needs (e.g., going to the bathroom). He did not spontaneously communicate more than 1-3 word phrases, and most responses were "yes/no." The group and change rules presented in the current study were the longest strings of words he has used in the classroom setting. Few words were spoken clearly enough to be understood. Neal was a very energetic, compliant student and had a friendly demeanor. He also was very procedural and routine oriented. He liked order, neatness, and consistency. Neal's mathematical abilities were more advanced than his reading abilities. The prescreening test results showed that Neal could identify numerals 1-10, count with one-to-one correspondence, create sets of up to 10 objects, identify addition and subtraction symbols, represent a number sentence with sets, and identify pictures that were same or different. Neal was not able to receptively or expressively identify more/less, solve the number sentence using the sets he had made, use a calculator to solve two-digit addition or subtraction problems, or solve group or change word problems independently.

Setting

The three participants attended an elementary school in a large metropolitan city in the Southeastern United States. Approximately 900 students attended the school, with 30.0% being African American, 20.3% Hispanic, 43.4% Caucasian, 2.7% Asian, and 3.6% other ethnicity. Forty-seven percent of students received free or reduced lunch. Participants received the majority of their daily instruction in a self-contained classroom for students with ASD within the elementary school, but were included for special area classes.

The study took place in a self-contained classroom for students with ASD in grades 2-5. The prescreening and generalization probes took place at a table in the back of the classroom where one-on-one and small group instructional lessons were conducted. The CBVI and daily mathematical probes were conducted at a table with two computers on it in the back of the room. There were three iPads, two computers (one with a touchscreen), and one SMART Board™ in the classroom. The desktop Dell® computer with a Keytec® Magic Touch Add-on Touch Screen was used in this study. The classroom had one special education teacher and one paraprofessional. The speech teacher came in twice weekly during the morning. Participants completed the instructional lessons and probes between 8:00 A.M. and 11:00 A.M. daily. Caleb was pulled from the adjacent self-contained classroom for students with ASD in grades K-5 during his morning work time from 9:30 A.M. to 10:10 A.M. in order to complete the instructional lessons and probes.

Daily instruction. Participants had mathematics instruction for approximately 60-75 min per day in the self-contained classroom. Daily mathematics instruction started with a 10-min warm-up activity where students worked on independent seatwork addressing their individualized education program (IEP) goals, such as adding and subtracting, graphing, time, and money. Next, students participated in a 35-min group mathematics lesson delivered on the SMART Board™, which targeted skills such as calendar, graphing, weather, money, and place value. Lessons were either teacher-made or downloaded from SMART Exchange, a website where teachers with SMART Boards™ can share activities. Students also sang along to mathematics songs from YouTube on the SMART Board™ (e.g., "Count to 100 by 1's" and "Coin Song"). Students spent the remaining 30 min rotating between mathematics centers. These included Splash Math on the iPad®, Touch Math instruction with the paraprofessional, and Connecting Math Concepts: Level A with the special education teacher. As the school year progressed, the amount of time spent in rotating centers decreased, and many days students did not engage in these activities at all. Caleb's teacher followed a similar schedule, and Caleb's independent seatwork involved writing numerals, matching, counting with one-to-one correspondence, and simple addition. Caleb's teacher did not use a formal curriculum to teach mathematics during rotating centers and instead focused on IEP goals in small groups.

Materials

SBI lessons and word problems. Both the SBI scripted lessons used to develop the intervention package and the word problems were developed by a research team at the University of North Carolina at Charlotte for The Solutions Project, IES Grant #

R324A130001. The research team was comprised of Principal Investigator, Diane Browder, Ph.D., Co-PI, Fred Spooner, Ph.D., Co-PI, Ya-yu Lo, Ph.D., Research Associate/Project Coordinator, Alicia Saunders, M.A.T., and Graduate Research Assistant, Jenny Root, M.Ed. This study addressed one of the goals of The Solutions Project, which was measuring the degree to which students can learn word problem solving through CBVI, a generalization measure of the project. The study addressed two problem types, including group and change. The sequence of problem type introduction was consistent with the recommendation by Christou and Phillipou (1999) and was used by Rockwell (2011, 2012). The scripted lessons were developed based on the SBI work done by Jitendra and colleagues (1996, 2002, 2008), Neef et al. (2003), and Rockwell and colleagues (2011, 2012), as well as the research on teaching mathematics to students with moderate/severe ID (Browder et al., 2008; Browder et al., 2013). The instruction on each problem type consisted of two phases with a total of four phases across both problem types. In the first (addressing group type) and third (addressing change type) phases, participants learned conceptual knowledge, or how to understand the mathematical problem structure through problem comprehension and representation (Jitendra, 2008). In the second (addressing group type) and fourth (addressing change type) phases, participants learned procedural knowledge, or how to solve word problems of group problem types (Jitendra, 2008). Detailed information about the content of the four phases is provided below.

SBI delivered through CBVI included several critical features, including task analytic instruction, read alouds, video modeling, rules, graphic organizers, story grammar instruction and story mapping, and the use of virtual manipulatives. First, the complex skill of arithmetic problem solving was taught through task analytic instruction; steps for solving a word problem were broken down into 12 sequential steps. These steps were taught through forward chaining and broken into two chunks; the first six steps (i.e., Read the problem, Find the “what,” [Items being] Same or different?, Find label in the question, Use my rule, and Choose GO [graphic organizer]) addressed teaching conceptual knowledge (Phases I and III), and the last six steps (i.e., Find “how many?” Fill-in number sentence, Addition or subtraction?, Make sets, Solve, and Write answer) taught procedural knowledge (Phases II and IV). A table including each step of the task analysis and the expected student response is included below.

Table 1: Steps in the Task Analytic Instruction and Expected Student Response

Step of Task Analysis	Expected Student Response
Conceptual Knowledge	
1. Read the problem	Clicked the problem to have it read aloud (CBVI), or requested experimenter to read aloud (generalization).
2. Find the “what”	Dragged-and-dropped circles (CBVI) or circled the two nouns with pictures over them (generalization). These nouns corresponded to the two small groups in a group problem, and the one group that changed in some way in a change problem.
3. Same or different?	Determined if the two nouns were the same thing or different things and dragged-and-dropped circle (CBVI) or circled

	option on template (generalization). This was one of the steps that helped students determine the problem type.
4. Find the label in question	Underlined/circled the noun in the question and dragged-and-dropped label (CBVI) or wrote label (generalization) in blank of number sentence.
5. Use my rule	Stated chant that corresponded to problem type.
6. Choose GO	Selected graphic organizer for corresponding problem type and input into box on template either by dragging-and-dropping (CBVI) or manually placing (generalization).
Procedural Knowledge	
7. Find how many	Circled numbers in word problem by dragging-and-dropping circles (CBVI) or with pen (generalization).
8. Fill-in number sentence	Filled-in numbers in boxes on number sentence by dragging-and-dropping numbers (CBVI) or writing (generalization).
9. + or -	Determined if problem was addition or subtraction and inserted symbol in circle on number sentence by dragging-and-dropping (CBVI) or writing (generalization).
10. Make sets	Used virtual manipulatives (CBVI) or concrete manipulatives (generalization) to make sets on graphic organizer.
11. Solve	Solved problem by counting total/remaining manipulatives.
12. Write answer	Dragged-and-dropped number (CBVI) or wrote number (generalization) into last box on number sentence.

Task analysis. Task analytic instruction was used in place of a heuristic, such as *RUNS* (Rockwell et al., 2011) or *FOPS* (Jitendra, 2008), which is traditionally found in SBI, because it is an evidence-based practice for teaching mathematics to students with moderate/severe ID. Memorizing a heuristic may overload the working memory of individuals with ASD and moderate ID, and students may not have enough literacy skills to relate the letters of the heuristic to the words for which each letter stands. As a result, the task analysis was presented in a self-monitoring checklist, referred to as the "student self-instruction sheet," and the participants followed the sheet and checked off each step as they completed each step during the instruction. Pictures were paired with each step to support emerging readers. Figure 5 presents a screen shot of the student self-instruction sheet with the 12-step task analysis.

1.			**Read the problem**
2.		horses	**Find the "what"**
3.		or	**Same or different?**
4.		How many ___?	**Find label in question**
5.			**Use my rule**
6.			**Choose GO**
7.		0 1 2 3 4 5 6 7 8 9	**Find "how many"**
8.			**Fill-in number sentence**
9.			**+ or -**
10.			**Make Sets**
11.			**Solve**
12.			**Write answer**

Figure 5: Student self-instruction sheet used for generalization probes.

Read alouds. Read alouds were used to address reading deficits of the participants in this study. Each step of the task analysis and the entire word problem were programmed to be read aloud when a participant clicked a link in the CBVI instruction.

Video modeling. Video modeling, with either adult as model or point-of-view modeling, were used to explain content or show the participants how to perform each step of the task analysis. The videos were embedded in the lesson and were relooped for the participants to view again upon making an incorrect response. Video models of the problems in action were used in change problem type for the procedural knowledge instruction as a visual support to help participants identify whether problems were addition or subtraction.

Rules. Rules were developed to describe the key components of the problem structure in order to teach problem schema identification in a concrete manner. A chant was used to help each participant remember the rule, and hand motions representing the schema for each problem type were paired with the chant. The group hand motion and chant was performed by holding up the left hand in an “o” shape and saying “small group,” holding up the right hand in an “o” shape and saying “small group,” and then bringing hands together and to make one big “O” with fingertips touching and thumbs touching and saying “BIG Group” in a deeper voice. The change hand motion and chant was performed by holding up the left pointer finger and saying “one” and quickly flipping over left palm so it faced up and simultaneously saying “thing,” then pretending to pick up counters from upper right of left palm and placing on left palm with right hand while saying “add to it,” followed by pretending to remove counters from left palm and discard to lower right of left palm with right hand and saying “OR take away,” and finally moving left palm in a left to right motion and saying “change.” The accompanying hand motions could be performed directly over the graphic organizers to help the participants relate the problem structure to the schema. The chant and hand motions were taught through video modeling in a model-lead-test format at the start of the CBVI instruction during Phase I for group problem type and Phase II for change problem type and were reviewed in subsequent lessons.

Graphic organizers. Graphic organizers were developed to visually represent each problem type. Figure 6 shows the screenshots of the graphic organizers. In the group graphic organizer, the two small green and red circles represented the small groups, and the large blue circle represented the big group. The circles were connected with lines to be symbolic of the part-part-whole relationship of group problem type. In the change graphic organizer, the cabinet represented the place where students gathered additional counters needed for adding to the initial start group, just as a cabinet in a kitchen serves the same purpose, and the trash can represented where counters were discarded from the start group, just as things are discarded in a trash can. The dotted arrows and solid arrow were representative of the dynamic relationship in change problem type. Both graphic organizers were developed by Dr. Diane Browder and the Solutions Project team with the assistance of Dr. Asha Jitendra.

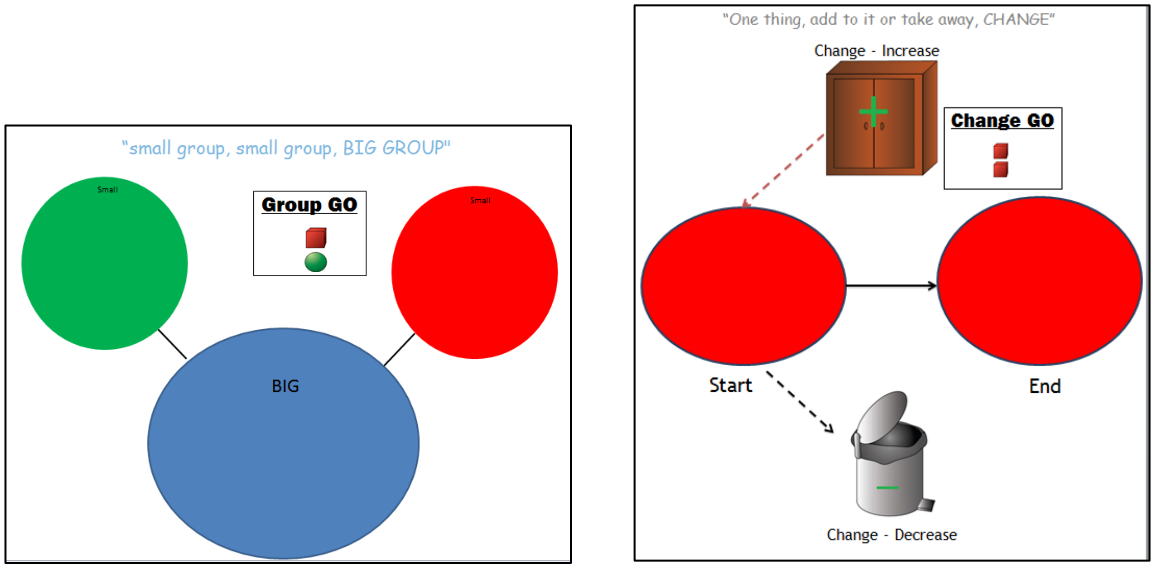

Figure 6: Graphic organizers for group type (left) and change type (right).

Story grammar instruction and story mapping. Steps 2-5 of the task analysis consisted of explicitly teaching story grammar instruction and story mapping, including "find the what," "same or different," "find the label in the question," and "use my rule," in both group and change problem types. Participants were taught to analyze the text and locate structural features which led to choosing the correct problem type. For change problem type, story grammar instruction and story mapping were used to teach participants how to determine if the problem was addition or subtraction.

Virtual manipulatives. Virtual manipulatives were counters created in the SMART Notebook software. They were used to support computation and to visually reinforce the concept of addition and subtraction, particularly when used in accompaniment with the graphic organizers.

Word problems were developed by five special educators of students with ASD and ID based on themes they felt were highly motivating to students in their class.

Teachers were trained on writing word problems using recommendations from the literature, such as using a consistent formula to write word problems (Neef et al., 2003), using easy-to-decode words and common verbs (Stein et al., 2006), and using common names from diverse cultures (Xin et al., 2008). All word problems were edited by a graduate research assistant, and reviewed by the experimenter, who serves as the Project Coordinator for the Solutions Project. Fifteen themes with five corresponding word problems were developed for both group and change problem types in order to align with the principles of contextual mathematics (Bottge et al., 2002), to offer variation and maintain interest of students while repeatedly practicing the same skill (Browder et al., 2013), and to promote generalization through teaching sufficient examples (Cooper, Heron, & Heward, 2007; Stokes & Baer, 1977). The experimenter selected some word problems from the teachers-developed problems for use in this study, and excluded those that were (a) not actual group or change problems, (b) not following the formula for writing word problems, and (c) lacking high interest for the participants in this study (e.g., going to the hair salon). The experimenter developed additional word problems using themes of high preference and familiar names for the participants. A total of 104 problems were used in participant probes and generalization probes.

CBVI lessons. Instruction for Phases I through IV consisted of three lessons for the group problem type and five lessons for the change problem type, for a total of eight lessons. Instruction for Phases I and III each included two CBVI lessons, whereas Phase II and Phase IV included one and three CBVI lessons, respectively.

Lesson 1 and Lesson 4 were the first lesson for the group type and the change type, respectively. Lessons 1 and 4 both began with an introductory explanation video of the primary experimenter providing the objective for the lesson. Next, a video model with adult-as-model was provided showing how to perform the chant using a “model-lead-test” format. Then, a video model with point-of-view modeling (i.e., bird’s eye view over experimenter’s hands) showed how to perform the chant over the graphic organizer for the targeted problem type. Participants then began the lesson on conceptual knowledge for the targeted problem type. Lesson 1 for group problems included three problems, two of which followed a “model-lead” format and the final problem served as a “test.” Only targeted problem type word problems were used in Lesson 1. The first two examples in Lesson 1 of the group type consisted of the participant watching a video model of how to perform each of steps 1-6, followed by an opportunity for the participant to perform each step immediately after the model. The third example faded the model and provided the participant with an opportunity to perform each step independently prior to providing verbal or model prompts. Least intrusive prompting (LIP) in the form of two levels of hints were used if the participant did not respond after 5 s had elapsed. Hint 1 was represented by a “?” next to the step and provided a specific verbal prompt (e.g., “The next step is ‘read the problem.’ Click on the problem to read aloud.”). Hint 2 was represented by a green play button icon and provided a video model of how to perform each step as a pop-up video. For error correction, the participant was directed to Hint 2, the video model prompt. Unfortunately, this pop-up video feature of the software had several glitches and often would not work. If this was the case, the experimenter used “model-retest,” where she would model how to perform the step and provide the participant with an opportunity to try the step again. Lesson 4 of the change problem type was very similar, but only one problem used the “model-lead” format, and then the participant was provided with two "test" problems with LIP embedded. This decision was made because Lesson 1 was taking too long for a participant to progress through the lesson due to the alternation of a video, then performing a step, then a video, then performing a step, and so on. Additionally, in Lesson 4, steps 1, 2, and 4 were chunked together in a video because they were already taught from the instruction on group problem; then steps 3, 5, and 6 were taught separately.

Lesson 2 and Lesson 5 were the second lesson for the group type and the change type, respectively, and included four problems. The first problem followed a "model-lead" format and the final three problems served as the "test" problems, which included a combination of group and change problems for discrimination. The second lesson of each problem type differed from the first because it explicitly taught discrimination of problem type (i.e., "group" versus "not group" and "change" versus "group") using think alouds modeled through video models. For example, the script for *Step 5: Use My Rule* for a nonexample problem in the group problem type would be: "The two *whats* in this problem are the *same*, but *group* problems have two small groups of *different* things. This cannot be a *group* problem, so I will cross off the problem and move to the next problem." The lesson began with two 3-min videos with video models showing how to proceed through steps 1-6 on the task analysis and use think alouds to determine if the problem was an example or a nonexample. All other procedures for Lessons 2 and 5 were the same as Lessons 1 and 4. First, the participant watched a video model for each step followed by an opportunity to perform the step immediately after the model. In addition, LIP was used in the exact same manner as described in Lessons 1 and 4.

Phases II and IV taught procedural knowledge, or how to solve each problem type. Phase II included one lesson for the group problem type (Lesson 3) and Phase IV included three lessons for the change problem type (Lessons 6, 7, and 8). The reasoning for breaking Phase IV into three different CBVI lessons was to scaffold the instruction and explicitly model how to solve change-addition, change-subtraction, and then provide a mixture of both. In Lessons 3, 6, 7, and 8, participants completed all 12 steps of the task analysis. Because steps 1-6 were taught to mastery during Phases I and III, the experimenter provided “model-retest” for error correction if a participant performed a step incorrectly. After discriminating between problem type (steps 1-6), participants were directed to only solve problems of the targeted problem type in Phase II, but could solve all problems in Phase IV. CBVI for steps 7-12 consisted of modeling the procedural component of problem solving for each problem type followed by an opportunity for the participant to respond after each model. In Phase IV (for change problem type), Lesson 6 targeted teaching participants to solve change addition problems, Lesson 7 targeted teaching change subtraction problems, and Lesson 8 was a combination of change addition and change subtraction problems. Real-life or computer-animated video models of the word problems in action were also incorporated into Lessons 6, 7, and 8 for the participant to see the action and determine if the the problem was addition or subtraction. Participants could click on a movie icon next to the word problem to see the problem in action.

Figure 7 displays the breakdown of the lessons across problem types and phases, as well as a list of instructional components included for each step across lessons. It is important to note that any step that was previously taught using explicit instruction and did not change its content during a lesson were completed using LIP rather than repeated using explicit instruction. There were some cases where certain previously taught and mastered steps had to be modeled using point-of-view modeling in the video in order for the discriminative stimuli for a new step to be present. In these cases, the steps were chunked together and simply modeled by the experimenter before moving into the explanation of the new step. For example, in Lessons 4 and 5, the problem had to be read aloud, the “whats” had to be circled, and the label was dragged into the blank prior to providing explicit instruction on determining if the “whats” and label were the same or different.

	GROUP			CHANGE				
	Phase I		Phase II	Phase III		Phase IV		
Step	Lesson 1 - Conceptual Training, Examples Only	Lesson 2 - Conceptual Training with Discrimination	Lesson 3 - Procedural Training	Lesson 4 - Conceptual Training, Examples Only	Lesson 5 - Conceptual Training with Discrimination	Lesson 6 - Procedural Training, Addition	Lesson 7 - Procedural Training, Subtraction	Lesson 8 - Mixed (+,-) Procedural Training
1. Read the problem	EI, VM-POV, & RA	EI, VM-POV, RA, SGM	LIP	VM-POV	VM-POV	LIP	LIP	LIP
2. Find the "what"	EI, VM-POV, SGM	EI, VM-POV, SGM	LIP	VM-POV	VM-POV	LIP	LIP	LIP
3. Same or different?	EI, VM-POV, SGM	EI, VM-POV, SGM	LIP	EI, VM-POV, SGM	EI, VM-POV, SGM	LIP	LIP	LIP
4. Find the label in question	EI, VM-POV, RA, SGM	EI, VM-POV, RA, SGM	LIP	VM-POV	VM-POV	LIP	LIP	LIP
5. Use my rule	EI, VM-A, R, SGM	EI, VM-A, R, SGM	LIP	EI, VM-A, R, SGM	EI, VM-A, R, SGM	LIP	LIP	LIP
6. Choose GO	EI, VM-POV, GO	EI, VM-POV, GO	LIP	EI, VM-POV, GO	EI, VM-POV, GO	LIP	LIP	LIP
7. Find how many			EI			VM-POV	VM-POV	VM-POV
8. Fill-in number sentence			EI			VM-POV	VM-POV	VM-POV
9. + or -			EI			EI, SGM	EI, SGM	EI, SGM
10. Make sets			EI, GO, VMan			EI, GO, VMan	EI, GO, VMan	EI, GO, VMan
11. Solve			EI, GO, VMan			EI, GO, VMan	EI, GO, VMan	EI, GO, VMan
12. Write answer			EI			VM-POV	VM-POV	VM-POV

Codes: EI = Explicit instruction; VM-POV = point-of-view video modeling; VM-A = adult as model video modeling; RA = read alouds; LIP = least intrusive prompting, R = rule, GO = graphic organizer; SGM = story grammar instruction and story mapping; and VMan = the use of virtual manipulatives

Figure 7: Instructional components embedded within each phase of the CBVI lessons.

CBVI and SMART Notebook software. CBVI was used to deliver SBI using SMART Notebook software on the classroom computer with a touchscreen. The experimenter of this study developed mathematical problem solving lessons with embedded video, audio, pictures/graphics, graphic organizers, virtual manipulatives, and practice problems using SMART Notebook software. The SMART Notebook collaborative learning software is interactive learning software with the ability to build activities, record sound, link to videos or web pages, add pictures or graphics, clone items, and write using a variety of pens and colored markers.

Videos. Video modeling was done in three ways. First, videos of the experimenter performing a step of the task analysis on the SMART Notebook software (i.e., point-of-view video modeling) were filmed using the screen capture software, Camtasia Studio 7, and inserted as a flash video file in the SMART Notebook slide. All steps except Step 5 (i.e., Use my rule) used point-of-view modeling with the experimenter demonstrating the steps so the participant could see how to perform the skill on the screen exactly as he would be performing it. Second, videos of the experimenter providing introductory explanations or demonstrating a step (i.e., adult as model) were filmed using a Flip Camera and inserted into the SMART Notebook slide as a flash video file. These included introductory clips and the experimenter demonstrating the hand motion and chants, as well as performing Step 5: Use my rule. Third, videos of the experimenter demonstrating a word problem in action using point-of-view modeling and computer-simulated videos of word problems in action were recorded using the Flip Camera or SMART Notebook and Camtasia Studio 7, respectively, to teach step 9, add or subtract, in change problems only. An example of the the experimenter demonstrating a word problem included her starting with six eggs in a carton, cracking three of the eggs in a bowl, and posing the question, “how many eggs are left in the carton?” An example of a computer-simulated problem included the experimenter narrating as the screen showed three sheep in a pen on a farm, one sheep escaping and running off the screen, and then narrating the question, “how many sheep are left in the pen?”

Probes. Probes were administered using the SMART Notebook software during baseline and maintenance with no CBVI instruction, and prior to each CBVI session during intervention. No probes were administered during the first two sessions of each CBVI lesson. The computer screen appeared exactly the same for all probes. On the screen, the student self-instruction checklist was on the left side with a cloned, pre-made check for participants to drag and drop. The word problem appeared in the top center with the number sentence directly below. Cloned small and large translucent blue circles were placed to the right of the word problem for participants to drag and drop onto the numbers and targeted nouns in the word problem, respectively. The speaker icon below the word problem read the question aloud again so participants could hear the label without having to hear the entire word problem read aloud. The section for the graphic organizer was placed directly below the number sentence, whereas cloned numerals 1 through 10 were at the bottom of the page. The “same” and “different” icons appeared at the top right for participants to circle by dragging the large, cloned translucent blue circle; the two targeted graphic organizers and one distractor graphic organizer appeared on the right hand side below the icons. The addition and subtraction symbols, and manipulative materials for counting appeared below the graphic organizers. Figure 8 shows a sample screenshot of the probe screen.

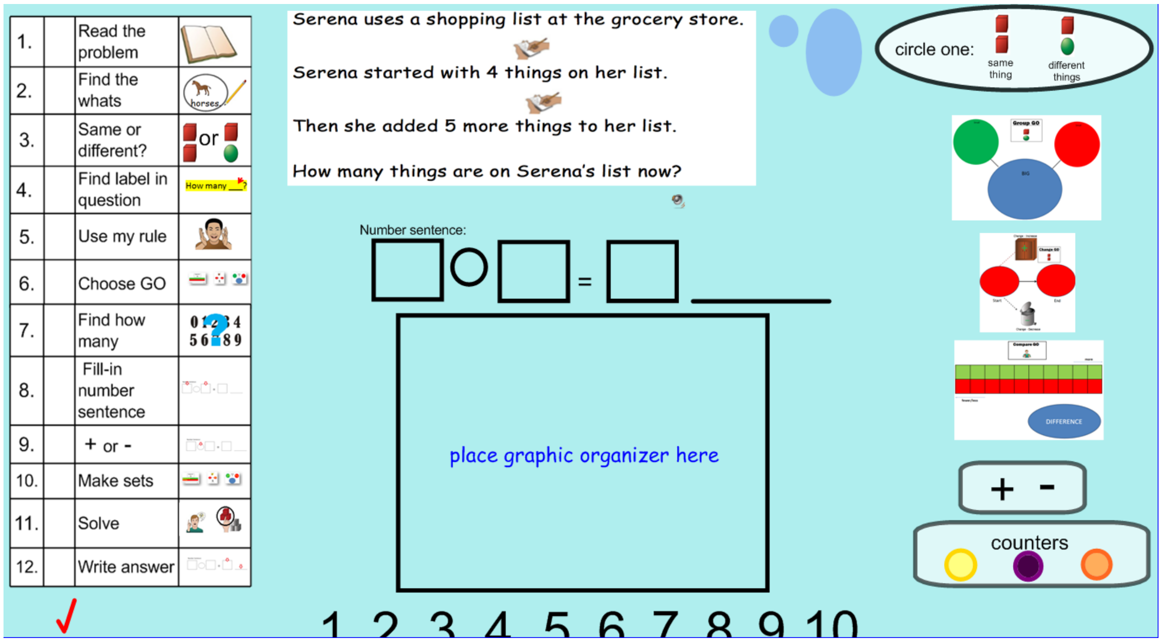

Figure 8: A sample screenshot of the probe screen using the SMART Notebook software.

There were four problems for each probe, including two of the targeted problem type (i.e., group or change) and two nonexamples from the other problem type. Problems selected for each probe varied by themes and were novel problems. The order of presentation of the problem type varied from probe to probe to prevent from memorization. The problem types were coded 1-4 (e.g., 1: group problem #1, 2: group problem #2, 3: change-addition problem, and 4: change-subtraction problem) and the order was randomized using www.random.org. An example of a word problem for the group problem type was: *Sarah had to put away her shoes. Sarah put away 3 pairs of sneakers. She also put away 3 pairs of sandals. How many pairs of shoes did she put away?* An example of a word problem for the change-addition problem type was: *Lee unpacks boxes of games at his store. When Lee got to work, there were 6 boxes to unpack. Then 2 more boxes arrived. How many boxes does Lee have to unpack now?* An example of a word problem for the change-subtraction problem type was: *Sophie had to do chores. She had 5 chores on her list. She did 3 chores. How many chores does she have left to do?*

Generalization probes were administered at a table in the back of the classroom using a paper-and-pencil format. Participants were given: (a) a laminated self-instruction checklist; (b) a laminated problem solving mat with space for the word problem at the top, the words “same” and “different” directly below, the number sentence below that, and a space for the graphic organizer at the bottom; (c) four laminated word problems; (d) counters; (e) one laminated “group” graphic organizer, one laminated “change” graphic organizer, and one distracter graphic organizer; and (f) a Vis-à-vis pen and paper towel to erase any errors. Figure 9 presents a screenshot of the problem solving mat.

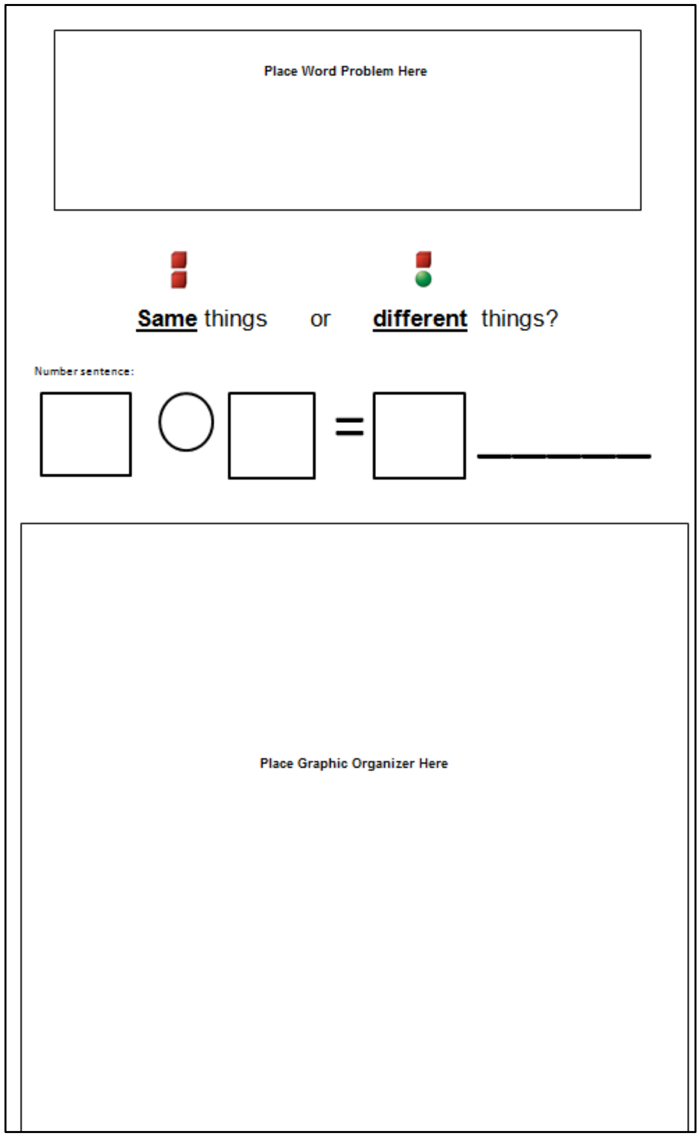

Figure 9: Screenshot of the problem solving mat.

Content Validity

The validity of content included in the CBVI was evaluated by an SBI expert and a general education elementary mathematics expert. The SBI expert evaluated and provided feedback on the scripted lessons, formulas for writing word problems, and graphic organizers that were adapted into CBVI. The mathematics expert also validated the scripted lessons and reviewed a sample CBVI lesson. In addition, the mathematics expert validated the formulas for writing word problems used to develop the word problems in this study.

Experimenter, Interventionist, and Data Collectors

The experimenter, interventionist, and the primary data collector of this study was a doctoral candidate in special education. The experimenter holds a special education teaching license in K-12: Adapted Curriculum and General Curriculum and has 10 years of experience working with students with ASD and ID. She has conducted research involving the use of technology in instruction, including CBVI and video modeling, with students with ASD and moderate ID. The experimenter has worked on a federal grant focusing on general curriculum access for students with severe disabilities, including students with ASD and moderate ID, in the content areas of mathematics and science for the past 5 years, and has taught a college course on general curriculum access for students with severe disabilities. She also is the Research Associate/Project Coordinator of The Solutions Project. She has co-authored a published mathematics curriculum, *Early Numeracy* (Jimenez, Browder, & Saunders, 2013).

A graduate research assistant pursuing a doctoral degree in special education took procedural fidelity data. On occasion, she implemented the CBVI and probes when the primary interventionist was unable to deliver the instruction. She has prior experience conducting research with students with ASD. The experimenter trained the secondary observer on implementation of CBVI and probes, as well as data collection.

Dependent variables

There were two dependent variables in this study, including mathematical problem solving and discrimination. The primary dependent variable, problem solving, was measured as the number of task analysis steps performed correctly on problem solving probes involving the two targeted problem type problems of group and change for a total of 24 steps. Participant responses were recorded using a stacked upside-down task analysis (see Appendix D), where the first step appeared at the bottom and continued upwards to the last step. Because the participants were solving two targeted problem type problems in each probe, two task analyses were stacked. The number of required steps varied between Phases I and III (first six steps of task analysis) and Phases II and IV (all 12 steps) of both group and change problem types with 12 being the maximum number of possible steps for Phases I and III, and 24 being the maximum number of possible steps for Phases II and IV.

The secondary dependent variable, discrimination, was measured as the number of correct discriminations of problem type (e.g., group *vs.* change) each participant performed on probes. The experimenter used a discrete trial data collection method. On each probe, the participant was given four problems to discriminate problem types. Each of the probes administered during Phases I and II (i.e., instruction focusing on the group problem type) required the participants to identify whether each problem was a group problem or a non-group problem. Each of the probes administered during Phases III and IV (i.e., instruction focusing on the change problem type) required the participants to identify whether each problem was a group or a change problem. A correct discrimination was defined as the participant selecting the correct graphic organizer for the corresponding word problem and placing it in the designated area on the screen or problem solving mat for generalization probes. Discrimination data were graphed using cumulative number of independent responses. The number of independent correct responses recorded during each session were added to the total number of responses recorded during all previous sessions in order to see the rate of change over time (Cooper et al., 2007). The purpose of using a cumulative record was because a noncumulative graph may show greater variability in data than actually existed because the number of opportunities in a single session was limited to four. The cumulative graph more accurately reflected the relation between the behavior (i.e., discrimination of problem type) and the intervention (i.e., SBI delivered through CBVI).

The same data collection methods for the problem solving and discrimination of problem type were used for the paper-and-pencil generalization probes. This was to determine the degree to which the participants transferred the problem solving and discrimination skills to a traditional paper-and-pencil assessment (i.e., generalization across materials).

Data Collection of Dependent Variables

Each probe began with the SMART Notebook open on the computer. Four problems were presented in random order, including two of the targeted problem type and two of the nonexample problem type. Probes included two group problems, one change-addition, and one change-subtraction problem. The experimenter used www.random.org to randomize the order for all 21 probes prior to the start of the study and entered the order into a spreadsheet. Only the targeted problem types were scored for primary dependent variable (i.e., problem solving). Probes were conducted using a single opportunity method (Cooper et al., 2007). Participants were given 10 s to perform each step. If a participant did not initiate the first step within 10 s, all subsequent steps were marked as incorrect for that problem, and the experimenter advanced to the next problem.

The purpose of using a single opportunity probe *vs*. a multiple opportunity probe, where the experimenter would perform the missed step in order to provide the discriminative stimulus for the next step, was to prevent learning during probes. No LIP or error correction was given during probes. If a participant became distracted (i.e., looks away from the computer, starts engaging in stereotypic behavior), the experimenter reminded the participant to “keep working” or “eyes on computer.” Participants were praised for engagement as needed. In order to control for practice effects, 21 probes were developed with all different problems and numbers in the problems. Probes could be repeated a maximum of one time and not within the same week.

Probes delivered during baseline were collected daily during the classroom mathematics rotation on both dependent variables with a minimum of one generalization probe being administered. The experimenter recorded participant responses on baseline data sheets (Appendix D). Probes delivered during the intervention phase were conducted prior to each CBVI lesson. No probes were administered during the first two sessions of each CBVI lesson. The purpose of administering probes prior to the intervention was to get an accurate measure of participant progress with a delay between instruction and the probe to ensure the participant was acquiring the skill. Because the end of the school year was quickly approaching, during the last 6 weeks of the study, some participants did double sessions. There were sessions where the participant viewed CBVI during the first session and completed a probe during the second session with at least 1-2 hr between sessions to avoid fatigue. Caleb was the exception. He completed three double sessions during the entire study, but he had a very difficult time with the change in his schedule, so these were discontinued for him. The experimenter recorded participant responses on

Phase I/III and II/IV data sheets (Appendix D). Both dependent variables were collected daily whereas a minimum of one generalization probe was collected during each phase of the intervention.

Interobserver Agreement

Interobserver agreement was collected on both dependent variables by the secondary observer for at least 40% of the primary probes and at least 25% of the generalization probes across experimental conditions for all participants. Interobserver agreement was calculated using the item-by-item method by dividing the number of agreed items by the total number of agreements plus disagreements and multiplying by 100. An aggreement occured when both observers score a step the same (primary dependent variable) or when both observers score the discrimination the same (secondary dependent variable).

Social Validity

Social validity data were taken in the form of a questionnaire and an inteview on goals, feasibility, and outcomes of the study. The social validity questionnaire (Appendix E) was used to measure the perceptions of the participants on the effectiveness and feasibility of using CBVI to deliver problem solving instruction. This questionnaire was distributed by the experimenter after the conclusion of phase IV probes. The participant questionnaire consisted of eight “yes/no” response questions addressing their perceptions regarding the ease and appropriateness of the CBVI program and if they perceived the program to be helpful in improving their learning. Two additional open-ended questions addressed what the participants liked or did not like about the CBVI program for teaching problem solving. All questions were read aloud to the participants. Participants provided a response to the experimenter and she circled the form or wrote down the participants' responses to the open-ended questions. The secondary data collector was present during the administration of the questionnaire with all three participants. This information will be used to refine CBVI implementation in later iterations for The Solutions Project.

The experimenter also interviewed Anthony's and Neal's classroom teacher (i.e., teacher of primary setting where intervention took place) and Caleb's classroom teacher at the end of the study to provide their perceptions on the CBVI intervention for problem solving, the effectiveness of the intervention on the participants' problem solving and mathematics skills, and their overall perceptions of the intervention. The secondary data collector videorecorded the interview session with Anthony's and Neal's teacher. Caleb's teacher was absent and provided her answers in a written document (see Appendix F).

Experimental Design

The experimental design for this study was a multiple probe across participants design (Horner & Baer, 1978; Tawney & Gast, 1984). The implementation of the design adhered to the criteria established by the What Works Clearinghouse (WWW; Kratochwill et al., 2010, 2013). The study consisted of five conditions: CBVI training, baseline, CBVI Phases I and II: Group problem type, CBVI Phases III and IV: Change problem type, and maintenance. Data were collected on the number of steps performed correctly and the number of discriminations of problem type performed correctly on problem solving probes across baseline, CBVI, and maintenance conditions. The effectiveness of the independent variable on the dependent variables is established through a functional relation and determined through visual analysis of the graph (Cooper et al., 2007; Gast & Ledford, 2014; Johnston & Pennypacker, 1980).

After a minimum of five data points were collected in baseline (i.e., no problem solving instruction) with a stable or decreasing trend, the participant with the lowest baseline mean and the most stable baseline data path began CBVI instruction targeting conceptual knowledge (i.e., discrimination of problem type; Group lessons 1-2) for a minimum of two sessions. Following initial instruction on Lessons 1-2, the participant was administered a probe prior to each CBVI Phase I lesson on group problem type until reaching mastery. The mastery criterion for Phase I was set at 2 out of 4 discriminations correct and 5 out of 6 steps performed correctly across both problems of the group problem type for two consecutive sessions (i.e., 10 out of 12 steps across two problems).

Once the participant reached mastery for Phase I, he entered the CBVI instruction targeting procedural knowledge for solving group problems (i.e., solving all 12 steps of the problem; Lesson 3) for a minimum of two sessions. Following instruction on Lesson 3, the participant was administed a probe prior to each CBVI Phase II lesson on group problem type until mastery was reached. The mastery criterion for Phase II was set at 2 out of 4 discriminations correct and 11 out of 12 of steps performed correctly across both problems of the group problem type for two consecutive sessions (i.e., 22 out of 24 steps across two problems). It is important to note that initially, the experimenter had set a mastery criterion for 3 out of 4 discriminations; however, this would have held participants in the conceptual training phase too long. Due to a concern for the school ending, the criterion was lowered to 2 out of 4 discriminations (i.e., participant could identify at least the *group* problems correctly).

Once the participant reached mastery for Phase II, he entered the CBVI instruction targeting conceptual knowledge for solving change problem type (i.e., Phase

III) until reaching mastery at 2 out of 4 discriminations correct and 5 out of 6 steps performed correctly across both problems of the group problem type for two consecutive sessions. Once the participant reached mastery for Phase III, he entered the CBVI instruction targeting procedural knowledge for solving change problems (i.e., solving all 12 steps of the problem; Lessons, 6, 7, and 8) for a minimum of three sessions. Following initial instruction on Lessons 6, 7, and 8, the participant entered the intervention condition for Phase IV of the change problem type. The mastery criterion for Phase IV was set at 3 out of 4 discriminations correct and 11 out of 12 of steps performed correctly for both problems of the change problem type for two consecutive sessions.

When the first participant's data indicated a clear change in level and trend during the CBVI condition, the next participant with the lowest, but most stable baseline performance entered the intervention for the group problem type. A minimum of three baseline data points were taken prior to the second and third participants entering intervention, and every participant was probed one time prior to a new participant entering intervention to adhere to the WWC guidelines (Kratochwill et al., 2010, 2013). This process repeated until both problem types were taught to mastery across all three participants. Generalization data were collected at least once in every condition and a minimum of every eighth session to adhere to WWC guidelines (Kratochwill et al., 2010, 2013).

Procedures

General study procedures. During all conditions, the special education teachers continued their mathematics lessons as described previously in the daily instruction section but did not teach word problem solving. They did not receive training on SBI.

The experimenter and secondary data collector administered all probes and delivered all CBVI sessions.

During baseline and maintenance conditions, participants completed the probes on the computer; however, no SBI or CBVI lessons took place. During the intervention condition, participants were probed prior to each CBVI lesson. No probes were administered during the first two sessions of each CBVI lesson. Generalization probes across all conditions were administered using a paper-and-pencil format and no CBVI occurred during those sessions.

CBVI training. Once participants were prescreened and selected for participation in the study, they were trained by the experimenter to use the SMART Notebook software on the computer prior to baseline. Participants were shown how to navigate from page to page, listen to audio and video clips, drag-and-drop manipulatives and numbers, click on hints (e.g., question mark for specific verbal prompt and play button for video model of targeted skill), and write in the document. When the participants could independently perform each of the skills noted upon request, he entered the baseline condition. All three participants completed the requirements in two training sessions. Participants were familiar with SMART Notebook and most of the features because they each had previously used it in the classroom. They each just needed the tutorial and practice using this specific interface. CBVI training probes took approximately 15 min to complete.

Baseline. During baseline, the special education teacher continued to teach as previously described in the daily instruction section. No word problem instruction occurred during this time. The primary and secondary dependent variables were collected daily whereas a minimum of one generalization probe was collected during the baseline condition. The time to complete baseline probes varied by participant and took anywhere from 4 min to 12 min to complete.

CBVI. SBI was delivered through CBVI using SMART Notebook software. The experimenter opened the SMART Notebook file to the lesson and told the participant, “You may begin!” When the participant opened the first screen, the experimenter reminded the participant to “click on the picture (in task analysis), follow the directions, then check off.” The experimenter sat with the participant and monitored his behavior to make sure he stayed on-task. Due to limitations in SMART Notebook software, the experimenter had to closely monitor the participant during all lessons because these lessons involved LIP. Currently, it is not possible to deliver the prompts on timed intervals using SMART Notebook software. Therefore, if a participant was unsure how to perform a step and did not click on the question mark beside the step within 5 s, the experimenter provide the first non-specific verbal prompt, “click on the question mark (Hint 1: specific verbal prompt) to help you.” If the participant clicked on Hint 1 but did not perform the skill within 5 s, the experimenter prompted, “click on the play button beside the step (Hint 2: video model prompt).” If the participant failed to perform the step after both hints, the experimenter used “model-retest” and showed the participant how to perform the skill and then had the participant repeat the step. “Model-retest” was also used for error correction as needed when the participant made an incorrect response or did not follow directions. In addition, the experimenter monitored transitioning from slide to slide (i.e., problem to problem) to ensure the participant did not simply click through the program to the end. Each CBVI lesson took approximately 30 min to complete. When

CBVI was first introduced, both Caleb and Anthony needed each lesson divided in half, so Lessons 1-2 took 4 days to complete at 15 min per session.

Participants viewed Lessons 1-2 for two sessions (i.e., Phase I) prior to being probed. The purpose of doing so was to prevent frustration from over-testing. Upon the introduction of intervention probes, the first participant, Caleb, was getting frustrated due to the length of a probe session (approximately 20-25 min) followed by a CBVI session (25 min). Because of this, Caleb could not make it through an entire CBVI lesson following a probe. Once Caleb showed a decrease in performance during session 4 in Phase I, the experimenter decided to instate “booster” sessions where no probe was given and the participant would complete the previous CBVI lesson in entirety. Additionally, when a participant showed a decrease in performance for two consecutive sessions with no progress, a booster session with CBVI only was administered the next session. Upon meeting mastery in Phase I, participants entered Phase II to view Lesson 3 for two sessions prior to being probed. Upon meeting mastery in Phase II, participants entered Phase III and viewed Lessons 4 and 5 for a minimum of two sessions each prior to being probed. Upon meeting mastery of Phase III, participants entered Phase IV and viewed Lessons 6, 7, and 8 for a minimum of two sessions each prior to being probed. When a participant had viewed each of the CBVI lessons at least twice per phase, he was probed each session prior to repeating Lesson 2 of CBVI in Phase I, Lesson 3 of CBVI in Phase II, Lesson 5 of CBVI in Phase III, and Lesson 8 of CBVI in Phase IV until he reached mastery for that phase.

It is important to note that all three participants struggled with the discrimination criteria because they did not seem to have a solid understanding of the concept of same/different. It became evident that all three participants needed massed trials of step 3 discriminating the concept of same and different. No participant was selecting the correct concept in step 3 with consistency (i.e., guessing or always selecting different). It is recommended in the literature to teach difficult steps in a chained task using massed trial format (Bellamy, Horner, & Inman, 1979). As a result, the experimenter developed a 5-min warm-up game using a T-chart, where the participants sorted problems that were read aloud into “same” and “different” columns. This addition of the warm-up game started for each participant prior to the first viewing of Lesson 3 (Phase II: group procedural knowledge instruction). The word problems used in the warm-up game were novel problems that did not appear in CBVI or probes. Participants earned points for correctly placing the word problem in the correct column, or the experimenter could “steal” the point if the participant got it incorrect and she answered it correctly. The goal was for the participant to beat the experimenter. Once the problems were sorted, they were transferred to a new T-chart with “group” and “not group” columns. Participants practiced sorting the problems and then using the group rule with the nouns from the problem. Anthony could do this with consistency, whereas Neal and Caleb were still struggling with the concept and could not sort with consistency. After watching Caleb do a matching game on the computer during reward time, the experimenter realized he had the concept of “matches” but not “same.” The experimenter then selected 20 picture cards from a Memory® game, five pairs of matches and five pairs of nonmatches. She used example/nonexample training to teach sorting and paired the word “same” with “match” (e.g., “Bird and bird are a match. They are the same.”). This new adaptation was introduced on May 19th, prior to the fifth data point in Phase III for Caleb and the second data point in Phase III for Neal. Anthony began this version of the game with the introduction of Phase IV due to decreases in discriminations in his last two sessions of Phase III. Once both Neal and Caleb were able to sort the pictures with consistency into the corresponding column, the experimenter associated "same" with the *group* rule and "different" with the *change* rule and had participants practice stating the rule and then inserting the noun labels in the rule (e.g., "small group, small group, big group, cat, dog, pets"). By Phase IV, all three participants were discriminating "same/different" in step 3 and discriminating problem type with 3 out of 4 or 4 out of 4 discriminations each session.

Maintenance. When a participant met the mastery criteria of 3 out of 4 discriminations correct and 11 out of 12 of task anslysis steps performed correctly for both problems of the change problem type for three consecutive sessions, he entered the maintance condition. Maintenance data were collected weekly on group problem type during Phases III and IV for Caleb and Neal and during Phase IV for Anthony. Due to the school year ending, maintenance data for the change problem type were only collected one time for Neal, who met mastery of Phase IV, the following week after finishing Phase IV.

Procedural Fidelity

A nine-item procedural fidelity checklist was used by the secondary data collector to mark the occurrence of each step performed by the experimenter (see Appendix G). Steps 1-4 in Appendix G were used for probe only sessions (i.e., baseline, maintenance, and generalization), steps 5-9 were used for CBVI-only training sessions (i.e., first two sessions of each CBVI lesson), and all nine steps were used for sessions where probe was administered first followed by CBVI. Procedural fidelity data were collected for at least 25% of probe only sessions (i.e., baseline, maintenance, and generalization), at least 31% of CBVI-only training sessions, and at least 48% of all intervention sessions (i.e., probe plus CBVI) across the participants. The procedural fidelity checklist consisted of steps regarding whether or not the experimenter made the CBVI lesson available, prompted the participant to start the CBVI lesson, monitored the participant's off-task behavior, ensured the participant completed the daily assessment, and collected the participant assessment data. Procedural fidelity was calculated by dividing the number of steps completed correctly by the experimenter by the total number of steps possible (i.e., 4, 5, or 9) and multiplying by 100 to obtain a percent. The minimal level of acceptance for procedural fidelity is 90% across conditions to control for threats to internal validity.

Data Analysis

Results of each participant's daily probes and generalization probes on both dependent variables were graphed using Microsoft Excel®. The graphs were visually analyzed to look for changes in level, trend, variability and immediacy of effects across all conditions, overlap between conditions, and replications of intervention effects. A functional relation was determined if a positive change in level or trend is observed in the number of correctly performed steps or if the number of correct discriminations from the baseline to the intervention phases show an increasing slope and was replicated across the three participants.

CHAPTER 4: RESULTS

Interobserver Agreement

Interobserver agreement (IOA) data were collected on probe sessions and generalization sessions for all participants across all conditions. Interobserver agreement was determined by dividing the number of agreements by the number of agreements and disagreements and multiplying by 100. The second observer collected IOA data during baseline for 60% of sessions for Caleb (3 out of 5 sessions), 43% of sessions for Anthony (3 out of 7 sessions), and 40% of sessions for Neal (4 out of 10 sessions); the agreement was 100% for all three participants. The second observer also took IOA data during intervention for 48% of sessions for Caleb (13 out of 27 sessions), 52% of sessions for Anthony (12 out of 23 sessions), and 67% of sessions for Neal (8 out of 12 sessions); IOA was 98.9% (range 86-100) for Caleb and 100% for both Anthony and Neal. Additionally, the second observer collected IOA data during 60% of generalization probes (100% during baseline and 50% during intervention) for Caleb, 40% of generalization probes (100% during baseline and 25% during intervention) for Anthony, and 83% of generalization probes (50% during baseline and 100% during intervention) for Neal, and the mean IOA was 100% for both Caleb and Anthony and 99.5% (range 98-100) for Neal.

Procedural Fidelity

Procedural fidelity data were collected on CBVI implementation and probe administration. The second observer observed initial sessions on videotapes but attended the majority of sessions and collected procedural fidelity data in person. Procedural fidelity data were recorded on the nine-step checklist found in Appendix G. Procedural fidelity data were calculated by dividing the number of steps the experimenter performed correctly by the number of applicable steps on the checklist and multiplying by 100%.

CBVI implementation. Procedural fidelity data were collected by the second observer across CBVI sessions for 32% of Caleb's sessions (6 out of 19 CBVI sessions), 31% of Anthony's sessions (5 out of 16 CBVI sessions), and 44% of Neal's sessions (7 out of 16 CBVI sessions), and the mean procedural fidelity was 100% for all three participants.

Probe administration. The second observer collected procedural fidelity data during baseline probes for 60% of sessions for Caleb (3 out of 5 sessions), 43% of sessions for Anthony (3 out of 7 sessions), and 40% of sessions for Neal (4 out of 10 sessions). The second observer also collected procedural fidelity data during the intervention probes across phases for 26% of sessions for Caleb (7 out of 27 sessions), 43% of sessions for Anthony (10 out of 23 sessions), and 67% of sessions for Neal (8 out of 12 sessions). Additionally, the second observer collected procedural fidelity data during 60% of generalization probes for Caleb, 40% of generalization probes for Anthony, and 83% of generalization probes for Neal. The mean procedural fidelity for all probe administration was 100% for all three participants.

Results for Question 1: What were the effects of SBI delivered through CBVI on the acquisition of mathematical problem solving skills in students with ASD and moderate ID?

Figure 10 shows the effects of SBI delivered through CBVI on the acquisition of mathematical problem solving. The graph shows the number of correct independent responses performed by each participant on the task analysis steps for two problems of each problem type by experimental conditions and CBVI phases. During baseline, all three participants showed zero to low levels of correct responding for both problem types. Following the introduction of CBVI training, all three participants showed a change in level (i.e., an increase in the number of steps performed independently correct on the task analysis) or an increasing trend, with no overlapping data with the baseline performance. Visual analysis of the graph indicated a functional relation between SBI delivered through CBVI and participants' mathematical problem solving (i.e., the number of steps performed independently correct on the mathematical problem solving task analysis during probe sessions) for all three participants.

Caleb. Caleb's baseline data were low and stable with a mean score of 0 for both problem types. Once CBVI was introduced for the group problem type, an immediate effect was observed, as there was a change in level, indicated by the clear jump between the last three data points in baseline and the first three data points in Phase I of the intervention, followed by an increasing trend with a mean score of 8.4 (range 5-11). Phase II (group problem type) showed a change in level again with a mean score increasing to 18.7 (range 14-22). Although some variability existed in the data path in Phase II, there was no overlap with the data in the previous phase. Overall, there was an increasing trend for the group problem type (Phases I and II combined) across the 16 CBVI sessions. Phases III and IV (change problem type) showed consistency of the data pattern across phases when compared to the results from Phases I and II with a mean score of 9.1 (range 5-12) during Phase III and a mean score of 18 (range 16-19) during Phase IV with no overlapping data with those in the previous phase. A similar increasing trend was observed for the change problem type (Phases III and IV combined). Caleb reached the mastery criterion of 10 out of 12 steps performed independently correct across two consecutive sessions (i.e., conceptual knowledge for group and change problem types) for Phases I and III in nine and seven sessions, respectively. Caleb technically met the mastery criterion in Phase I for this dependent variable after six sessions, but one additional probe was given to see if he could reach the original mastery criterion for the number of discriminations (i.e., 3 out of 4) as well. Caleb reached the mastery criterion of 22 out of 24 steps performed independently correct across two consecutive sessions for Phase II in seven sessions, but not for Phase IV after four sessions at which point the school year ended. The mean maintenance data for group problem type during the last 3 weeks of the study was 22.6 (range 19-24). No maintenance data were collected for change problems due to the school year ending. Caleb received one booster session (as indicated with an asterisk in Figure 10) in Phase I, two booster sessions in Phase II, and two booster sessions in Phase III.

Anthony. Anthony's baseline data reveal zero correct responses throughout the baseline condition with both problem types. Once CBVI on the group problem type was introduced, an immediate effect was observed, as there was a slight change in level, an overall gradual increasing trend, and no overlapping data with the data during baseline, with a mean score of 7 (range 4-11). Phase II (group problem type) showed a change in level with a mean score increasing to 19.8 (range 16-22). There was some variability observed in the data path in Phase I. The decrease in performance during sessions 4, 7, 10, and 11 in Phase I was a result of Anthony incorrectly choosing “same” instead of “different” in step 3 for a group problem so he could cross off the problem and move to the next problem, thus shortening the probe session and moving on to a more preferred activity. Overall, there was an increasing trend for the group problem type (Phases I and II combined) with a substantial increase within shorter sessions to reach mastery during Phase II. Phases III and IV (change problem type) showed consistency of the data pattern when compared to the results from Phases I and II with a mean score of 9.1 (range 5-12) during Phase III and a mean score of 18 (range 16-19) during Phase IV with no overlapping data. There exists a similar increasing trend and clearer pattern than the group problem type for the change problem type (Phases III and IV combined). Anthony reached the mastery criterion of 10 out of 12 steps performed independently correct across two consecutive sessions for Phase I (i.e., conceptual knowledge for group problem type) after 9 sessions. Although Anthony met mastery criterion during eighth and ninth CBVI sessions, the experimenter decided to conduct an additional probe due to his inconsistency in performance. Unfortunately, Anthony decreased his number of correct responses during the next two probe sessions. The experimenter continued probes with Anthony in Phase I until an increase was observed again in session 12 at which point he moved to Phase II. Anthony reached the mastery criterion for both phases II and III in four sessions, but did not reach the mastery criterion for Phase IV after three sessions at which point the school year ended. A decrease in the number of steps performed correctly for both problem types on the last probe for Anthony (i.e., also the last day of school). The mean maintenance data for group problem type during the last 3 weeks of the study was 19.7 (range 19-21). No maintenance data were collected for change problems due to the school year ending. Anthony received four booster sessions in Phase I and one booster session in Phase III.

Neal. Neal's baseline data were low and stable with a mean score of 1 (range 0-2) for group problems and 0.5 (range 0-1) for change problems. Once CBVI for the group problem type was introduced, an immediate effect was observed, as there was a change in level indicated by the clear increase from the last three data points in baseline to the first three data points in Phase I of the intervention with a mean score of 10.5 (range 8-12). There was no overlap in data with those in the previous phase. Phase II (group problem type) showed a clear and substantial change in level with a mean score increasing to 23 (range 22-24). Phases III and IV (change problem type) showed consistency of the data pattern across phases when compared to the results from Phases I and II with both data points being 12 during Phase III and both data points being 23 correct responses during Phase IV with high stability within each phase and no overlapping data between phases. Neal reached the mastery criterion of 10 out of 12 steps performed independently correct across two consecutive sessions for Phases I and III (i.e., conceptual knowledge for group and change problem types) in six and two sessions, respectively. He reached the mastery criterion of 22 out of 24 steps performed independently correct across two consecutive sessions for Phases II and IV (i.e., procedural knowledge for group and change problem types) in two sessions each. Mean maintenance data for group problem type during the last 2 weeks of the study was 23.8 (range 23-24). Following CBVI, the number of correct steps performed by Neal on group problem type remained at 24 out of 24 steps, but decreased slightly to 20 out of 24 steps for the change problem type. Neal received two booster sessions in Phase I.

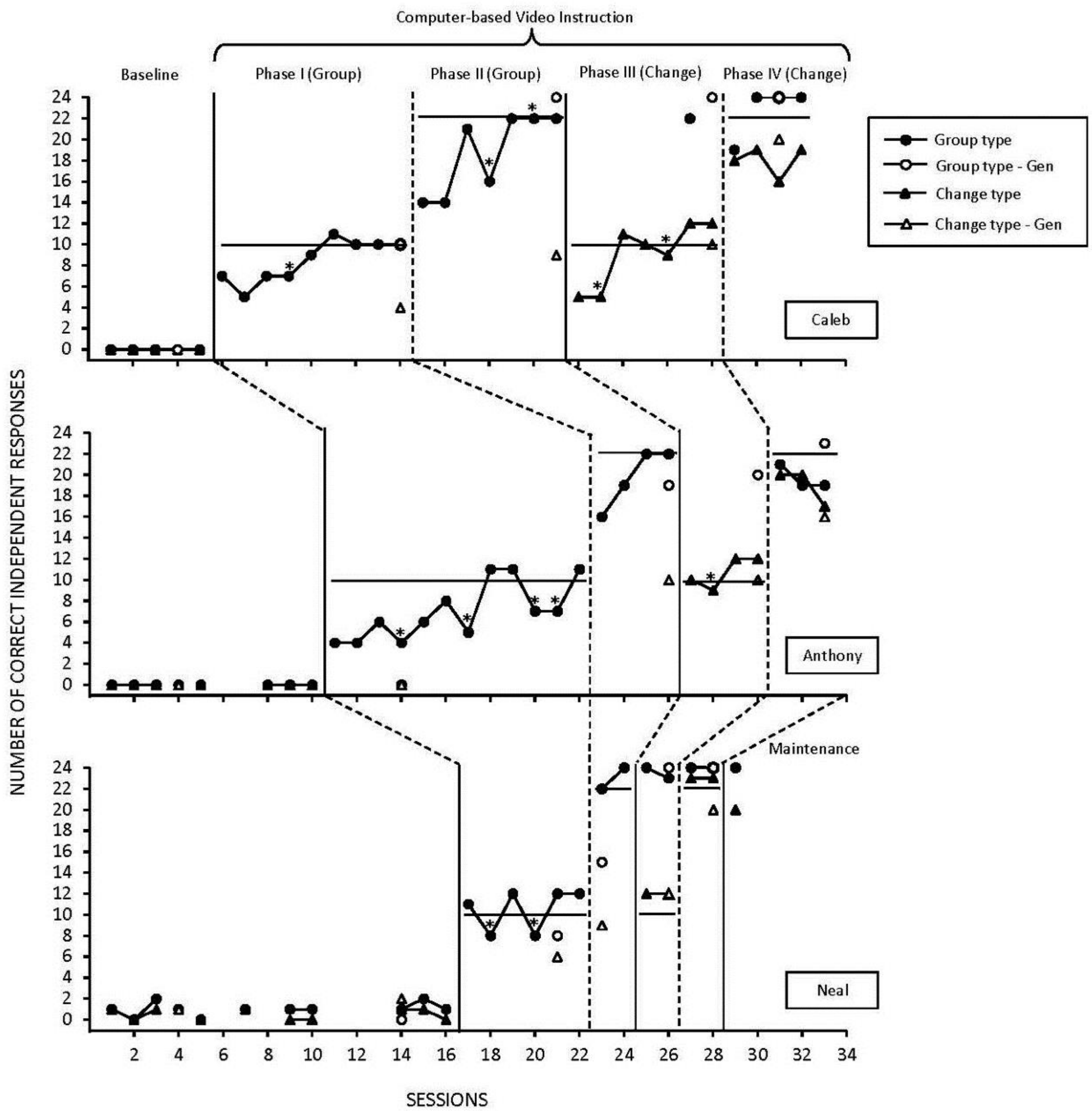

Figure 10: Number of correct independent responses on mathematical problem solving probes across experimental conditions and CBVI phases. *Note*. The horizontal solid lines within each phase represent the mastery criterion for that phase. The asterisks represent booster sessions during which the participant received a repetition of the CBVI lesson with no probe administered during that session, after showing a decrease in data point or remaining at the same response level for two consecutive sessions.

Results for Question 2: What were the effects of SBI delivered through CBVI on students' discrimination between problem types (i.e., group and change) in students with ASD and moderate ID?

Figure 11 shows the effects of SBI delivered through CBVI on participants' discrimination of problem type. The graph shows the cumulative number of independent responses (i.e., discriminations) each participant performed in order to see the rate of change over time (Cooper et al., 2007; Ferster & Skinner, 1957). An overall response rate was calculated for baseline, CBVI condition, and each CBVI phase by dividing the total number of responses recorded during each condition or phase by the number of data collection sessions (Cooper et al., 2007). The higher the overall response rate, the greater the effect. Following the introduction of CBVI training, all three participants showed acceleration, or higher overall response rates for the intervention condition than the baseline condition. In addition, the slope (i.e., rate of change) was calculated for baseline, CBVI condition, and each CBVI phase by dividing the vertical change (y2-y1) by the horizontal change (x2-x1) on a connected line. Because this was a multiple probe design, Neal and Anthony did not have continuous data in baseline, so no slope was calculated for those two participants for the baseline condition. Slope provides information that considers both vertical change (i.e., change in responses) and horizontal change (i.e., change in time) on a graph. The overall response rates, slopes, and visual inspection of the graph all indicated a clear effect of the SBI delivered through CBVI on the number of correct discriminations of problem type for all three participants. Table 2 shows the overall response rate and slope per phase for each participant.

Table 2: Overall Response Rate and Slope per Phase for Each Participant

	Caleb		Anthony		Neal	
Condition/Phase	ORR	Slope	ORR	Slope	ORR	Slope
Baseline	0.00	0.00	0.00	n/a	1.50	n/a
CBVI	2.33	2.38	2.83	2.95	3.15	3.09
CBVI-Phase I	1.44	1.50	2.83	3.09	3.00	3.00
CBVI-Phase II	2.43	2.50	2.50	2.67	2.50	2.00
CBVI-Phase III	2.57	2.67	2.75	2.33	3.00	3.00
CBVI-Phase IV	3.75	4.00	3.33	3.00	4.00	4.00
Generalization – Baseline	0.00	n/a	0.00	n/a	1.00	n/a
Generalization – CBVI	2.75	n/a	2.75	n/a	3.00	n/a

Note. ORR = Overall response rate (i.e., average rate of response over a given time period), calculated by dividing the total number of responses recorded during a period by the number of observation periods; Slope (i.e., rate of change), calculated by dividing the vertical change (y2-y1) by the horizontal change (x2-x1) on a connected line.

Caleb. During baseline, Caleb's overall rate of response was 0 discriminations per session, and during intervention it was 2.3 discriminations per session. The overall rate of response for Caleb during Phase I, II, III, and IV was 1.4, 2.4, 2.6, and 3.8, respectively, showing increases across the four CBVI phases. The slope for Caleb was 0 in baseline and 2.4 for CBVI (1.5 for Phase I, 2.5 for Phase II, 2.7 for Phase III, and 4.0 for Phase IV). Caleb's rate of change increased across the four CBVI phases.

Anthony. During baseline, Anthony's overall rate of response was 0 discriminations per session, and during intervention it was 2.8 discriminations per session. The overall rate of response for Anthony during Phase I, II, III, and IV was 2.8, 2.5, 2.8, and 3.3, respectively, showing a decrease during Phase II but an increase during Phase IV. The slope for Anthony was 3.0 for CBVI (3.1 for Phase I, 2.7 for Phase II, 2.3 for Phase III, and 3.0 for Phase IV). Anthony's change in rate across phases was fairly stable with a decrease observed in Phases II and III.

Neal. During baseline, Neal's overall rate of response was 1.5 discriminations per session, and during intervention it was 3.2 discriminations per session. The overall rate of response for Neal during Phase I, II, III, and IV was 3.0, 2.5, 3.0, and 4.0, respectively. This indicates a decrease in the overall rate of response during Phase II; Neal improved his overall rate of response by at least 1.0 during Phase IV, when compared to other CBVI phases. The slope for Neal was 3.1 for CBVI (3.0 for Phase I, 2.0 for Phase II, 3.0 for Phase III, and 4.0 for Phase IV). Neal's rate of change was relatively the same as the overall slope for Phases I and III, but decreased by 1.0 in Phase II and increased by 1.0 in Phase IV.

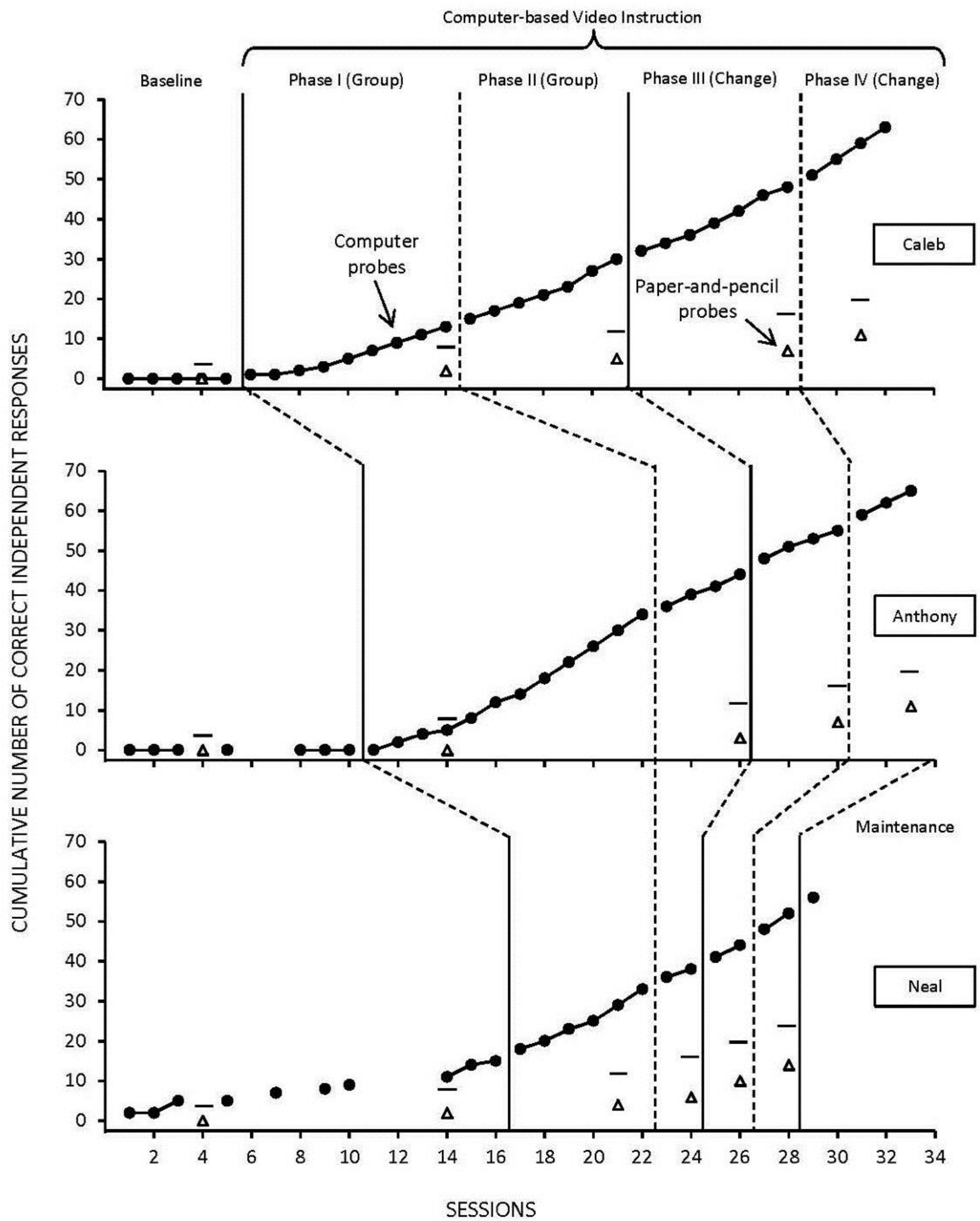

Figure 11: Cumulative number of correct independent responses during mathematical problem solving probes (i.e., discriminations of problem type). *Note.* The horizontal dash lines represent maximum cumulative number of correct responses for generalization paper-and-pencil probes.

Results for Question 3: What were the effects of SBI delivered through CBVI on the generalization of the learned mathematics skills to novel problems presented in paper-and-pencil format in students with ASD and moderate ID?

Problem solving task analysis steps. The open circles (for the group problem type) and open triangles (for the change problem type) in Figure 10 show the effects of SBI delivered through CBVI on the generalization of mathematical problem solving skills (i.e., number of steps performed correctly on the mathematical problem solving task analysis) to novel problems presented in paper-and-pencil format. Generalization data were analyzed in terms of targeted problem type by Phase (i.e., group in Phases I and II and change in Phases III and IV), non-targeted problem type (i.e., change) in Phases I and II, and maintenance effects.

Caleb. In baseline, Caleb did not perform any steps correctly for either problem type. For the group problem type, he increased to 10 out of 12 steps in Phase I and 24 out of 24 steps in Phase II. There was some generalization to the non-targeted problem type (i.e., change), as illustrated by the increase to 4 out of 12 steps in Phase I and 6 out of 12 steps in Phase II for the change problems. Some steps were the same across phases regardless of problem type, which is reflected in these scores. For the change problem type, Caleb increased to 10 out of 12 steps in Phase III and 20 out of 24 steps in Phase IV. He maintained a high level of steps performed correctly for group problem type during the generalization probes in Phases III and IV with 24 out of 24 steps correct during both probes. His generalization data were at (during Phase I and III) or slightly above (during Phases II and IV) the level of the data from the CBVI probes for targeted problem types, and he maintained a high level of steps performed correctly for the group problem type during the last two phases.

Anthony. In baseline, Anthony did not perform any steps correctly for either problem type. For the group problem type, he did not perform any steps correctly in Phase I, but increased to 19 out of 24 steps in Phase II. There was some generalization to the non-targeted problem type (i.e., change) in Phase II, as illustrated by the increase to 10 out of 24 steps in Phase II for the change problems. Again, some steps were the same across phases regardless of problem type, which is reflected in these scores. For the change problem type, he completed 10 out of 12 steps correctly in Phase III and 16 out of 24 steps in Phase IV. He maintained a high level of steps performed correctly for group problem type during the generalization probes in Phase III with 20 out of 24 steps correct and Phase IV with 23 out of 24 steps correct. With the exception of Phase I, Anthony's generalization data were at the same level as the data from the computer probes for targeted problem types, and he maintained a high level of steps performed correctly on the group problem type during the last two phases.

Neal. In baseline, Neal correctly performed a mean of 0.5 (range 0-1) steps out of 24 on group problems and a mean of 1.5 (range 1-2) steps out of 24 on change problems. For the group problem type, he increased to 8 out of 12 steps in Phase I and 15 out of 24 steps in Phase II. There was some generalization to the non-targeted problem type (i.e., change), as illustrated by the increase to 6 out of 12 steps in Phase I and 9 out of 12 steps in Phase II for the change problems. To reiterate, some steps were the same across phases regardless of problem type, which is reflected in these scores. For the change problem type, he increased to 12 out of 12 steps in Phase III and 20 out of 24 steps in Phase IV.

He maintained a high level of steps performed correctly for group problem type during the generalization probes in Phases III and IV with 24 out of 24 steps correct during both probes. Following CBVI during the maintenance probe, the number of correct steps performed by Neal on group problem type remained at 24 out of 24 steps, but dropped slightly to 20 out of 24 steps for the change problem type. His generalization data were at a similar level as the data from the computer probes for targeted problem types in Phases I, III, and IV, and lower than the computer probe data in Phase II but still remained above the level in Phase I so there were no overlap in the data. He maintained a high level of steps performed correctly on the generalization probes for the group problem type during the last two phases and during the maintenance probe, and dropped slightly during the maintenance probe on change problem type.

Discriminations. The overall response rate for the discriminations on the generalization probes was calculated. Because there was no continuous data collection on the generalization probes, slope was not calculated. See Table 2 for each participant's overall response rate on the generalization probes. In the baseline generalization probe, Caleb and Anthony were not able to discriminate problem type for any of the four problems. Neal was not able to discriminate problem type during his first generalization probe for any of the four problems, but he did discriminate two out of the four problem types in his second generalization probe. Following the introduction of CBVI, the number of correct discriminations during generalization probes increased for each participant across all phases. The overall rate of response for Caleb was 0 discrimination per session for the baseline generalization probe and 2.8 discriminations per session for intervention generalization probes, so an increase in rate was observed between conditions. Caleb's overall response rate increase from baseline to intervention generalization condition was slightly higher than his overall response rate increase for computer probes (i.e., baseline = 0 discrimination per session; intervention = 2.3 discriminations per session). Anthony's overall response rate for baseline generalization probes was 0 discrimination per session and 2.8 discriminations per session for intervention generalization probes, so a change in rate was also observed between conditions. Anthony's overall response rate increase from baseline to intervention generalization condition was the same as his overall response rates for computer probes. Neal's overall response rate for baseline generalization probes was 1.0 discrimination per session and 3.0 discriminations per session for intervention generalization probes, representing an increase in rate between conditions. Neal's overall response rates for baseline and intervention generalization were comparable to his overall response rates for computer probes (i.e., baseline = 1.5 discriminations per session; intervention = 3.2 discriminations per session).

Results for Question 4: What were the perceptions of participants and their teachers on the effectiveness and/or feasibility of learning word problem solving through CBVI in students with ASD and moderate ID?

Participants. All three participants answered a social validity questionnaire to determine: (a) their perceptions on the effectiveness of CBVI; (b) if they would like to continue using CBVI to learn to solve mathematical word problems; (c) the effectiveness of various components of the intervention (i.e., videos and graphic organizers); and (d) if they would like to use the computer to learn mathematics in the future. The results of the participants' social validity questionnaire indicated that they thought CBVI was effective, they would like to continue using CBVI to learn solving mathematics word problems, they liked the video and graphic organizer components of the intervention, and they would like to continue to use CBVI in the future to learn additional mathematics (see Table 3). There were two open-ended questions at the end of the survey asking participants what they liked or did not like about the computer program and none of the three participants answered.

Table 3: Participants' Social Validity Data (n = 3)

Items	Yes	No
1. I like doing math on the computer.	3	
2. The program was fun for me to use.	3	
3. The computer program helped me learn math.	3	
4. The computer program helped me learn to solve word problems.	3	
5. Watching videos helped me know what to do when solving word problems.	3	
6. The graphic organizers helped me solve word problems.	3	
7. I would like to do the computer program again for other math.	3	
8. I would like to learn more word problems on the computer.	3	

Teachers of student participants. Although the special education classroom teachers did not deliver the intervention, Anthony's and Neal's special education teacher was present in the classroom while participants worked on CBVI, did computer probes, and completed generalization probes. Caleb's special education teacher and Anthony's and Neal's special education teacher both were invited to observe the participants completing the CBVI, computer probes, and generalization probes at least one time. Both teachers of the participants were interviewed regarding the effectiveness of CBVI on early numeracy skills and problem solving, the perceptions of participants in their class on the CBVI mathematics instruction, critical components of the intervention they observed (i.e., graphic organizers and chants), if they felt it was beneficial, and if their students would want to continue using it in the future. Both teachers felt the intervention was beneficial, students enjoyed it, they learned mathematical problem skills and problem solving from it, and their students would like to continue to use it to improve mathematical problem solving skills in their classrooms. Both teachers noted collateral effects of improved early numeracy skills in all three participants. Caleb's teacher noted social behavior collateral effects in her work sessions with him, such as sitting and attending for longer periods of time and reduced off-task behavior. Additional comments by the teachers and their responses are shown in Table 4.

Table 4: Teacher Social Validity Data (n = 2)

Items	Yes	No
1. Did the participants enjoy doing math on the computer?	2	
2. Did the computer program help improve their math skills?	2	
3. Do you think the computer program improved their ability to solve math word problems?	2	
4. Based on what you saw, did the graphic organizers/chant help them understand and solve word problems?	2	
5. Do you think they would benefit from additional computer-based math instruction in the future?	2	
6. Do you think they would like to continue learning to solve word problems on the computer next year?	2	
7. Additional Comments: Anthony's and Neal's teacher provided two additional comments: • "I liked watching them do it [solve word problems] step-by-step. That was really cool." • "I liked watching them grow most of all. I liked watching them go through the steps, check off, self-talk, and work their way through the problems. It was really cool to watch them use the visuals [checklist and graphic organizers] and do it themselves." Caleb's teacher provided two additional comments: • "I did notice Caleb being able to sit for longer periods of time during group instruction." • "I noticed Caleb improved in his ability to count groups and add using manipulatives."		

CHAPTER 5: DISCUSSION

The purpose of this study was to determine if SBI delivered through CBVI was effective in teaching mathematical problem solving skills to students with ASD and moderate ID and to what extent the skills generalized to a paper-and-pencil format assessment. A multiple probe across participants design was used to determine the effects of SBI delivered through CBVI on mathematical problem solving, discrimination of problem type, and generalization to novel problems. In this chapter, outcomes are discussed by research question. Further, this chapter will include contributions to the field, limitations of the study, directions for future research, and implications for practice.

Question 1: What were the effects of SBI delivered through CBVI on the acquisition of mathematical problem solving skills in students with ASD and moderate ID?

Results of this study indicated a functional relation between SBI delivered through CBVI and all participants' mathematical problem solving skills for both group and change problem types. Specifically, the number of correct independent responses on word problem skills for all three participants showed a clear increase in response level (i.e., Neal) and/or an ascending trend across sessions (i.e., Caleb and Anthony) during the CBVI condition, compared to a low and stable baseline performance, with no overlapping in data between baseline and CBVI phases. All three participants met the mastery criterion of 22 out of 24 steps for group problem types and could solve group problems with accuracy. Caleb and Anthony did not meet the mastery criterion set in this study due to time constraints (i.e., school year ending), but they did exhibit a high level of correct number of steps performed in the change problem type prior to the school year ending.

In response to federal mandates, one area of current focus in teaching mathematics in special education is the use of consistent, high quality instruction delivered with effective practices on a daily basis, which provides students with ASD and moderate ID the opportunity to show growth in mathematics and problem solving skills while gaining 21st Century skills. Participants in this study were able to make progress on grade-level standards aligned to the CCSSM and the *Standards for Mathematical Practice* set forth by the CCSSM by successfully solving mathematical word problems after receiving SBI delivered through CBVI. This study contributed to existing literature because few studies have addressed higher level thinking in mathematics for students with ASD and moderate ID (Browder et al., 2008).

The findings in this study were similar to the findings of using SBI with students with learning disabilities and those who are at risk for mathematics failure in that it decreased cognitive load requirements and improved problem solving skills (Fuchs et al., 2004; Jitendra, Dupuis, et al., 2013; Jitendra, Petersen-Brown, et al., 2013; Powell, 2011; Xin & Zhang, 2009). The high quality, explicit instruction with repeated opportunities for practice helped improve participants' problem solving skills (Darch et al., 1984; Jaspers & Van Lieshout, 1994). The SBI in this study differed from the studies on SBI with students with high incidence disabilities by using additional strategies that have been found effective in teaching literacy and mathematics to students with low incidence disabilities (Browder et al., 2006, 2008; Spooner et al., 2012) in order to support the learning of the participants with ASD and moderate ID, such as task analytic instruction and systematic instruction with prompt fading and error correction. It also was delivered through CAI, specifically CBVI with embedded video modeling, which has been shown to be effective for individuals with ASD (Knight et al, 2013; Mechling, 2005; Pennington, 2010). As a result, it would be more appropriate to refer to the SBI in this study as "modified SBI."

The findings of using CBVI as a delivery method for instruction were consistent with prior literature. CAI, specifically CBVI, was effective at teaching academic mathematics content to students with ASD and moderate ID (Burton et al., 2013; Chen & Bernard-Opitz, 1993; Knight et al., 2013; Whalen et al., 2010). In addition, it addressed the need to teach more complex academic skills (Pennington, 2010). There are many factors that may have contributed to the success of CBVI in this study. Specifically, the material was presented in a progressive fashion using small steps that built upon previous content, immediate feedback was provided, participants had autonomy over their instruction, and the rate of errors were minimized (Lockee et al., 2008; McDonald et al., 2005; Skinner, 1986). The CBVI was designed using empirically-based teaching strategies to facilitate learning, such as explicit instruction, systematic instruction with error correction and feedback, and video modeling (Babbitt & Miller, 1996; Lockee et al., 2008; Mechling, 2005; Seo & Bryant, 2009; Weng, Maeda, & Bouck, 2014). The evidence-based practice for individuals with ASD, namely video modeling, was embedded to explicitly demonstrate and teach targeted skills (Bellini & Akullian, 2007). Videos were kept at 3 min or less per the recommendation of Shukla-Mehta et al. (2010). The interactivity and consistency of the screen display throughout the study increased attention span (Weng et al., 2014). Self-determination in the form of a self-instruction checklist for the participants to monitor their progress, active participation, decision making, and supportive feedback were critical components that helped improve motivation, maintain interest, and increase independence skills (Lockee et al., 2008; Seo & Bryant, 2009). This study achieved five of the six benefits of CBVI noted by Kodak et al. (2011) including generalization to another setting, reduction in organization of materials time, ability to randomize order and position of content in presentation, increased number of instructional opportunities for students, and implementation by someone other than the teacher. The study was done one-on-one with participants so there was no reduction in staff.

The positive results obtained in this study also were consistent with using task analytic instruction (Cihak et al., 2006) and systematic instruction (Collins et al., 2011; Jimenez et al., 2008) to teach chained tasks in mathematics to students with ASD and moderate ID. Specifically, the use of 12-step task analytic instruction with least intrusive prompting taught the participants how to identify key information from the word problem, to determine the word problem type, and to apply a rule in order to solve the problem correctly using a forward chaining procedure. Additionally, explicit instruction, specifically the “model-lead-test” approach, and discrimination training further strengthen the participants’ learning to solve mathematical word problems. Both explicit instruction and discrimination training has been successful in teaching mathematics to students with high incidence disabilities (Baker et al., 2002; Darch et al., 1984; Gersten et al., 2009; Stein et al., 2006); however, their application in teaching students with ASD and moderate ID is relatively limited (Cihak et al., 2006; Neef et al., 2003; Rockwell et al., 2011; Rockwell, 2012). Browder et al. (2008) suggested that some mathematics skills may need more explicit instruction to teach students with ASD and moderate ID, rather than systematic instruction alone. This study supported their hypothesis and indicated that explicit instruction and discrimination training as a part of the intervention may have an added value to its effectiveness for students with ASD and moderate ID.

The individual components of this intervention likely addressed the executive functioning and linguistic deficits that have prevented students with severe disabilities, including those with ASD and moderate ID, from effectively solving mathematical word problems (Donlan, 2007). Graphic organizers helped relieve working memory deficits by providing visual representations of the problem situation to help participants organize key information (Zahner & Corter, 2010). Rules, taught in a chant with hand motions in this study, promoted schema induction by relating the conceptual knowledge of the problem type to the procedural knowledge of the problem type. CBVI reduced the amount of external and irrelevant stimuli helping with attention deficits in the participants with ASD (Bellini & Akullian, 2007; Delano, 2007; McCoy & Hermansen, 2007; Sherer et al., 2001; Shukla-Mehta et al., 2010). Video models taught metacognitive strategy knowledge by modeling think-alouds to help participants explain their reasoning (Jitendra et al., 2009). Read alouds aided with reading requirements for the non-proficient readers (Browder et al., 2007; Neef et al., 2003). Explicit instruction on story grammar and story mapping helped with language comprehension (Xin et al., 2008). Virtual manipulatives helped with early numeracy deficits (Bouck et al., 2014). Finally, the task analytic checklist helped with self-regulation of participants progressing through problem solving independently (Cooper et al., 2007). In addition, this study controlled the linguistic difficulty of the problem. Strategies included using one sentence per line, using simple sentences (subject, verb, predicate), placing pictures above the key nouns, ordering of the key information in the word problem sequentially, and refraining from including extraneous information (Fuchs & Fuchs, 2007). Word problems were also created using familiar names and activities from participants' daily lives. One component that differed from prior literature was the self-instruction component. Due to reading deficits in participants, a task analysis for problem solving embedded into a self-instruction checklist with picture and audio supports was used in place of heuristics traditionally found in SBI (e.g., *FOPS*; Jitendra et al., 2009; *RUNS*; Rockwell et al., 2011). Participants were able to self-monitor their progress by checking off steps as they were completed. This is also a form of metacognitive strategy instruction (Jitendra, Dupuis, et al., 2013; Powell, 2011).

The results of this study aligned with the findings from Neef et al. (2003), which taught a young man with moderate ID to solve *change* problems, and the Rockwell studies (2011, 2012), which taught three elementary-aged students with ASD to solve *group*, *change*, and *compare* problems through SBI. The participants in this study had ASD with a comorbid intellectual disability. Like Neef et al. study, this study included students with moderate ID. Also like Neef et al. study, it took many sessions for the participants to master the first problem type, particularly during the conceptual knowledge of learning (Phase I). Caleb took 16 probing sessions to reach mastery and 9 CBVI and booster sessions to reach mastery on probes. Anthony took 10 probing sessions to reach mastery and 12 CBVI and booster sessions to reach mastery on probes. Neal took eight probing sessions to reach mastery and eight CBVI and booster sessions to reach mastery on probes. Neal was the only participant to meet mastery on change problem type; it took him four probing sessions and eight CBVI and booster sessions to reach mastery on probes. Anthony was able to solve both addition and subtraction problems but did not meet the set mastery criterion. The participant in Neef et al. study took 80 sessions to master change problem type with both change addition and change subtraction problems. This was an expected finding, as students with low incidence disabilities require more repetition and trials to master a skill. The participants in Rockwell et al. (2011) only required 3 weeks of instruction to mastery all three problem types. Neef and colleagues also noted it might be unnecessary to separate out each precurrent behavior and teach to mastery before moving forward. Similarly, this study found that once taught, skills could be chunked and the number of steps reduced once skills were acquired. One major difference between this study and those by Neef et al. and Rockwell et al. (2011) studies was that they used missing initial and medial position numbers, making the problem solving more difficult. This study only used missing final positions. It is also important to point out that in both Neef et al. and Rockwell et al. (2011) studies, the participants could read, knew number facts rotely, and could solve problems with missing numbers in each position; contrarily, in this study, the participants had relatively limited literacy and numeracy skills at the start of the study.

Anecdotally, both the experimenter and second observer noticed that all three participants in this study gained a better understanding of the previous phase's content while learning the new problem type or procedure. Two explanations are possible. First, many of the steps carried over from the group problem type to the change problem type (i.e., Step 1: Read the problem; Step 2: Find the whats; Step 3: Same or different; Step 4: Find label in question; Step 7: Find how many; Step 8: Fill-in number sentence; Step 9:

"+" for change-addition problems; and Step 12: Write answer [change-addition could still potentially be solved even with the incorrect graphic organizer]); so once participants achieved mastery for group problems, they were able to use the skill and apply it to the change problem, therefore progressing more rapidly. Second, researchers in mathematics have found the development of conceptual and procedural knowledge influence one another, but children's initial conceptual knowledge predicted greater gains in procedural knowledge, and sequentially gains in procedural knowledge then resulted in conceptual gains (Rittle-Johnson, Siegler, & Alibali, 2001). This may also explain why it took participants so long to reach mastery in Phase I, but less time in Phases II, III, and IV. All three participants had a conceptual understanding of addition at the start of the study, but no prior knowledge or experience with problem types. It is probable that if the sequence of the lessons were changed so participants were taught procedural knowledge of solving group problems from beginning to end first, prior to introducing the concept of discriminating problem types, they would have made more accelerated gains. In addition, participants would have experienced the naturally occurring reinforcer of solving a problem in entirety and finding a solution; whereas, there was no naturally occurring reinforcer for discriminating problem type first, because participants simply moved to the next problem after step 6 in Phase I.

Despite clear patterns showing increases in the number of correct independent responses of all three participants from baseline to CBVI for both problem types, Anthony showed a decreasing trend in response during Phase IV. It is important to note that this was not a decrease in skills but a lack of motivation to complete the task even with his token economy in place. When asked how to solve a problem, Anthony would verbalize what needed to be done but would not physically perform the skill on the computer in order for the performed steps to be counted as correct independent responses. In addition, Anthony's three sessions during Phase IV coincided with his last 3 days in elementary school, and he was leaving the following day to go to Disney World. The excitement of going to Disney World may have affected his performance and motivation to complete work.

There also was some variability in the data, which is to be expected from day to day when working with students with moderate ID accompanied by the behavioral challenges of ASD; however, the variability observed in Phase I across all participants, as noted by drops in data at some points along the data path, was a result of a potential flaw in the procedures. The participants were taught that if two things were the "same" in step 3, then it was *not a group* problem and they should cross off the problem and move to the next problem (i.e., because *change* problems had not been taught during Phase I, participants were not expected to progress through steps 4-6). As a result, when a participant incorrectly selected "same" instead of "different" in step 3, he consequently missed steps 3, 4, 5, and 6, which were 4 out of the 6 possible responses per question. Anthony chose to do this as much as possible because he quickly figured out that he could only do three steps in each problem and progress through the probe much quicker. This may have explained why it took Anthony much longer to reach mastery in Phase I than the other two participants.

There were a few unexpected findings related to the first research question that are worthy of discussion. In Phase IV of this study, participants were asked to solve change-addition and change-subtraction problems. One interesting finding was related to the graphic organizer. The graphic organizer for the change problem confused all three participants more than it helped them. Both Neal and Anthony were able to solve both problem types, but reverted back to the touch point strategy (i.e., counting by touching imaginary touch points on the numerals which correspond to the value of the number) to find their answer for step 12 after attempting to make sets and solve. Anthony never correctly made sets or solved problems using the virtual manipulatives, but was able to produce the correct solution for both change-addition and change-subtraction problems in the first two probes of Phase IV. Neal was able to make sets and solve, but would check his answer using touch points prior to writing. The only step Neal missed was inserting the wrong symbol for subtraction problems (i.e., selected "+"). Caleb only made sets correctly one time for a change-addition problem among the eight change problems he completed in Phase IV. He was able to solve two change-addition problems correctly, one without making sets correctly. For the other two change-addition problems, he marked as subtraction but still did not make the sets properly even when solving incorrectly. He was not able to solve any subtraction problem correctly. A discussion of this error pattern with his teacher suggested that Caleb had only worked on subtraction problems a handful of times during the school year, so subtraction was an entirely new concept for him. One potential reason for the confusion with the change graphic organizer may be the abstractness of the concept of the cabinet to represent addition, and the trashcan to represent subtraction. Students with ASD tend to have difficulty with abstractness. Another potential reason may have been that the graphic organizer for the change problem presents both operations, which required very different physical manipulations of the virtual manipulatives. For example, to solve a change-addition problem, participants made an initial set, then added the change amount to the cabinet using additional manipulatives, and then moved all manipulatives to the end oval to count. For change-subtraction, participants made an initial set just like they did in change-addition, but then moved manipulatives from that already existing set to the trashcan, and then moved the remaining counters in the initial oval to the end oval to count. Correct problem representation is essential to achieving procedural gains, especially as more problem types are introduced (Rittle-Johnson et al., 2001); therefore, revisions to the graphic organizer for the change problem are important in the future to better support the learning needs of students with ASD and moderate ID. It may be beneficial to represent change-addition and change-subtraction on different graphic organizers, especially when students are first learning the procedure of solving change problems, or to use very concrete items to show the change-addition and change-subtraction areas, such as a large plus sign and a large minus sign in place of the cabinet and trashcan.

Results for Question 2: What were the effects of SBI delivered through CBVI on students' discrimination between problem types (i.e., group and change) in students with ASD and moderate ID?

Overall response rates, rates of change (i.e., slope), and visual analysis of the cumulative data on the discrimination between problem types indicated that SBI delivered through CBVI was effective in teaching the participants to determine the correct problem type when given group and change word problems. During baseline, the overall response rate was 0.0 for Caleb, 0.0 for Anthony, and 1.5 for Neal. During the CBVI condition, the overall response rate was 2.3, 2.8, and 3.2 for Caleb, Anthony, and

Neal, respectively. As noted previously, discrimination training was a major component of this intervention for teaching differentiation of problem type, similar to Rockwell et al. (2011) and Rockwell (2012). In Rockwell et al. (2011) study, the participant had difficulty with discrimination of problem type, so the experimenters added a sorting activity during group problem instruction using problems from all three problem types, and had the participant sort the problems into belonging or not belonging to the targeted problem type. Once the participant sorted, she then had to explain her reasoning using the presence or absence of salient features for each problem type. Rockwell used the same strategy in her dissertation study (2012).

In this study, the participants' correct discrimination did not occur as immediately as that in Rockwell et al. and Rockwell studies. Although all three participants successfully demonstrated labeling pictures as "same" or "different" during the prescreening, they experienced difficulty discriminating between "same" and "different." The experimenter discussed Caleb's and Neal's difficulty with discrimination with the mathematics expert, and he stated it was possible they may be too young to discriminate (first and second grade, respectively). During Phase I for Caleb, he reached the procedural mastery criteria of 10 out of 12 steps for two consecutive sessions but not 3 out of 4 discriminations. One additional probe was given to see if he could reach the discrimination criteria, and he did not. It was decided at this point to move him forward and lower the discrimination criteria to prevent participants from not progressing through phases, especially if the younger participants would not be able to achieve mastery of discrimination. The warm-up game was added at the beginning of Phase II to see if building a solid understanding of the concepts of "same" and "different" would help. The initial game was similar to Rockwell's, and participants sorted the word problems into a T-chart with "same" and "different" columns, and then transferred them into "group" and "not group" columns. Anthony was very successful with this during the game, but did not exhibit mastery in Phase II because of motivation problems. Caleb and Neal still had difficulty with this and continued to be inconsistent with discriminations in Phase II. The game was modified to the Memory card version where they sorted pairs of cards into "same" or "different" columns and practiced using the nouns in the corresponding chants towards the end of Phase III. By Phase IV, all three participants were discriminating with accuracy during probes. Without the addition of the warm-up game and the Memory card, participants in this study may not have finally reached mastery of this dependent variable (i.e., 3 out of 4 discriminations) with consistent, purposeful discriminations. One major difference between Rockwell studies (2011, 2012) and this study is that Rockwell included participants who had mild to no intellectual disability, could read, and had much more expressive language, whereas the participants in this study did not have the same level of reasoning skills, reading abilities, or expressive language abilities. Thus, the salient features of each problem type were simplified and taught using the corresponding chant and by analyzing the problem to see if it was about different things or the same thing.

Understanding that group problems are about two *different* groups of things that are joined together by some commonality and change problems are all about the *same* thing that is changed dynamically over time are critical to discriminating group and change problem types, but this cannot be done without the foundational concept of same and different. An important implication for future iterations for teaching discriminations of problem type to students with ASD and moderate ID is to consider adding the concept of same and different as a prerequisite skill, or it could be taught concurrently during group procedural knowledge instruction.

One unexpected finding from this study was that discriminative stimuli for the order of the task analysis varied by student. Anthony attempted to circle all nouns in the word problem, including the “whats” (step 2) and the “label in the question” (step 4), prior to determining “same” or “different.” This unexpected finding actually worked much better for discrimination because participants would have had three words to help them determine same thing or different things versus two words. Lesson 4 modeled this new sequence for participants (i.e., step 1, step 2, step 4, and then step 3). It is important to note here that although the experimenter modeled chunking steps 1, 2, and 4 together during the video model when the change problem type was introduced, the participant could perform them in the order he preferred and the order on the task analysis did not change. Participants also tended to discriminate better if the targeted nouns in steps 2 and 4 were high frequency sight words, familiar words, or easy to decode words. For example, “cats, dogs, pets” are much easier to read and say than “trucks, cars, vehicles.” This finding is consistent with the recommendations by Fuchs and Fuchs (2007) for alleviating linguistic difficulty in mathematical word problems. The videos used in change problems to demonstrate the action/stimuli may also alleviate this problem and provide a method for using more complex and unfamiliar nouns. In the future, anchoring the instruction using an introductory video to provide a context for a set of word problems may also strengthen understanding (Bottge et al., 2010).

Results for Question 3: What were the effects of SBI delivered through CBVI on the generalization of the learned mathematics skills to novel problems presented in paper-and-pencil format in students with ASD and moderate ID?

Visual analysis of Figures 10 and 11 (open data points), as well as overall response rates (Table 2), showed that participants were able to generalize their problem solving skills, including both completing steps on the task analysis and discriminations, to novel problems in paper-and-pencil format.

Generalization is an important variable for consideration when teaching problem solving because one of the ultimate goals is for students to generalize learning to real-world problems (Van de Walle, 2004). Instruction should be planned with strategies to facilitate generalization (Cooper et al., 2007; Stokes & Baer, 1977). This study implemented multiple exemplar training (Stokes & Baer, 1977) in that during each CBVI training session and the probe, the participants were exposed to different and novel problems, presented in the same sentence structure and format. There were 104 different problems in probes, in addition to the 32 trained problems used in the CBVI lessons. In addition, CBVI lessons on the change problem type used videos of real-world problems in action via point-of-view modeling or computer animated simulations to assist with determining the operation. The benefit of this was the ability to provide a variety of stimulus and response examples using real-life environments or computer-simulated environments, as well as the ability to program common stimuli (Mechling, 2005). This provided a very cost-effective way to program common stimuli and train multiple exemplars of real-word applications without leaving the classroom. The generalization probes in this study targeted participants' generalization of skills across settings (i.e., computer to table) and materials (i.e., computer to paper-and-pencil, concrete manipulatives, problem solving mat, and written word problems). The exposure to a large set of word problems may have contributed to the participants' skill to generalize to the novel, paper-and-pencil format. This is a key finding because paper-and-pencil format is a similar format to the state's alternate assessment. Although not exactly the same, Rockwell et al. (2011) measured the participant's generalization to solving word problems with unknowns in the initial and medial positions, and Rockwell (2012) addressed generalization to word problems with irrelevant information. Both studies by Rockwell and her colleagues looked at a different form of generalization to novel problems. Along with the Rockwell studies, the findings on generalization of this study support the effects of SBI with additional effective practices on generalized mathematical word problem solving.

In addition to the inclusion of multiple exemplar training, the generalization effects may have been due to the availability of the problem solving mat and self-instruction checklist, both of which served as visual prompts and self-directed learning strategies (Cooper et al., 2007). These were used in place of the heuristic commonly found in SBI literature, such as *RUNS* (Rockwell et al., 2011) and *FOPS* (Jitendra, 2008) to support students with ASD and moderate ID, who may not have the working memory capacity or literacy skills to relate the letters of the heuristic to the steps for problem solving. Although the participants used the self-instruction checklist and the problem solving mat in a virtual format during CBVI training sessions, they had access to the same self-instruction checklist and a similar problem solving mat during generalization probes, but just in a hard copy format. The presentation of common stimuli may have further promoted the participants' success in generalization (Cooper et al., 2007; Stokes & Baer, 1977). Anecdotally, on the last day of this study, the experimenter handed Neal a blank sheet of paper and asked him to re-create the group and change graphic organizers. The secondary data collector and Neal's teacher both observed as he drew both group and change graphic organizers with accuracy, including all major parts. This is an important finding because it suggests that as students become more fluent with skills, some materials, prompts, or additional supports that have guided their behavior may be faded over time. Breaking the problem solving steps into steps using a task analysis, incorporating that task analysis into a self-monitoring checklist to promote student-led instruction, and then adding visual and auditory supports helped reduce cognitive load and dependency on work memory. The self-instruction checklist combined with a template that provided structural organization and visual representations of each problem type, all worked together to reduce cognitive load. As students become more proficient with the steps, they may be able to rely less on these supports, and eventually some could be faded to more naturalistic things, such as the number sentence, or students could draw or write the supports like Neal did, thus promoting schema-broadening instruction (Fuchs et al., 2008, 2009).

An important finding worth mentioning is that in addition to generalizing the skills on paper-and-pencil, participants also exhibited using "think alouds" modeled in the video models while progressing through generalization problems. Although this was not a direct measure in this study, the participants were recorded on videotape using think aloud strategy. This suggests that students with ASD and moderate ID can generalize metacognitive strategies if supported through multiple generalization strategies (e.g., teaching sufficient stimulus examples).

Results for Question 4: What were the perceptions of participants on the effectiveness and/or feasibility of learning word problem solving through CBVI in students with ASD and moderate ID?

Participants and teachers both reported that the intervention was effective at improving participants' problem solving skills and their early numeracy skills. Participants and teachers also reported that the intervention was enjoyable. These findings are similar to the social validity findings from the participants and parents in Rockwell et al. (2011) and Rockwell (2012) studies supporting the importance of teaching mathematical word problem solving skills and the use of SBI. Similar to the findings in the CAI and CBVI literature (Ota & DuPaul, 2002; Mechling, 2005; Pennington, 2010; Soares et al., 2009), teachers of participants in this study also reported that CAI produced positive collateral effects that expanded in their instruction time with the participants. Within the study, Caleb showed a reduction in off-task behaviors and improved his time-in-seat to periods up to 40 min. Anthony progressed from needing to be prompted to complete each step at the beginning of the study to using the checklist to progress through an entire problem independently. All three participants improved their ability to self-monitor and self-direct their learning, an important advantage of CAI and CBVI (Mason, Davis, Boles, & Goodwyn, 2013). According to the teachers' social validity interview results, all three participants showed collateral improvements in their early numeracy skills in the classroom as well. The positive reports from the teachers of the participants may be contributed to two factors. First, the structure of CBVI taught a chained task with sufficient support guiding students through each step. The CBVI program offered carefully designed instruction that teachers may not have known in teaching mathematical word problem solving. In fact, neither teacher had heard of SBI prior to this study, and neither teacher knew about problem structure. Second, participants made noticeable gains in word problem solving and many related skills (e.g., using think alouds, using a checklist to self-monitor and complete a chained task independently, and solidifying early numeracy skills) that were absent prior to the intervention. Teachers were able to truly see the participants' potential in learning more complicated mathematics skills, something they may not have known was possible prior to the intervention.

Limitations of the Current Study

There are several limitations in the study. These limitations concern the design of the intervention, the selection of the software, and the duration of the intervention.

Design limitations. This study used an intervention package. Because the intervention incorporated several components, including task analytic instruction, read alouds, video modeling, explicit instruction, rules, graphic organizers, story grammar instruction and story mapping, and the use of virtual manipulatives, it cannot be determined which component (or combination of components) had the effect on the number of steps performed correctly. Although the inclusion of the individual components was based on strong literature support for teaching mathematical skills to students with ASD and moderate ID, future researchers should look at each component individually with this population to determine potential effects. A component analysis of the intervention package may be of special value in future research.

Another design limitation relates to revisions and added components needed to further promote the participants' learning. Some revisions to the procedures were necessary during the course of the study, such as the addition of booster sessions, the warm-up game, and teaching participants to do steps 1, 2, and 4 together during the change problem type. The decisions were made because this is the first study with such intensity to teach students with ASD and moderate ID to solve mathematical word problems, and some modifications were essential. Booster sessions were needed to review content in entirety in order to prevent frustration during probes. If participants made no progress or showed drops in data, it was in their best interest to review the material rather than administering probes without the student having a chance to make gains in knowledge. The warm-up game was needed to teach the concept of same and different on the task analysis using massed trials. Deficits in knowledge of this concept was inhibiting participants from making progress and developing firm conceptual knowledge of problem type. Finally, modeling a new sequence of steps 1, 2, and 4 was necessary because the natural discriminative stimulus for determining "same" or "different" was different for the participants than originally designed. Participants could still choose their preferred sequence during probes. The advantage of using single-subject design is that some modifications can be made during the study; however, too many changes can affect the internal validity. This study tried to control for this by only making changes at the beginning of a new phase, indicated by a phase line, so the modifications were controlled systematically and were replicated across remaining phases and across participants.

Software. Several limitations pertained to the feature limitations in the technology software, SMART Notebook. Text-to-speech with highlighting is highly needed as a curricular adaption for this population who struggle with reading, including fluency and comprehension. Although the word problems were read aloud to the participants upon clicking on them, there was no highlighting, so participants who were not proficient readers or who got distracted and looked away could not follow along. This feature would have been extremely beneficial for participants who could not read critical words, such as the “whats” or the label in the question, and when they needed to review the third sentence in change word problems to look for the change action to determine the correct operation. It also would have been beneficial if participants were able to touch specific words in the problem and have them read aloud.

Additional limitations of the SMART Notebook software were the inability to provide participants with LIP on scheduled intervals of time, the inability to provide immediate error correction, and the inability to provide intermittent reinforcement. This required the experimenter to have a more involved role in the CBVI training sessions than anticipated. During CBVI, the experimenter had to remind the participant to click on the step if no response was made within the desired amount of time, and she had to prompt the participant to click on the question mark and play icons for LIP. For error correction, the experimenter had to provide the prompt to redo the step or perform a model-retest. For example, if the participant placed too many manipulatives on the graphic organizer, the experimenter stopped him and prompted him to recount. Also, Skinner (1986) recommended CAI incorporate variable ratios of reinforcement to improve motivation, but SMART notebook did not have the option to program intermittent reinforcement for correct responding. This could have potentially helped with Anthony's motivation.

A final limitation of the SMART Notebook software was related to technical glitches. SMART Notebook frequently crashed or did not open, especially if file sizes were large or had links to external videos, sounds, or other file pages within the program. It was very inconsistent when saving files, especially ones including external videos, sounds, and links, as previously saved changes often would not appear the next time the file was opened. In further replications, educators and interventionists should preview the files in entirety before training.

Duration of data collection. Time constraints were another major limitation of the study. The school year ended before two participants could reach mastery in the final phase, with no maintenance data available for the change problem type for all three participants. Both Caleb and Anthony showed promise that they could achieve mastery solving change problems based on their increases in correct independent responses during Phase IV, but the time constraints prevented them from demonstrating mastery within the study.

Recommendations for Future Research

This study provides several recommendations for future research. First, this study showed that students with ASD and moderate ID could solve *group* and *change* problems, whereas Neef et al. (2003) showed that a young man with moderate ID could solve *change* problems. Future researchers should investigate if students with ASD and moderate ID can solve *compare* problems and discriminate the three different problem types. In addition, future research should investigate if students with ASD and moderate

ID can solve problems with unknowns in the initial and medial positions as Rockwell et al. (2011) showed in students with higher functioning ASD, and whether they can solve problems with sums greater than 10.

Second, the computer was the vehicle for instructional delivery in this study. As discussed previously, the use of SMART Notebook software presents several challenges and limitations. Future research is warranted to examine critical design features for optimal learning, such as text to speech with highlighting, immediate feedback, delivery of LIP on scheduled timer, intermittent reinforcement, interface layout, and making the ability for a student to respond as efficient as possible. Automatic data collection and reporting would make it more alluring to educators as well. Additionally, future research may examine if teachers using scripted lessons could produce the same effects, whether CBVI leads to faster skill acquisition than face-to-face instruction, and whether teacher instruction paired with CBVI could accelerate the acquisition of problem solving skills for students with ASD and moderate ID. Due to the nature of the CBVI that allows students to receive instruction with limited teacher support, it could be used as a supplemental instruction, or even a booster for students who may not be achieving at the same levels as other peers during small group instruction.

Third, future studies should investigate if graphic organizers, the problem solving mat, and the self-instruction sheet could be faded over time. Future studies also should redesign the *change* graphic organizer. One option would be to make the addition and subtraction sets less abstract such as by using large plus and minus signs in place of the cabinet and garbage can. Another option would be to separate out addition and subtraction when first teaching so only one operation is performed on the graphic organizer, and then combine them once students have mastered the skill. Schema-broadening instruction, where the use of schematic diagrams (i.e., graphic organizers representing problem types) is faded to using the number sentence only, has been successful with students with high incidence disabilities (Fuchs et al., 2004). Another possibility would be fading the support of the task analysis by chunking steps together in the task analysis, and potentially progressing towards the use of a heuristic that students could memorize, like *RUNS* (i.e., "<u>R</u>ead the problem," "<u>U</u>se a Diagram," "<u>N</u>umber sentence," and "<u>S</u>tate the answer," Rockwell et al., 2011). If these individual supports could be faded, students would have a better chance for generalizing the skills to different settings and situations.

Implications for Practice

The findings of this study provide several areas for practical implications. First, despite the positive effects of CBVI demonstrated in the current study, creating CBVI is very time consuming. As noted in the literature (Higgins & Boone, 1996), SMART Notebook is a form of authoring CAI software that serves as a template for designing instruction, which provides flexibility in designing instruction, selecting content, and embedding evidence-based and research-based practices, but also can be very time consuming. This held true for this study. After the initial formats were built, each CBVI lesson took approximately 10-15 hr to create and each computer-based probe took 30 min to create. Educators should consider the pros and cons of commercial versus authoring software when selecting CAI or CBVI to teach mathematical word problem solving. When purchasing commercial software, practitioners should look for research-based software programs that have easier customizability options, such as incorporating students' names, using high preference activities/locations for the context, and selection of reinforcers and schedules of reinforcement.

Another implication for practice relates to students' prerequisite skills. It became evident throughout the implementation that a preceding unit solidifying early numeracy skills (e.g., making sets with 1:1 correspondence using virtual manipulatives, solving simple addition and subtraction problems with numbers using virtual manipulatives on the graphic organizers) and the concept of same and different may have greatly benefitted students and reduced time to mastery. Because the participants were learning many essential skills concurrently, it may have overloaded their working memory and increased the amount of time in intervention. This was apparent with the addition of the warm-up Memory game sorting cards into "same/different" columns. Once participants grasped the concept of same/different with accuracy and consistency and could associate it with the group and change rules, the intervention went much faster, and all three participants began discriminating problem type with 3 out of 4 or 4 out 4 discriminations. It may be beneficial for educators to preteach some skills in order to make the instruction more efficient (i.e., representing a number sentence with sets, combining sets to add, decomposing sets to subtract, understanding the concept of same/different).

Third, although it is necessary initially for the participants to use mathematical manipulatives and graphic organizers to conceptually understand the combining of sets to add in group problems, or creating an initial set and then adding to it or taking away from it in change problems, for students who know basic number facts or who have developed other strategies such as using touch points to add/subtract, the support of using mathematical manipulatives could be faded to support more efficient problem solving.

There were instances with both Neal and Anthony where creating sets (step 10) and moving to count and solve (step 11) became cumbersome and confusing because they displayed more efficient way to perform the same skills. For example, during procedural *change* probes, Neal and Anthony attempted to make sets and solve, but then reverted to using their methods for adding and subtracting prior to writing the answer. In addition, Anthony provided a great example of the need for differentiating critical *vs.* nonessential steps in a task analysis (Test & Spooner, 1996). In this study, the participants followed 12 steps in the task analysis for each problem, which required a great amount of physical effort, especially for Anthony who did not like to emit. Anthony knew how to find the numbers in the word problem and transfer them into the number sentence without needing to circle them in the word problem (step 7). Anthony's early numeracy skills were much more advanced than his peers. He was able to identify basic addition facts and could use a touch point strategy to subtract. Both of these required less effort than making sets and combining them to add or decomposing them to subtract in order to solve (steps 10 and 11). CAI has the ability to provide this individualization without having to create an abundance of materials because the task analysis for problem solving could be tailored to the steps each student needs to perform.

Finally, teachers in a classroom have more flexibility to gauge students' progress and adapt instruction based on their individual needs and/or progress. Because this was a research study, participants were given frequent probes to measure progress. In a special education classroom, or if this were used in an inclusive classroom, it may be more beneficial to provide students with continuous CBVI lessons over the course of a week and probe weekly or biweekly to measure progress and avoid repeated testing. In this study, it was fairly easy to gauge students' readiness to move on by observing how many prompts or error corrections they needed. Caleb, for example, could have benefitted from more CBVI sessions; whereas, Neal potentially could have done one session in some cases. In a classroom, immediate error correction on probes, either after a problem or even after a step, would have been more beneficial than letting a student progress through an entire probe and make mistakes without any knowledge of what was missed. For example, if a student mistakenly selected "same" for a group problem, an immediate error correction to move the circle to "different" would have allowed him or her to continue through the remainder of the steps and get the additional practice.

Summary

Standards-based reform has changed the field of special education in that it required students with severe disabilities to access the general curriculum, which has led to higher academic expectations for students with severe disabilities. This study addressed the need for teaching academic mathematics, but dually addressed the "so what" factor that many special education experts question when the subject of teaching academics to students with severe disabilities is discussed. Problem solving is arguably one of the most critical, functional mathematics skills for individuals with severe disabilities to have because it is the basis for solving real-world problems (Van de Walle, 2004). The problems in this study used contexts with relevant applications to real-world situations and activities that were meaningful to the students and their everyday lives (Browder, Trela, et al., 2012; Collins et al., 2011). In addition, mathematical problem solving is likely to build independence and self-determination as demonstrated in this study, and eventually employability skills in individuals with ASD and moderate ID.

This study addressed many limitations in current literature. First, it targeted teaching mathematics to students with ASD and moderate ID, moving beyond basic *numbers and operations* and *measurement* skills of time and money. Second, not only does this study add to the limited literature that students with ASD and moderate ID can learn grade-aligned mathematical content, but also it shows they can learn the higher order thinking skill of mathematical problem solving. This study provides new evidence that students with ASD and moderate ID can learn to solve mathematical problems using SBI with embedded evidence- and research-based practices for students with severe disabilities and those with ASD, and it successfully showed that participants could generalize to novel problems in a paper-and-pencil format. In addition, it addressed the need for more empirical studies showing that CBVI can be used to teach mathematics to students with ASD and moderate ID, as well as the need for CBVI to teach more complex, higher order thinking skills.

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APPENDIX A: PARENTAL CONSENT

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

Parental Informed Consent for Parents of Students with Disabilities
Project Solutions

What are some things you should know about this research study?
You are being asked to give permission for your child to participate in a research study. Joining the study is voluntary. You may refuse for your child to join, or withdraw your consent for your child to be in the study, for any reason, without penalty. Research studies are designed to obtain new knowledge. This new information may help people in the future. Your child may not receive any direct benefit from being in the research study. There also may be risks for being in research studies. Details about this study are discussed below. It is important you understand this information so that you can make an informed choice about your child being in this research study. You will be given a copy of this consent form. You should ask the researchers named below any questions you have about this study at any time.

Investigators:

Diane Browder, PhD, Professor, UNC Charlotte, dbrowder@uncc.edu, 704-687-8836
Fred Spooner, PhD, Professor, UNC Charlotte, fhspoone@uncc.edu, 704-687-8851
Ya-yu Lo, PhD, Associate Professor, UNC Charlotte, ylo1@uncc.edu, 704-687-8716
*Alicia Saunders, MAT, Project Coordinator, UNC Charlotte, A.Saunders@uncc.edu, 704-687-8449 (primary investigator for this substudy)

What is the purpose of this study?
The purpose of this study is to develop a way to teach students with moderate and severe intellectual disability to solve word problems in math. The intervention will include using read alouds and a standard problem format to make the written problem accessible to nonreaders. Students will use a chart that helps them organize their answer. We will evaluate whether students can take their knowledge and apply it across materials, math concepts, technology (iPad, Smartboard), real life activities, video models, and instructors/settings. Your child is being considered for this study because he or she has the prerequisite skills to begin working towards solving math word problems.

Are there any reasons you should not be in this study?
Your child should not be in this study if he or she does not have an intellectual disability, if you do not want him or her to receive some math instruction in a general education class, or if you do not give your informed consent.

How many people will take part in this study?
One special education teacher and 3 students with autism and a moderate intellectual disability will be recruited for the study.

How long will your child's part in the study last?
The intervention will take about 30 minutes daily in your child's classroom. Your child will receive math instruction from the Project Coordinator on the computer in the special education classroom.

What will happen if your child takes part in the study?
We will work with your child's teacher to develop math lessons based on current research. These lessons will include the teacher reading aloud the problem and teaching the student to solve the problem step-by-step with prompting and praise.

What are the possible benefits of being in this study?
This research is designed to benefit students with moderate and severe intellectual disability with enhanced math skills. Your child may benefit by learning to solve word problems.

What are the possible risks or discomforts involved from being in this study?
There are minimal risks. Your child may experience some nervousness about being observed or videotaped during implementation of the intervention or frustration with learning a new task. This risk will be minimized by using praise and encouragement during the instruction and by discontinuing videotaping if the child begins to act out or expresses a desire to quit.

What if we learn about new information or findings during the study?
You will be given any new information gained during the course of the study that might affect your willingness for you to have your child continue participation.

How will information be protected?
All paper records for this study will be kept in locked file cabinets. All electronic or computer records will be password-protected. Only members of the research team will have access to records that identify your child.

Participants will not be identified in any report or publication about this study. Although every effort will be made to keep research records private, there may be times when federal or state law requires the disclosure of such records, including personal information. This is very unlikely, but if disclosure is ever required, UNC Charlotte will take steps allowable by law to protect the privacy of personal information. In some cases, your child's information in this research study could be reviewed by representatives of the University, research sponsors, or government agencies (e.g., the FDA) for purposes of quality control or safety.

For purposes of student evaluation and research dissemination to professional audiences, some of the intervention sessions will be video-recorded. As part of your child's participation in this study, your child will be video-recorded. The investigators will take precautions to safeguard the video-recordings of your child by keeping them on a secure network drive or in a locked file cabinet. These video-recordings will be coded by an identification number rather than your name or any personal information. Upon the completion of this project, the individual recordings will be archived on secure networks at UNC Charlotte. Access to the vide-recordings will be restricted to research personnel on this study unless you provide the additional video consents shown at the end of this form.

What if you want to stop before your part in the study is complete?
You can withdraw your child from this study at any time without penalty. The investigators also have the right to stop your child's participation at any time. This could be because your child has had an unexpected reaction, fails to respond to the intervention, or because the entire study has stopped.

Will you receive anything for being in the study?
There is no payment for your child's participation.

Will it cost you anything to be in the study?
It will not cost you anything for your child to be in this study.

Who is sponsoring this study?
This research is funded by the Institute of Education Sciences through the U.S. Department of Education. This means that the research team is being paid by the sponsor for doing the study. The research does not, however, have a direct financial interest with the sponsor or in the final results of the study.

What if you have questions about the study?
You have the right to ask and have answered any questions you may have about this research. If you have questions about the study (including payments), complaints, concerns, or if a research-related injury occurs, you should contact the researchers listed on the first page of this form.

What if you have questions about your rights as a research participant?
All research on human volunteers is reviewed by a committee that works to protect your rights and welfare. If you have questions or concerns about your rights as a research subject you may contact, anonymously if you wish, the Institutional Review Board at 704-687-1888 or by email to uncc-irb@uncc.edu.

Participant's Agreement

I have read the information provided above. I have asked all the questions I have at this time. I voluntarily agree for my child to participate in this study.

Child's Name

Signature of Parent Date

Printed Name of Parent

Signature of Research Team Member Obtaining Consent Date

Printed Name of Research Team Member Obtaining Consent

Contact Information (for mailing materials)

Address:

Phone Number:

Email:

Video Permission

In addition to the use of the video recordings that are essential to your child's participation in this project, it would be helpful to be able to use the recordings of your child in other ways. Giving us permission to do this is optional and will in no way affect your or your child's ability to participate in the study. We would like you to indicate how you are willing for us to use these video recordings by initialing below. You are free to initial any number of spaces from zero to all of the spaces. We will only use the video recordings in ways that you agree to. In any use of the video recordings, we will not give any identifying information about you beyond what appears in the recordings.

Please initial:
____The video recordings can be used in professional presentations.

____The video recordings can be used in educational trainings and university classrooms.

____The video recordings can be used for publications (e.g., instructional DVDs) related to this intervention program or study.

____The video recordings can be used for web-based content related to this intervention program or study.

____

Signature of Parent   Date

____

Printed Name of Parent

APPENDIX B: STUDENT ASSENT

UNC CHARLOTTE
The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223-0001
Project Solutions
College of Education
Phone: 704-687-8449
Fax: 704-687-1625

Assent Form for Minors

Using Computer-Based Video Instruction to Teach Problem Solving

My name is Alicia Saunders, and I am a student at The University of North Carolina at Charlotte. I am doing a study to see if children can learn math word problem solving better.

If you want to be in my study, you will do math at the computer each day. You will watch a video of me teaching you how to do math, and then you will solve problems on the computer. I will watch you do math on the computer to see how much math you learned from watching the math video each day. You will learn how to solve math word problems.

You can ask questions at any time. You do not have to be in the study. Once you start the study, you can stop any time you want and no one will be mad at you.

I hope that this new way of learning math will help you and other students learn more math, but I am not sure it will. This study will not hurt you in any way. It is designed to help you.

After we finish the study, I will write a report about the study. I will not use your name, but I will describe you in the study. After I write the report, I will share some things that I found out during my study with you.

If you want to be in this study, please sign your name and write the date.

____________________________________ ____________________

Signature of Participant Date

____

Printed Name of Participant

Signature of Research Team Member Obtaining Consent Date

Printed Name of Research Team Member Obtaining Consent

We would like to show videos of you to help others. Can we show your videos to other people?

_____ YES _____NO

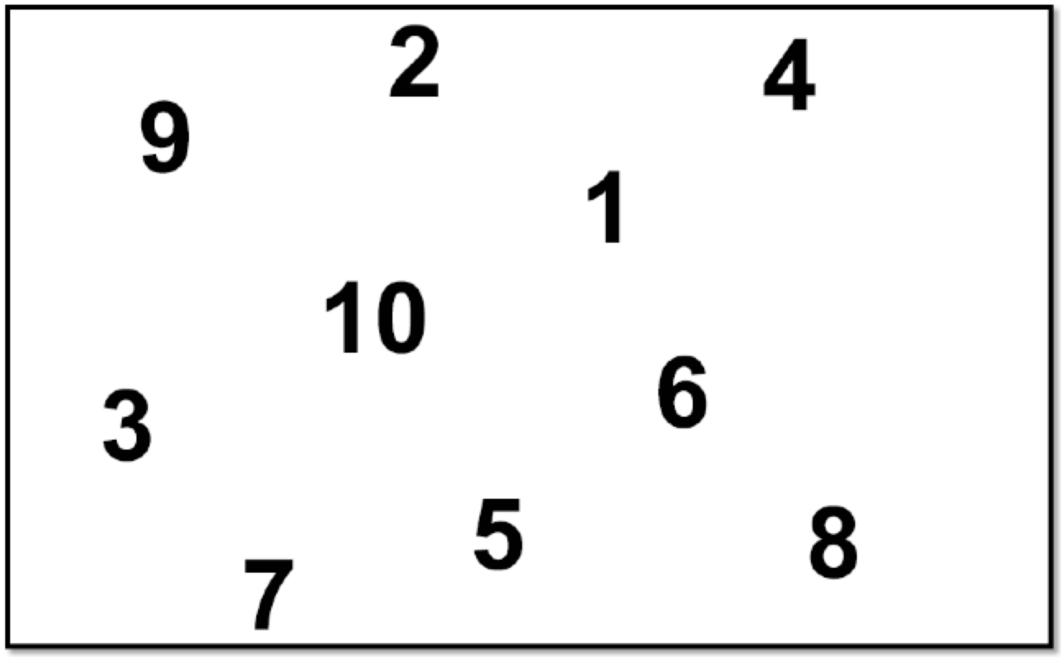
Signature of Child Date

Printed Name of Child

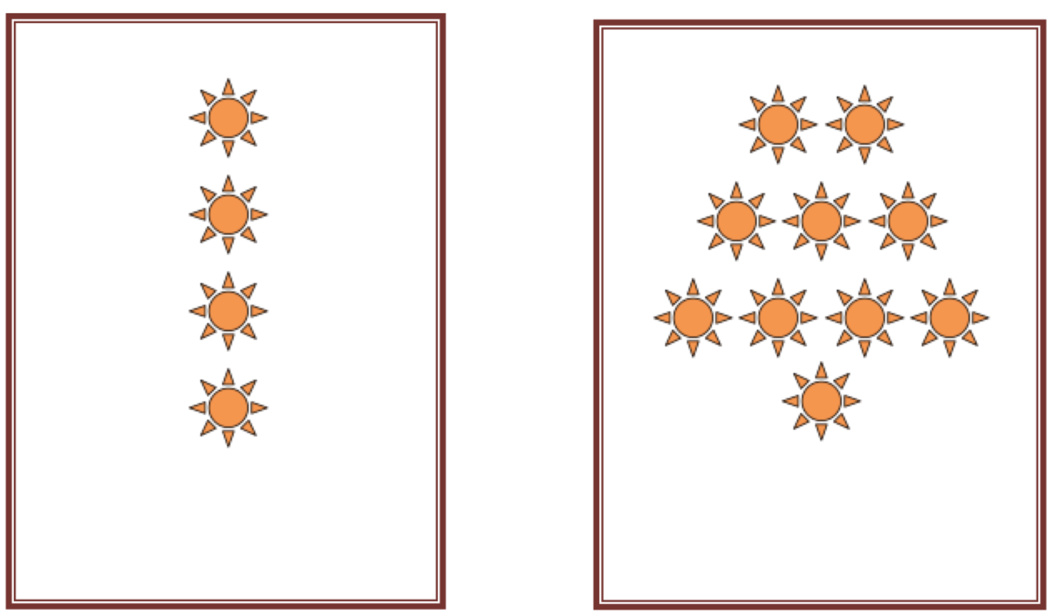
Emancipated Minor (as defined by NC General Statute 7B-101.14) is a person who has not yet reached their 18th birthday and meets at least one of the following criteria: 1) has legally terminated custodial rights of his/her parents and has been declared 'emancipated' by a court; 2) is married, or 3) is serving in the armed forces of the United States.

APPENDIX C: PRESCREENING TOOL

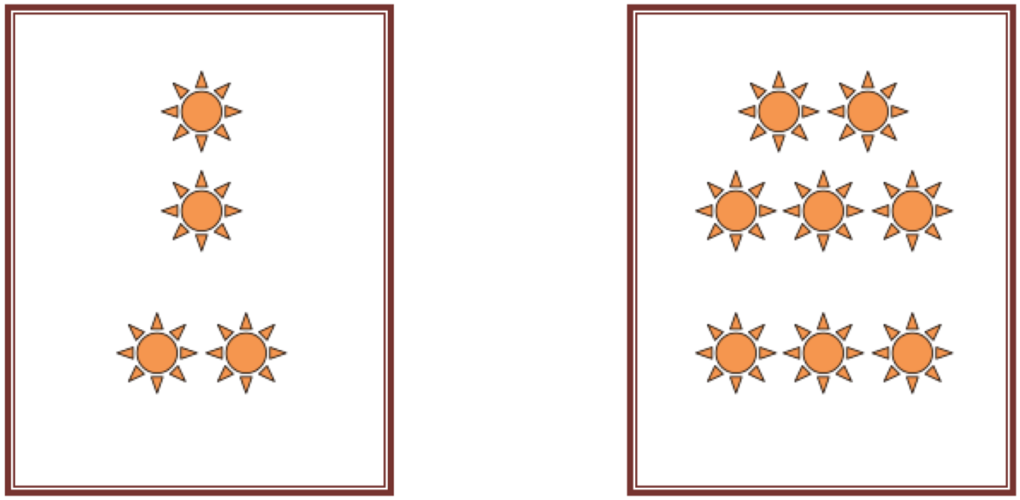
Let student read all numbers aloud independently. If student needs a starter prompt, say "when I point to a number, say its name."



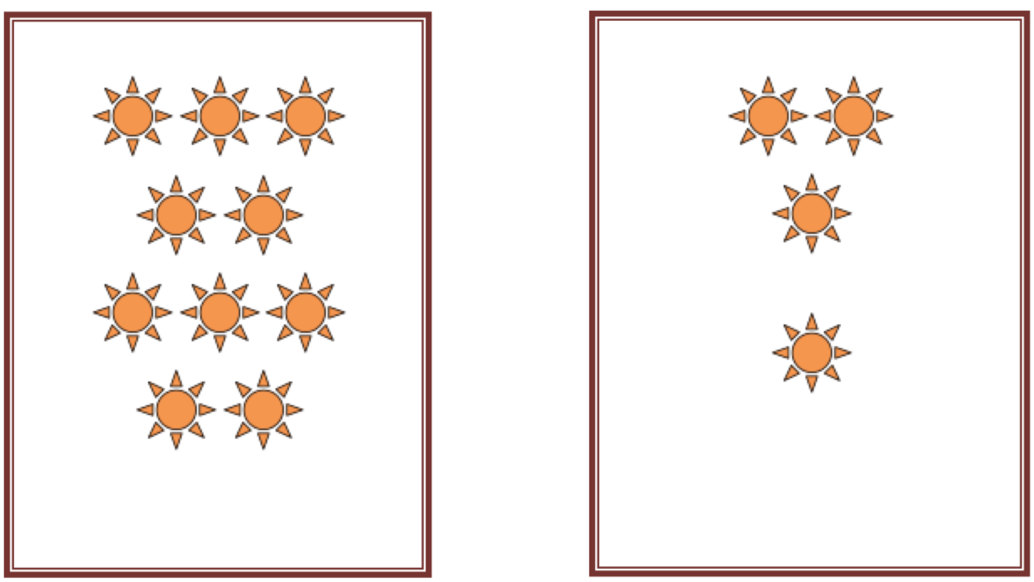
"Point to the box that has more?"
Remember to praise students for answering. Record response.



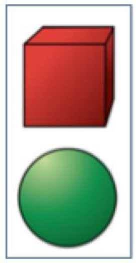
"Point to the box that has less?"
Remember to praise students for answering. Record response

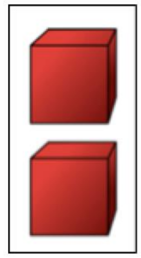


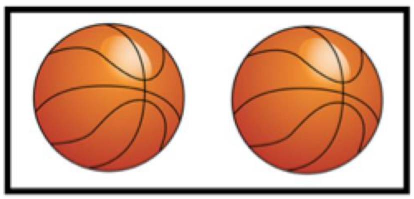
Point to the second box and ask, "Does this box have more or less?"
Remember to praise students for answering. Record response.

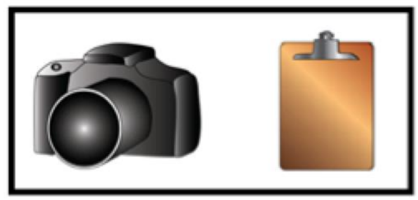


Point to the first picture and say, "These two objects are different." Point to the second picture and say, "These two objects are different." Pause, then say, "Show me the objects that are different." Repeat for same.

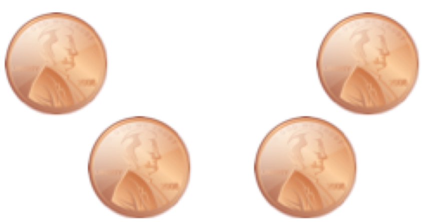




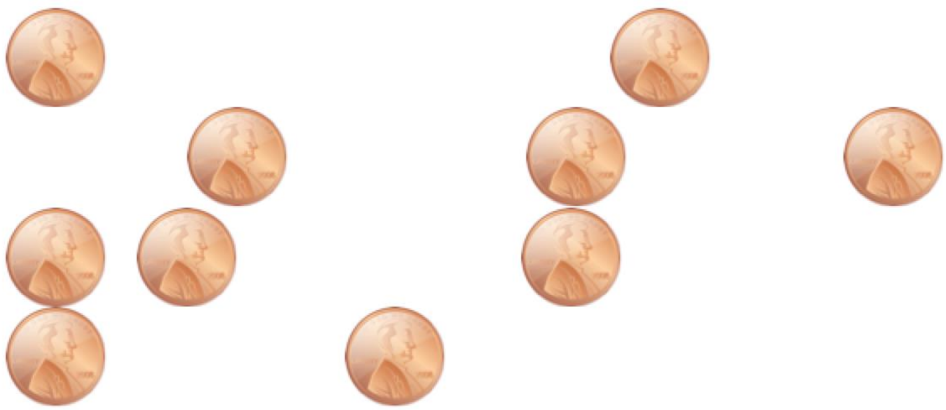




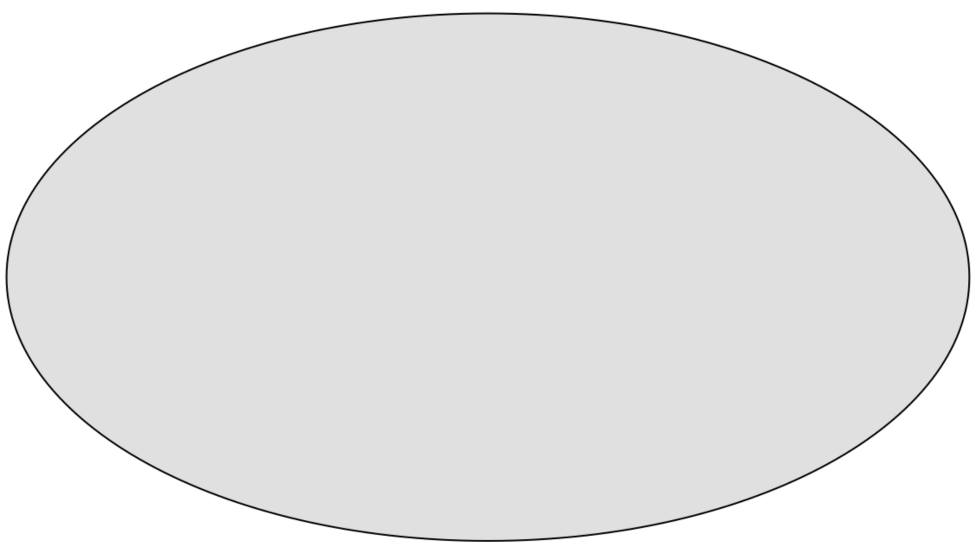
"Count the pennies." Remember to praise students for answering.



"Count the pennies." Remember to praise students for answering.

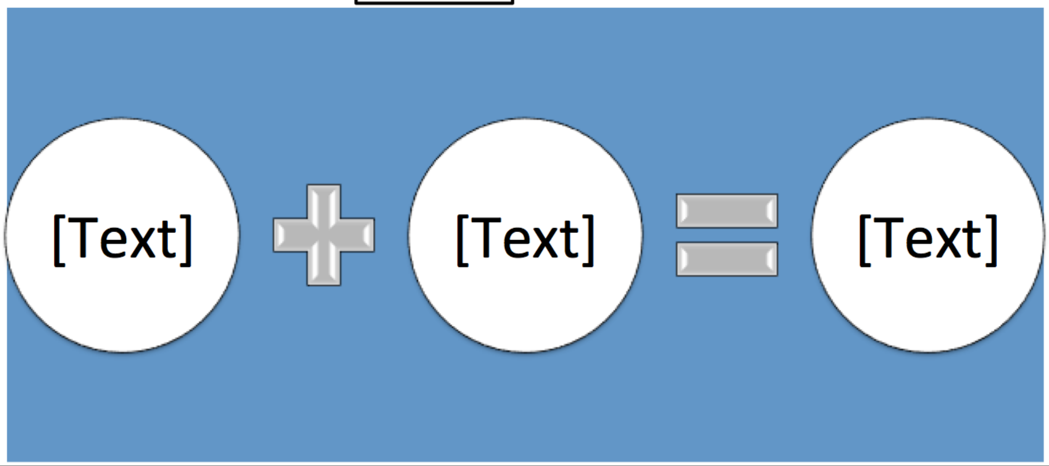


Place 10 counters in front of the student. Say, "Make a set of five in the circle."
Clear set maker and then say, "Make a set of eight in the circle."



Give students 11 or more counters. Say, “Use the counters to solve this problem”:

$$3 + 7 = \boxed{?}$$



Point to the box on the right. Say, “Show me the plus sign.” Repeat for minus/take away.

Give student a calculator. Say, “Use the calculator to solve these problems.”

$$\begin{array}{r} 25 \\ \underline{+\ 14} \end{array}$$

$$\begin{array}{r} 39 \\ \underline{-\ \ 27} \end{array}$$

$$\boxed{\begin{array}{c} + \\ \\ - \end{array}}$$

Say, “I am going to read some word problems and ask you to solve them. If you cannot solve them, it is ok. Just try your best.”

1. Ashley saw 4 birds on her nature walk. Michelle saw 3 squirrels. How many animals did they see altogether?

2. Karon had 9 books to sell at his family’s yard sale. He sold 6. How many books does he have now?

Prescreening Tool Data Sheet

Student: ____

Date: ______________

Skill		**Points**	**C/I**	**Notes**
Number ID	Verbally ID numbers	1	+ -	1 2 3 4 5 6 7 8 9 10
More/less	More Less Expressive ID	3	+ - + - + -	
Same/different	Same Different	2	+ - + -	
Count pennies	4 10	2	+ - + -	
Making sets	5 8	2	+ - + -	
Adding with sets		1	+ -	
Calculator	Show me + Show me – Solve + Solve –	4	+ - + - + - + -	
Solve	Group Change	3	+ - + -	

Score: ______

APPENDIX D: PROBE DATA SHEETS

Probe for Baseline and Maintenance

Solving Word Problems

Problem	Task analysis steps	Date/Phase/Student					
Problem 4:	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #'s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find "how many"	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
Problem 3	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #'s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find "how many"	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
Problem 2	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #'s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find "how many"	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1

Problem 1	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #'s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find "how many"	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
	Notes:	TOTAL CORRECT ON STEPS ON **GROUP** PROBLEM TYPE:	**/24**	**/24**	**/24**	**/24**	**/24**
		TOTAL CORRECT ON STEPS ON **CHANGE** PROBLEM TYPE:	**/24**	**/24**	**/24**	**/24**	**/24**
		Discriminations	**E E N N**	**E E N N**	**E E N N**	**E E N N**	**E E N N**
		TOTAL CUMULATIVE DISCRIMINATIONS CORRECT:					

Scoring Procedure	Criteria for Mastery
-Circle steps performed independently and correctly -Total number of independent correct steps and write score in designated box (" /24") -Circle correct discriminations -Write cumulative number of discriminations in designated box	Correctly discriminates of 3/4 problems as examples/non-examples AND 11/12 steps across both problems for 2 consecutive sessions, move to next problem type. Take maintenance data once per week for three consecutive weeks.

Probe for Phases I and III: Problem Type ________________
Student: ________________

Discrimination of Problem Type

Problem	Task analysis steps	Date/Phase/Student					
Problem 2	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
Problem 1	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the "what"	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
	Notes:	TOTAL CORRECT ON STEPS:	**/12**	**/12**	**/12**	**/12**	**/12**
		Discriminations	**E E N N**	**E E N N**	**E E N N**	**E E N N**	**E E N N**
		TOTAL CUMULATIVE DISCRIMINATIONS CORRECT:					

Scoring Procedure	Criteria for Mastery
-Circle steps performed independently and correctly -Total number of independent correct steps and write score in designated box (" /12") -Circle correct discriminations -Write cumulative number of discriminations in designated box	Correctly discriminates of 2/4 problems as examples/non-examples AND 5/6 steps across both problems for 2 consecutive sessions.

Probe for Phases II and IV: Problem Type ________________
Student: _______________

Solving Word Problems

Problem	Task analysis steps	Date/Phase/Probe Number					
Problem 2	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #’s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find “how many”	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the “what”	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
Problem 1	12. Write answer	Writes/Selects numeral	12	12	12	12	12
	11. Solve	Manipulates sets to solve	11	11	11	11	11
	10. Make sets	Creates sets in circles	10	10	10	10	10
	9. + or -	Writes/moves #’s in # sentence	9	9	9	9	9
	8. Fill-in # sentence	Writes numerals in # sentence	8	8	8	8	8
	7. Find “how many”	Circles #s in word problem	7	7	7	7	7
	6. Choose GO	Selects correct GO	6	6	6	6	6
	5. Use my rule	States rule	5	5	5	5	5
	4. Find label in?	Drags & drops/Fills-in label	4	4	4	4	4
	3. Same or different?	Circles same or different	3	3	3	3	3
	2. Find the “what”	Circles nouns	2	2	2	2	2
	1. Read the problem	S clicks on/reads problem/requests teacher read (generalization only)	1	1	1	1	1
	Notes:	TOTAL CORRECT ON STEPS:	**/24**	**/24**	**/24**	**/24**	**/24**
		Discriminations	**E E N N**	**E E N N**	**E E N N**	**E E N N**	**E E N N**
		TOTAL CUMULATIVE DISCRIMINATIONS CORRECT:					

Scoring Procedure	Criteria for Mastery
-Circle steps performed independently and correctly -Total number of independent correct steps and write score in designated box (“ /24”) -Circle correct discriminations -Write cumulative number of discriminations in designated box	Correctly discriminates of 3/4 problems as examples/non-examples AND 11/12 steps across both problems for 2 consecutive sessions, move to next problem type. Take maintenance data once per week for three consecutive weeks.

APPENDIX E: PARTICIPANT SOCIAL VALIDITY QUESTIONNAIRE

Social Validity Questionnaire

Student: ________________________ Interviewer: __________________ Date: ________

"I have some questions to ask you. I want to see how you felt about the computer math program."

1.	I like doing math on the computer.	Yes	No
2.	The program was fun for me to use.	Yes	No
3.	The computer program helped me learn math.	Yes	No
4.	The computer program helped me learn to solve word problems.	Yes	No
5.	Watching videos helped me know what to do when solving word problems.	Yes	No
6.	The graphic organizers helped me solve word problems.	Yes	No
7.	I would like to do the computer program again for other math.	Yes	No
8.	I would like to learn more word problems on the computer.	Yes	No

9. What did you like about the computer program?

10. What did you not like about the computer program?

APPENDIX F: TEACHER SOCIAL VALIDITY INTERVIEW

Teacher Social Validity Interview

Teacher: ___________________ Interviewer: _____________________ Date: ________

"State your response to the following questions. If you have additional comments to add pertaining to each question, feel free to state them."

1.	Did the participants enjoy doing math on the computer?	Yes	No
2.	Did the computer program help improve their math skills?	Yes	No
3.	Do you think the computer program improved their ability to solve math word problems?	Yes	No
4.	Based on what you saw, did the graphic organizers/chant help them understand and solve word problems?	Yes	No
5.	Do you think they would benefit from additional computer-based math instruction in the future?	Yes	No
6.	Do you think they would like to continue learning to solve word problems on the computer next year?	Yes	No

7. Additional Comments:

APPENDIX G: PROCEDURAL FIDELITY CHECKLIST

Procedural Fidelity Checklist for Probe and CBVI Implementation

Key: use "+" for steps completed; use "–" for steps not completed; use "NA" for step 1 during session that it is not applicable

Date:						
Observer:						
Phase:						
1. Experimenter opens probe for student.						
2. Experiment ensures student completes probe without skipping any questions.						
3. Experimenter collects data on both primary and secondary dependent variables.						
4. Experimenter provides no error correction or feedback during probe. Redirection to probe is acceptable if student is off-task or engaging in stereotypy.						
5. Experimenter sets up computer so that CBVI lesson for day is open.						
6. Experimenter provides cue, "You may begin!"						
7. Experimenter monitors student to ensure student is on-task and redirects off-task behavior when necessary during CBVI.						
8. Experimenter provides LIP when needed.						
9. Experimenter provides error correction for steps 1, 2, 4, 5, 7, 10, and 11.						
Number of steps completed	/9	/9	/9	/9	/9	/9
% Fidelity						

Additional observations: