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THE EFFECTS OF COMPUTER-ASSISTED INSTRUCTION ON THE MATHEMATICS ACHIEVEMENT OF STUDENTS WITH EMOTIONAL AND BEHAVIORAL DISORDERS

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THE EFFECTS OF COMPUTER-ASSISTED INSTRUCTION ON THE MATHEMATICS ACHIEVEMENT OF STUDENTS WITH EMOTIONAL AND BEHAVIORAL DISORDERS

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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Dedication

I would like to dedicate this work to my father, Roy McKinley Collier. Although you are not here physically, I know that you have been my guardian angel and I am sure that you are proud. Thank you, I love and miss you.

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Abstract

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Mathematics is essential in everyday life activities and most educational opportunities and careers require mathematical knowledge, thus it is vital that students with emotional and behavioral disorders (EBD) receive sufficient instruction that leads to proficiency in the subject. Performing poorly in mathematics can result in dire future outcomes. This is particularly true for students with EBD, who already experience significant difficulties throughout and after their educational career. While studies have documented the academic and behavioral problems of students with EBD, not until recently have studies begun to concentrate on academic interventions that may aid in preventing some of the academic challenges these students face. It is of great importance that researchers continue to identify effective and efficient strategies of providing academic instruction, particularly in mathematics, to students with EBD. The current study examined the extent to which a technology-based intervention was effective in math

instruction for students with EBD. In addition, to address the social/behavioral issues typically prevalent in students with EBD, students' task engagement was also examined and a social validity survey was used to examine their attitudes toward mathematics and technology-based instruction.

A single-subject multiple-probe design across six participants was selected for this study. The computer-assisted instruction (CAI) intervention, *I CAN Learn* computer software program, was implemented in a high school mathematics classroom. The overall results of the study indicated that the intervention improved the adolescents' mathematics achievement, but findings revealed that the intervention was more effective with some participants than others. In addition, results indicated that the intervention may not be associated with the participants' task engagement. The study's social validity survey showed that the participants had varying attitudes toward mathematics and CAI at the end of the study.

Chapter 1: Introduction

Approximately 500,000 American students receive special education and related services under the emotional and behavioral disorders (EBD) disability classification (United States [U.S.] Department of Education, 2008). One of the key characteristics of students with EBD is academic underachievement and research consistently shows that the academic outcomes for students with EBD are inferior to any other group of students with or without disabilities (Hodge, Riccomini, Buford, & Herbst, 2006; Reid, Gonzalez, Nordness, Trout, & Epstein, 2004). Consequently, among these students mathematics performance is below national averages (Anderson, Kutash, & Duchnowski, 2001; Nelson, Benner, Lane, & Smith, 2004).

Mathematics is essential in everyday life activities and most educational opportunities and careers require mathematical knowledge, thus it is vital that students with EBD receive sufficient instruction that leads to proficiency in the subject. Performing poorly in mathematics can result in dire future outcomes (Fleischman & Heppen, 2009). This is particularly true for students with EBD, who already experience significant difficulties throughout and after their educational career (Kauffman, 1999). According to the U.S. Department of Education (2008), about 50% of students with EBD drop out of school and experience poor employment histories. In addition, incessant absenteeism is significantly associated with these students' low performance in calculation and problem-solving (Wagner, Newman, Cameto, Levine, & Garza, 2006).

While studies have documented the academic and behavioral problems of students with EBD, not until recently have studies begun to concentrate on academic interventions that may aid in preventing some of the academic challenges these students face (Lane et al., 2010; Reid et al., 2004; Ruhl & Berlinghoff, 1992; Sutherland, Alder, & Gunter, 2003; Wehby, Lane, & Falk, 2003). It is of great importance that researchers continue to identify effective and efficient strategies of providing academic instruction, particularly in mathematics, to students with EBD. Such strategies may better equip these students in gaining access to the general education curriculum, prepare them for postsecondary education/employment, and help in closing the achievement gap.

Statement of the Problem

Although many national initiatives and federal mandates (e.g., Goals 2000: Heise, 1994; No Child Left Behind Act of 2001) have been implemented to improve the achievement of all students, students with EBD still fail to master fundamental mathematical skills. Research suggests that these deficits tend to increase as students with EBD advance through their school years (Hodge et al., 2006). Approximately 56% of students with EBD are at least three grade levels behind in math and their continued weakness in the subject usually results in motivational problems such as low expectations of success, disinterest in academic work, decreased self-confidence, chronic truancy, and high rates of school dropout (Blackorby, Chorost, Garza, & Guzman, 2003; Bottge, Rueda, and Skivington, 2006). While these students continue to lag behind in basic math skills, proponents of reform in mathematics education urge teachers to emphasize instruction that embeds real-world situations to enhance all students' problem-solving skills (National Council of Teachers of Mathematics Standards [NCTM], 2000; Gagnon & Bottge, 2006).

Identifying methods that build students' basic and problem-solving skills in math is a critical component for academic success and subsequently successful employment (NCTM, 2000), yet there is limited research on improving such skills with students with EBD (Mooney, Epstein, Reid, & Nelson, 2003; Pierce, Reid, & Epstein, 2004). To illustrate, Hodge et al. (2006) conducted a review of the literature on instructional interventions in mathematics for students with EBD and found scarce research on specific interventions (e.g., peer-mediated instruction, strategy instruction, computer-assisted instruction) which focused on improving these skills. The researchers examined studies from1985 to 2005 and only found 13 studies focusing on the math achievement of students with EBD. Of these studies, all but one targeted the acquisition of basic math skills. Limited research in this area perpetuates the dismal academic and future outcomes of students with EBD which typically consist of incidents that lead to student suspensions or expulsion from school, placement in restrictive settings, unemployment and other negative outcomes during school and post-school years (Gable, Hendrickson, Tonelson, & Van Acker, 2002).

Rationale for Study of the Problem

Prior to Hodge et al.'s (2006) review, Maccini and Gagnon (2000) identified the use of technology as a best practice for teaching mathematics to students with EBD. Similarly, the NCTM (2000) recommended the use of technology in mathematics as a best practice for all students. According to the NCTM, "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). Mathematical competence is vital to the future of students with EBD and the symbiotic relationship between technology and math can provide a basis for using technology-based instruction with these students who consistently struggle in math. Nevertheless, research is practically nonexistent regarding the effectiveness of technology-based interventions for students with EBD. This study sought to examine the extent to which a technology-based intervention was effective in math instruction for students who exhibit continued weakness in the subject and whose learning is often impeded by the manifestations of the EBD disability.

Statement of Purpose

Although students with EBD exhibit significant difficulties in mathematics, considerably less attention is devoted to remediating these problems in comparison to behavioral and social difficulties. Given the strong correlation between mathematics failure and overall success, the purpose of the study was to investigate the effects of computer-assisted instruction (CAI) on students' with EBD mathematics achievement. In addition, to address the affective issues typically prevalent in students with EBD, this study also examined how CAI affects students' task engagement and a social validity survey was used to examine their attitudes toward mathematics and technology-based instruction.

Literature/Research Background

Improving proficiency and eliminating achievement gaps in mathematics is a national interest in the United States. Currently, American children rank well below other students in developing countries and perform poorly on annual mathematics assessments (Slavin & Lake, 2008). In addition to these inefficiencies, achievement gaps persist between Caucasian students and students of color, middle-class students and students living in poverty, and students with and without disabilities (Eddy & Easton-Brooks, 2011; Georges & Pallas, 2010; Mitchells, 2005). In attempts to improve the current status of mathematics achievement in the United States, proponents of reform in mathematics education have suggested that teachers use student-centered approaches in instruction as opposed to traditional methods (NCTM, 2000). Incorporating active technology use in the classroom has been recommended as a potential tool for fostering student-centered learning and increasing mathematics proficiency.

CAI has been gaining wide acceptance as one of the most effective technologies used in the educational system; however, the literature indicates mixed results regarding the effectiveness of this intervention on all students' mathematics achievement (Kroesbergen & Van Luit, 2003; Laffey, Espinosa, Moore & Lodree, 2003; Tienken & Maher, 2008). Subgroups, particularly students at risk of academic failure and students with disabilities, have been experiencing more promising results of CAI (Koedinger, McLaughlin, & Heffernan, 2010; Okolo, 1992; Page, 2002).

In regards to CAI and students receiving special education services, most of the literature has focused on students with learning disabilities. The literature is currently deficient regarding CAI and students with EBD, despite these students' inferior achievement. Research that is available for students with EBD supports CAI in effectively teaching mathematical concepts to these students (Billingsley, Scheuermann, & Webber, 2009; Bottge et al., 2006). However, due to the lack of published studies specifically focusing on these students, it is difficult to critically analyze and determine the extent to which CAI is effective for students with EBD.

Research Questions

The overall goal of the present study was to examine the effects of CAI on students' with EBD mathematics achievement. Specifically, the study focused on the following research questions:

1. What is the effect of CAI on basic skills in mathematics?
2. What is the effect of CAI on problem-solving skills in mathematics?
3. What is the effect of CAI on task engagement in mathematics?

Methodology

A single-subject multiple-probe design across participants was selected for this study to demonstrate a functional relation between the independent variable, CAI, and the dependent variables, mathematics achievement and task engagement (Horner & Baer, 1978). Student academic performance (i.e., acquisition of target basic math and problem-solving skills) and task engagement was assessed via infrequent probes to provide indications of the participants' academic progression.

Definition of Terms

Basic mathematics: Computation using standard operations (i.e., addition, subtraction, multiplication, division) to solve problems involving whole numbers, decimals, and fractions.

Conceptual understanding/knowledge: The comprehension of mathematical concepts, operations, and relations (NCTM, 2000).

Drill-and-practice software: Primarily used to aid students in memorizing isolated facts and concepts through individualized practice and supplementing traditional instruction (Kausar, Choudhry, & Gujjar, 2008).

Emotional and Behavioral Disorders (EBD): According to the Individuals with Disabilities Education Improvement Act (IDEIA) (2004), EBD is "a condition exhibiting one or more of the following characteristics over a long period of time and to a marked degree that adversely affects a child's educational performance: (a) an inability to learn that cannot be explained by intellectual, sensory, or health factors; (b) an inability to build or maintain satisfactory interpersonal relationships with peers and teachers; (c) inappropriate types of behavior or feelings under normal circumstances; (d) a general pervasive mood of unhappiness or depression; (e) a tendency to develop physical symptoms related to fears associated with personal or school problems." [Code of Federal Regulations, Title 34, Section 300.7(b)(9)]

Higher-order skills: Skills involving visual and spatial reasoning and problem-solving.

Lower-order skills: Skills typically focusing on rote memorization and drill-and-practice.

Mathematics achievement: For the purpose of this study, achievement was operationalized as reaching 80% mastery in targeted basic math and problem-solving skills.

Mathematics proficiency: The ability to comprehend mathematical concepts; carry out procedures accurately and efficiently; formulate and solve problems logically and reflectively; and view the utility of the subject (Kilpatrick, Swafford, & Findell, 2001).

Problem-solving: Applying and adapting appropriate strategies to solve problems for which the solution is not known in advance (NCTM, 2000).

Technology-based instruction: The integration of technology in most or all instruction. Technological tools could include, but are not limited to, interactive software, interactive hardware (e.g., computers, projectors, whiteboards), and the Internet (Fitzgerald, Koury, & Mitchem, 2008).

Tutorial software: Instructs the learner by providing a complete sequence of instruction on a given topic (Kausar, Choudhry, & Gujjar, 2008).

Simulation software: Models a real or imaginary system to provide a likeness of a real life situation to learners (Kausar, Choudhry, & Gujjar, 2008).

Chapter 2: Review of the Literature

Conceptual Framework

Since the advent of instructional technology (e.g., computers, videos, educational software), educational researchers and practitioners have been developing theories of how technology promotes achievement (Clark, 1999; Sweller, 1999). Most of these theories are derived from standard and contemporary theories of learning (e.g., behaviorism, cognitivism, constructivism) and provide a framework for designing effective instructional materials that focus on the interaction between presentation and learner involvement (van Merrienboer & Sweller, 2005). Although the design of instructional technology materials is important, there is a greater need to understand the role of instructional technology on student achievement. A technology-enhanced, student-centered learning framework was employed in this study to examine the effects of CAI on students' with EBD mathematics achievement.

Technology-enhanced, student-centered learning. Stemming from the constructivist view of learning, which operates on the premise that one must construct learning in order to achieve true meaning (Bruner, 1966; Piaget, 1972; Vygotsky, 1978), student-centered learning is an instructional approach whereby students are actively engaged in learning as opposed to passively receiving information in a traditional teacher-centered classroom (Hannafin, Hill, & Land, 1997). This instructional approach allows students to address their own learning interests and needs while the instructor facilitates their learning with varying amounts of guidance (Land & Hannafin, 1997). Examples of student-centered learning approaches span across a wide variety of disciplines and typically incorporate activities such as cooperative learning groups, problem-based investigations, and inquiry-based learning (Cantone, 2001; Oldenburg, 2005). Recent advances in instructional technology have provided learning environments that can further enable active learning through the exploration of simulations, electronic resources (e.g., Internet, WebQuests), and other interactive activities (e.g., graphical representations, manipulations), thus enriching the understanding of abstract concepts via concrete experiences (Land & Hannafin, 1996). Since mathematics content encompasses concrete and abstract concepts, the technology-enhanced, student-centered framework can provide a basis for enhancing mathematics instruction and achievement.

Mathematics Achievement in the United States

Within the past two decades, the mathematics achievement of American children has been progressively improving; however, the U.S. remains behind other developed nations in international comparisons of mathematics proficiency (Slavin & Lake, 2008). Compared to 33 other industrialized countries, the U.S. ranked 25th in mathematics literacy (National Center for Education Statistics [NCES], 2010). According to the NCES (2010), only 27% of U.S. students scored at or above proficiency level four, which is the level at which students can complete higher order tasks such as visual and spatial reasoning and problem-solving. In 2011, the National Assessment of Educational Progress (NAEP) reported that more than 70% of fourth and eighth grade U.S. students had at least a basic knowledge of mathematics in their grade level compared to only 50% of students in 1990 (NAEP, 2011).

Although basic mathematics performance has grown substantially, students are not showing promising increases in proficient performance. NAEP (2011) mathematics test scores may suggest that instructional techniques used in mathematics are not successful in building relationships between students' conceptual knowledge and the procedures explicitly taught in school. In addition to these inefficiencies, mathematics achievement gaps persist between Caucasian students and students of color, middle-class students and students living in poverty, and students with and without disabilities (Eddy & Easton-Brooks, 2011; Georges & Pallas, 2010; Mitchells, 2005; NAEP, 2011). Such gaps potentially thwart efforts to compete globally with other countries. As federal legislation and various policy initiatives have become more rigorous in requiring every student to be mathematically proficient, debate continues over which instructional approaches are effective in achieving this goal.

Mathematics Instruction

Traditionally, mathematics instruction has been predominantly teacher-centered. This instructional approach has been regarded by critics as a teacher-delivered model of direct instruction that focuses on lecture and rote transmittal of facts (Peressini & Knuth, 1998; Thompson, 1992). It is argued that students who receive direct instruction are less likely to apply and extend acquired knowledge, particularly when encountering problem-solving tasks and other high-level cognitive skills, thus impeding mathematics proficiency (Barrett & Long, 2012). Opponents of teacher-centered instruction recommend student-centered instructional approaches which emphasize students actively and conceptually understanding mathematics through constructing their own knowledge (Hannafin et al., 1997). Conversely, proponents of teacher-centered instruction assert that direct instruction accelerates students' mathematical skills, ensuring that students are equipped with strategies that enable accuracy and fluency in computation and transfer to higher-order thinking tasks (Garelick, 2005; Reys, 2001).

The National Council of Teachers of Mathematics Standards (NCTM) has encouraged teachers to frequently use contemporary approaches, such as student-centered instruction, that emphasize mathematical thinking and reasoning in engaging and interactive environments

(NCTM, 2000). To attain these goals, the NCTM (2000) has suggested the integration of technology for creating high quality mathematical learning experiences.

The Integration of Technology in Mathematics Instruction

In the 1980s, widespread interest in computers as an instructional tool emerged in education catapulting what became known as CAI. CAI refers to instruction or remediation presented on a computer and used by students to practice academic skills (Bitter & Pierson, 1999; Fitzgerald et al., 2008). It is typically in the form of drill-and-practice programs, tutorials, or simulations and can be used alone or as a supplement to traditional instruction (Woodward & Rieth, 1997; Soe, Koki, & Chang, 2000). Due to its many uses, CAI became a focus of mathematics research in the 1980s prompting researchers to examine its effectiveness in mathematics instruction (Bitter & Pierson, 1999). Technological advancements in the 1990s (e.g., Internet) have expanded the utility of CAI, consequently prompting further examination of its integration in mathematics (Reiser, 2001). Although the integration of CAI has been promoted by many (Koedinger et al., 2010; NCTM, 2000), current research varies widely regarding the effectiveness of this instructional approach for different students (Lei & Zhao, 2007).

Organization of the Review of the Literature

This literature review analyzes empirical studies that have investigated the effects of CAI on students' mathematics achievement. With a specific focus on students with EBD, this review was organized to transition from a macro to micro exploration of CAI in education. First, studies regarding CAI and general education students were reviewed, followed by studies regarding CAI and students with or at-risk for disabilities.

Methodology of Literature Review

The search strategy employed for this review of the literature involved three stages: a) an electronic search of literature databases, b) an electronic hand search of key journals, and c) a search of embedded references of articles found in the previously mentioned stages. First, a computer-assisted search of three major databases was conducted. These databases included Educational Resources Information Center (ERIC), Education Research Complete, and PsychINFO. Each database was searched using the combinations of the following terms: computer-assisted instruction, educational technology, online learning, web-based instruction, mathematics achievement, special education, learning disabilities, and emotional and/or behavioral disorders.

Second, an electronic physical search was made of the following key journals: *Behavioral Disorders, Computers & Education, Computers in the Schools, Education and Treatment of Children, Exceptional Children, Journal of Computer Assisted Learning, Journal of Emotional and Behavioral Disorders, Journal of Learning Disabilities, Journal of Special Education, Journal of Special Education Technology, Learning Disability Quarterly, Mathematics and Computer Education, Remedial and Special Education, and Technology and Disability.* Finally, reference lists of electronic and hand searched articles were examined in effort to find any additional pertinent publications. All studies included in this review of the literature were vetted using the research standards of the American Educational Research Association (AERA, 2006).

Criteria for inclusion and structure of included articles. The initial search resulted in 106 articles related to computer-assisted instruction in mathematics. Articles were included in the literature review if they met each of the following criteria: a) they were published in peer-reviewed journals within the last 20 years (1992-2012), b) they examined the effects of CAI in mathematics in comparison to traditional instruction or other CAI formats, c) participants involved in the studies were enrolled in American schools and in grades Pre K-12, and d) the studies specifically reported results of mathematics achievement via performance scores measured by mathematics tests. Adhering to these criteria, 23 studies were identified. The majority of the articles were excluded from this review because they were not peer-reviewed and/or they were duplicates of studies already found.

The articles of this review were organized to transition from a macro to micro exploration of CAI in mathematics education. First, studies regarding CAI and general education students were reviewed. Second, studies regarding CAI and students with or at-risk for disabilities were reviewed. This structure was chosen to ultimately examine the effects of CAI on students' with EBD mathematics achievement.

CAI and General Education Students

Beal, Walles, Arroyo, and Woolf (2007) evaluated an on-line tutoring system designed to provide students with multimedia instruction in problem-solving. Two hundred two students, from two high schools, were assigned either to regular mathematics instruction or CAI via on-line multimedia tutoring. A total of 153 students participated in the CAI condition. Pre- and posttests of math problem-solving were administered to both groups. The on-line tutoring group worked with the CAI intervention for approximately 50 minutes for two days, while the control group participated in traditional mathematics class activities conducted by their teacher. Two days after the intervention, both groups were administered paper-and-pencil posttests. Overall scores of the pre- and posttests were compared with a one-way analysis of variance. Results revealed significantly higher scores on the pretest for the control group, but no significant difference in scores from the pre- to the posttest. The students in the treatment group, however, showed significant overall improvement from pretest to posttest and further examination revealed that benefits of CAI tutoring were greatest for students with low initial math skills.

In another study, Funkhouser (2002) examined both achievement and attitude effects of computer-augmented geometry instruction for 36 weeks. Participants consisted of 49 10th and 11th graders. The treatment group (*n = 22*) used *Geometric Supposer* (1993) software, which allowed students to explore and construct geometric concepts through inductive reasoning, enabling them to perform geometric constructions commonly accomplished by a straightedge and compass. The control group was taught the same concepts as the treatment group, using traditional methods and materials (e.g., compass, straightedge, and protractors). Both groups were given pre- and posttests on geometry content and attitudes toward mathematics. The results showed that the group receiving computer-augmented instruction performed significantly better on the geometry test (M =37, SD = 5.15) than the control group (M = 34.26, SD = 7.65). Overall, students who received CAI tended to make significantly stronger gains in acquiring geometry concepts, but did not tend to develop more positive attitudes toward mathematics than students who received traditional geometry instruction.

Despite various reported benefits of CAI, other studies have revealed that the use of technology has either no effect or a variable effect on mathematics achievement (Slavin, Lake, & Groff, 2009; Tienken & Maher, 2008). Often in these studies, the manner in which technology is used appears to lead to ineffective results. For example, in Tienken and Maher's (2008) study, the researchers used a quasi-experimental pretest/posttest control-group design to determine if there was a measurable difference in the mathematics achievement of eighth-grade students who received CAI compared to students who did not. The experimental group included 121 students and the control group consisted of 163. Mathematics content was consistent for both groups;

however, the control group received traditional instruction without technology. For 20 weeks students in the experimental group used a CAI intervention twice a week for 45 minutes. The intervention provided students opportunities for drill and practice of computation via websites based on the school's curriculum. Data from the study indicated that CAI did not have a statistically significant positive influence on participants' mathematics achievement and students who received CAI performed lower than their peers in the control group. Based on these results, the researchers cautioned that lower-order (i.e., drill and practice) use of computers in mathematics can be a detriment to the achievement of low-performing students.

Wenglinsky (1998) found similar results regarding lower-order computer usage when he conducted statistical analyses of the 1996 NAEP national database. Using two samples of students, 6,227 fourth-graders and 7,146 eighth-graders, Wenglinsky investigated the relationship between computer use and student mathematics achievement. The findings showed that achievement improved when computers were used to address higher order concepts (e.g., problem-solving) and decreased when computers focused on lower-order thinking skills (e.g., memorization, drill and practice).

In another CAI study, Tienken and Wilson (2007) used a pretest/posttest quasi-experimental design to examine the achievement differences between students taught to use websites and students who received regular instruction in basic mathematics skills. The participants consisted of seventh-grade students enrolled in four middle school classrooms. Teachers were randomly assigned to the classrooms and either instructed the students using drill and practice websites or traditional instruction on basic math skills. The students in the treatment group used technology two times per week for 20 weeks. Results of the study suggested that the CAI had a positive but small effect on the treatment group's basic mathematics achievement. The researchers noted that this slight improvement may have been due to the minimum focus of basic skills on the administered standardized tests. State assessments typically concentrate on open-ended problem-solving questions, thus increased performance on the test may have been seen if the treatment group spent more time on problem-solving activities as opposed to basic math skills.

CAI and Students with or At-risk for Disabilities

Historically, mathematics underachievement has been severe for students with disabilities and those at-risk for academic failure (Carnine, Jones, & Dixon, 1994; Jitendra & Xin, 1997; Zentall & Ferkis, 1993). The term at-risk is often used to refer to a variety of learners categorized as low-achieving or educationally disadvantaged (i.e., low socioeconomic status, limited English proficient) and at risk of dropping out of school (Laffey et al., 2003). Despite learning and/or adjustment problems, at-risk students often fail to qualify for special education disabilities (Gable, Hendrickson, & Rogan, 1996). Alternative instruction strategies are essential in meeting the needs of these students and technology may be a significant tool for educating these students as well as those with disabilities. As opposed to the more numerous reports of general education students benefiting from CAI with mixed results, the literature contains several studies of students susceptible to mathematics failure experiencing increased levels of achievement when engaging in CAI (Laffey et al., 2003; Waxman & Padron, 1995).

At-risk students. Laffey et al. (2003) examined the potential of CAI contributing to the learning and behavior improvement of at-risk elementary school students. The study employed a pretest/posttest experimental design comparing children receiving CAI in grades prekindergarten through 1st grade with students receiving traditional instruction. All students were administered their grade-level assessment in both pre- and posttest sessions. Over an eight-week period, the treatment group received two 20-25 minute CAI sessions each week on problem-solving skills regarding the recognition of numbers, shapes, and sizes. These sessions occurred outside of the regular classroom and during non-academic periods of the day (i.e., recess, PE). Student behaviors (e.g., attention, engagement, enthusiasm) were observed in 10- and 20-minute intervals. In addition, the students were briefly interviewed once a week to inquire about their perception of CAI. Students in the comparison group received instruction on the same mathematics content, without the use of technology. The study found that the at-risk students exposed to CAI performed significantly better academically and behaviorally than the comparison group. The authors did note that the pullout nature of the treatment may have led to decreased rates of problem behaviors.

In another study finding similar results with at-risk students, Page (2002) compared the achievement of elementary students in CAI classrooms and students in traditional classrooms. Two hundred eleven third and fifth-grade students from 10 classrooms and five schools participated in the quasi-experimental study. All students were of low socioeconomic status and of various backgrounds, races, and ability levels. Classes were randomly assigned to either treatment or control groups. The same curriculum was followed in both groups; however, the treatment group used technology (i.e., software) extensively throughout the day. Pre- and post-assessments assessed the participants' mathematics achievement, self-esteem, and classroom interaction. A univariate analysis of covariance was utilized to determine if differences existed between the treatment and control groups. Statistically significant differences were found in the treatment groups' achievement and self-esteem scores. In addition, interaction analyses revealed that instruction in the treatment groups was more student-centered, while instruction in the control groups was more teacher-centered.

Salerno (1995) conducted a study which investigated whether the mathematics achievement of at-risk students using CAI differed significantly from the achievement of at-risk students using other instructional methods. Using a pretest/posttest control group design, 150 fifth-grade students were randomly selected from a school district and then randomly assigned to one of two treatment groups (extended computer time or extended time-on-task in the form of worksheet activities) or to a control group. Findings revealed a significant difference in achievement between boys receiving extended CAI and boys in the extended time-on-task treatment group. Girl participants receiving extended CAI achieved greater gains than girls using extended paper and pencil activities; however, these gains were not at a statistically significant level.

Bottge, along with several of his colleagues (Bottge, 1999; Bottge & Hasselbring, 1993; Bottge, Heinrichs, Chan, & Serlin, 2001; Bottge, Heinrichs, Chan, Mehta, & Watson, 2003), have conducted numerous studies regarding secondary at-risk students and math achievement with the use of technology. Focusing on contextualized instruction or anchored instruction, the researchers examined the use of multimedia-based and hands-on math problems to support learning in generative learning environments. Bottge and Hasselbring (1993) compared two methods of problem-solving instruction. Thirty-six ninth-grade students in two remedial math classes participated in the study and received either traditional instruction with standard fraction word problems or videodisc instruction with contextualized fraction word problems. Both groups of students improved their performance on solving word problems, but students who received videodisc instruction did significantly better on the contextualized problem posttest and were able to use their skills in two transfer tasks that followed instruction.

Bottge (1999) employed a pretest-posttest experimental design to compare the effectiveness of word problem instruction and contextualized word problem instruction on the computation skills and problem-solving performance of 17 below-average eighth-grade students in one remedial math class and 49 average-achieving eighth-grade students in two pre-algebra classes. Students were randomly assigned to the control group, which received traditional instruction in word problems, or to the experimental group, which received contextualized word problem instruction via videodisc technology. Results indicated statistically significant differences on the contextualized word problems test and transfer tasks for students in the experimental group in both the remedial and pre-algebra classes. However, their performance on computation and traditional word problems did not show any statistically significant differences. Similarly, Bottge et al. (2001) expanded the Bottge (1999) study to investigate whether at-risk students could match the computation and problem-solving performance of average-achieving students with the use of contextualized videodisc instruction. Using a pretest-posttest, non-equivalent group design, the study was conducted with 75 middle school students in remedial and pre-algebra classes. One remedial math class and three pre-algebra classes served as the treatment (n = 34) and comparison (n = 41) groups. Following the same instructional procedures from Bottge's (1999) study, results revealed that all groups made gains from pre- to posttest on problem-solving measures; however, students in the pre-algebra class outperformed the low-achieving students in both conditions on the computation measure with a small effect size of .10.

Bottge et al. (2003) used a repeated measure design with a staggered baseline to explore the potential benefits of hands-on activities that used contextualized problems within the context of a video-based story compared to traditional problem-solving instruction. Thirty-seven eighth-grade students participated in the study. Eleven of the students were low-achieving students in a remedial math class, while 26 average-achieving students were enrolled in pre-algebra classes. As the researchers found in the previous studies, the low-achieving students performed better on higher-order thinking problems during the video-based instruction. In addition, the at-risk students were able to transfer these skills to similar problems.

Although several of the aforementioned studies (Bottge, 1999; Bottge & Hasselbring, 1993; Bottge et al., 2001; Bottge et al., 2003; Salerno, 1995) have demonstrated positive effects of CAI on at-risk students' mathematics achievement, some studies regarding CAI and at-risk students (Fuchs et al., 2006; Shirvani, 2010) have revealed variable effects. To illustrate, Fuchs et al. (2006) assessed the effects of CAI on the number combination skill of 33 at-risk first graders. The students were randomly assigned to math CAI or the control condition spelling CAI. The math CAI presented basic math facts to the students in a specific order focusing on addition and subtraction number combinations. Students in the math CAI condition significantly outperformed the students in the spelling CAI condition. Results showed student gains in addition skills; however subtraction skills and the ability to transfer arithmetic to problem-solving did not improve.

Shirvani (2010) examined whether CAI was as effective as traditional instruction for teaching lower-achieving students mathematics. One hundred twenty-seven ninth-grade algebra students participated in the study. Out of a total of six classes, three classes (n = 65) were placed in the experimental group and the other three classes in the control group (n = 62). The lower-achieving students in the CAI condition significantly outperformed the lower-achieving students in the traditional instruction condition. Despite these results, there were no overall significant differences in learning mathematics between learners in the two groups but results did indicate that CAI increased student attitudes towards mathematics.

Students with disabilities. In a study examining the relationship between the use of a web-based math tutor and mathematics achievement, Koedinger et al. (2010) conducted a quasi-experiment that evaluated whether ASSISTment had an effect on improving seventh-graders' year-end standardized test scores. ASSISTment is a formative assessment software program designed to give students individualized tutorial assistance via hints and feedback, while simultaneously collecting assessment data. Participants of the study consisted of 1,240 students in four middle schools. Three schools received the treatment and one served as a comparison school. Seventy-nine percent of the participants were general education students and 21% were special education students. Results of the study indicated that students in the treatment condition performed better than the comparison students on the posttest after controlling for pretest scores. Special education students in the treatment condition demonstrated the greatest gain related to using ASSISTment. There was a 5.7% gain compared to only a 0.9% gain for general education students.

Mautone, DuPaul, and Jitendra (2005) documented improved problem-solving and on-task behaviors for three second- through fourth-grade students with attention-deficit hyperactivity disorder (ADHD) who used computer software during mathematics. Using a single subject, multiple baseline design the researchers sequentially introduced the CAI intervention across the students. Baseline observations occurred during traditional instruction, and intervention observations occurred during CAI. The intervention consisted of using mathematics software on the computer for a total of 10-15 minutes, three times a week. Based on academic levels, the students' teachers determined which lessons the students would complete on the computer. The students' math performance was monitored twice a week using assessments of skill levels. In addition, their behaviors were observed twice a week during 15 minute observation sessions via momentary time sampling procedures. Results indicated that each student made gains in mathematics fluency and attentive behavior. While the CAI intervention produced an immediate decrease in off-task behaviors, academic skills improved gradually. Ota and DuPaul (2002) found similar results when they conducted an equivalent study on three fourth- through sixth-grade students with ADHD. The researchers examined the effects of using game format CAI to improve attention and multi-digit addition, subtraction and multiplication computation. Baseline observations occurred during traditional math instruction and independent seatwork. After two weeks of baseline stability for the first participant, the intervention phase was implemented sequentially. During the intervention phase, the participants worked on their math skills via an arcade style computer game for 20 minutes, three to four times a week. Findings revealed that the CAI game format led to increases in active engagement, decreases in off-task behaviors, and improvements in math computation for all participants.

Students with LD. Wilson, Majsterek, and Simmons (1996) conducted a study which compared CAI to teacher-directed instruction and attempted to ensure equivalent instructional variables in both conditions. The authors employed a single-subject, alternating treatments design to examine which method of instruction led to greater acquisition of multiplication facts for four elementary school students with LD. The CAI treatment consisted of using a software program which incorporated three instructional components (i.e., demonstration, practice, and game). The teacher-directed treatment contained the same components, however, flashcards were utilized for instruction. In both treatments verbal praise and corrective feedback were provided when warranted. Although all students mastered the multiplication facts and improved their automaticity skills under the CAI condition, results indicated that the teacher-directed instruction was more effective in achieving basic fact automaticity. Wilson et al. noted that the teacher-directed condition was possibly more successful due to unanticipated differences regarding student opportunities to respond. Data on opportunities to respond revealed that students in the teacher-directed condition received more chances to review facts and answers, respond to problems, and receive feedback.

In another study, Hitchcock and Noonan (2000) compared the effectiveness of CAI with teacher-directed instruction to examine which instructional method was effective in increasing the proficiency in basic preschool academic skills (i.e., matching colors, shapes, numbers, letters). The researchers combined the strategy of constant time delay, a method that uses cues and modeling if problems are answered incorrectly, in both conditions and ensured that all instructional components were comparable. Five preschool students with significant delays in cognitive, language, and/or adaptive behavior skills participated in the study. Hitchcock and Noonan used an adapted alternating treatments design. During the baseline phase, the teacher used conventional teaching methods (i.e. manipulative, modeling, direct instruction) to teach the matching skills. During the first alternating treatment phase, the students were asked to match and locate items while the teacher used a constant time delay of four seconds. The next alternating treatment phase, which occurred on the same day, required the students to practice matching skills using CAI. Both alternating treatment conditions continued until one condition was deemed superior. A follow-up condition of the superior condition was conducted until a criterion of 90% accuracy on three consecutive days was reached. Results indicated that both methods, CAI and teacher-directed instruction, were equally effective in enhancing the learning of the targeted skills. However, it was observed that CAI was superior in motivating the students and producing high levels of correct matching responses.

Okolo (1992) conducted a study focusing on the acquisition of addition facts through comparing two types of CAI (i.e., drill/practice, game). Forty-one students with LD enrolled in the fourth through sixth grade were randomly assigned to the treatment or comparison group. Prior to assignment, the students were identified as having high or low math attitudes. In the drill and practice condition, students were given two minutes to solve addition problems with answers provided in a multiple choice format. If problems were answered correctly, they were reinforced with positive animations. In the game condition, the students were presented with facts previously learned in the drill and practice session. Final analysis revealed that opportunities to respond were substantively greater in the drill and practice condition than in the game condition. Despite the difference in the number of opportunities to respond to various problems, both condition groups improved their addition facts proficiency. Results also indicated that regardless of math attitudes prior to administered treatments, students' attitudes did not change significantly; however, students with high attitudes toward math performed significantly better in the game condition than their peers in the drill and practice condition. Unfortunately, the study did not incorporate a control group to validate these findings.

In another study analyzing instructional features, Shiah, Mastropieri, Scruggs, and Fulk (1995) employed a pretest/posttest design to examine the effects of three different CAI programs on addition and subtraction word problem-solving and the transference of these skills. Thirty elementary students with LD were stratified by grade level and randomly assigned to one of three groups (i.e., seven-step word problem-solving strategy plus animation, seven-step word problem-solving strategy plus static picture, no strategy plus static picture). The word problem-solving strategy consisted of reading the problem, thinking about the problem, deciding the operation sign, writing the math sentence, solving the problem, labeling the answer, and checking all steps. All students significantly improved their word problem-solving skills and no significant differences were revealed among the three conditions. No evidence of skill transference was observed.

Students with EBD. In order to examine if students with EBD experience similar achievement outcomes as their peers with and without disabilities when exposed to CAI, Bottge et al. (2006) and Billingsley et al. (2009) both investigated the effects of CAI on the mathematics achievement of students with EBD. In the Bottge et al. study, the researchers examined the effects of multimedia instruction on the math achievement, specifically problem-solving performance, of 17 high school adolescents with challenging behaviors. The multimedia instruction was delivered via videodiscs. Bottge and colleagues used a quasi-experimental design, employing methods that used a one-group nonequivalent dependent variables design with multiple measures in multiple waves thus helping rule out most plausible threats to their study's internal validity. Results from the study indicated that the students scored higher on curriculum-aligned problem-solving assessments that employed videodisc instruction, but made no improvements on a standardized and a fractions computation test. The researchers reported that the participants exhibited high engagement and motivation when working on videodisc problems. However, the participants gave negative reactions when instructed and assessed on basic mathematical skills.

Billingsley et al. (2009) examined which instructional method (teacher directed, CAI, or a combination of the methods) was more effective in teaching math skills to 10 high school students with EBD. The combination of CAI and direct teaching instructional methods yielded higher math quiz scores for 7 out of the 10 participants. When used individually, the direct teaching method resulted in higher scores for two of the participants and CAI resulted in higher scores for only one participant. Overall, the researchers found that the non-technology instructional methods proved more effective for students with above average intelligence than for participants with lower cognitive abilities. The combined method of CAI and direct teaching demonstrated more effective results for the younger participants in the study. The researchers reported the effect sizes of the interventions as the following: .70 for CAI; .77 for direct teaching methods; and .83 for combined methods. Billingsley and colleagues addressed several rival hypotheses of their study. They reported that extraneous factors such as the students' absenteeism (e.g. suspensions, refusal to participate), time constraints of the study, and interactive and carryover effects may have compromised the effect size calculations.

Summary

Numerous studies have demonstrated various achievement benefits of using CAI over traditional instruction when teaching mathematics to general education students (Funkhouser, 2002; Huntley & Greever-Rice, 2007). Some of these benefits include fluency of basic mathematics computation skills, increased scores on annual state assessments, higher class grades, and a deeper understanding of problem-solving. Although a solid justification for integrating technology in American classrooms is at least arguable, a stronger case might be evident for inclusion among students with disabilities especially since this instructional approach is deemed as one of the more efficient ways of adapting instruction to individual differences, allowing students to work at their own pace and ability level (MacArthur, Ferretti, Okolo, & Cavalier, 2001). As with students at risk for academic failure, CAI can potentially increase student motivation, engagement, and academic performance of students with disabilities (Shiah, et al., 1995).

Most of the research on mathematics CAI in special education focuses on students with LD (Fitzgerald et al., 2008; Woodward & Rieth, 1997). This emphasis has been primarily due to the instructional features (e.g., individualization, self-pacing, immediate feedback, and modeling with representative examples) offered by technology (Anderson-Inman, Knox-Quinn, & Horney, 1996) and the profound learning characteristics (e.g., memory deficits, cognitive processing deficits, metacognitive deficits, distractibility) of students with LD. As a result, several studies exist focusing on the effects of embedded features in CAI programs. It is argued that these instructional features are key in helping create successful mathematical learning outcomes for these students (Okolo, 1992; Shiah et al., 1995); however, findings have been mixed.

There is a dearth of research focusing on the effects of CAI and the mathematics achievement of students with EBD. Like students with LD, students with EBD frequently exhibit significant academic deficits (Trout, Nordness, Pierce, & Epstein, 2003). Due to some overlap in the characteristics of students with LD and those with EBD (Hallahan, Kauffman, & Pullen, 2009), interventions found successful for students with LD are often inaccurately generalized to students with EBD (Lewis, Hudson, Richter, & Johnson, 2004). Researchers must remember that although academic profiles seem to parallel each other, deficits of students with EBD either remain stable or worsen overtime, whereas students with LD typically show some improvement over the years (Anderson et al., 2001). Therefore, justifying similar teaching methods without extensively researching the EBD population can result in numerous ramifications namely, the use of ineffective interventions and unintended effects on student performance and attitudes toward school. This literature review identified various studies which investigated the effects of CAI on students' mathematics achievement. Findings across most of the reviewed studies revealed mixed results (Funkhouser, 2002; Tienken & Wilson, 2007;

Wenglinsky, 1998) of the CAI intervention; however, studies that examined at-risk students and students with disabilities proved more favorable in increasing mathematics achievement (Koedinger et al., 2010; Laffey et al., 2003; Page, 2002). Of these studies, only two analyzed the effects of the CAI method on students with EBD (Billingsley et al., 2009; Bottge et al., 2006). The paucity of research in this area makes it difficult to draw definitive conclusions about the effectiveness of CAI for these students.

Since students with EBD often experience greater difficulty in mathematics than their peers with and without disabilities, it is instructive to further investigate the effects of CAI and not rely on the results of students with similar profiles. Also, as shown in this review, the impact of technology is highly dependent on the manner in which it used (Billingsley et al., 2009; Hitchcock & Noonan, 2000; Okolo, 1992), thus it is important to examine the teaching approaches and CAI formats that are effective with students with EBD. This review of relevant literature on the effectiveness of CAI in mathematics instruction has demonstrated an obvious gap with students with EBD, thus providing a strong basis for further investigation of the area.

Limitations of the Literature

Several limitations were found in the studies examined in this literature review. These limitations may have impacted the findings and conclusions regarding the effect of CAI on mathematics achievement.

Demographic data. Inadequate description of participants is a weakness of the current body of research. Several of the authors failed to identify their participants' demographic characteristics, thus precluding generalizability. To illustrate, of the 24 studies 38% (Beal et al., 2007; Bottge & Hasselbring, 1993; Koedinger, 2010; Laffey et al., 2003; Salerno, 1995; Shirvani, 2010; Tienken & Maher, 2008; Tienken & Wilson, 2007; Wenglinsky, 1998) did not include gender data, while 54% (Beal et al., 2007; Bottge, 1999; Bottge & Hasselbring, 1993; Bottge et al., 2001; Bottge et al., 2003; Funkhouser, 2002; Koedinger, 2010; Okolo, 1992; Salerno, 1995; Shiah et al., 1995; Shirvani, 2010; Tienken & Maher, 2008; Wenglinsky, 1998) did not report participants' ethnicity. Future research should include more detailed sample descriptions in order to increase the understanding for whom the intervention might be effective and enhance replication.

Target skill. In 38% of the studies (Beal et al., 2007; Koedinger, 2010; Mautone et al., 2008; Page, 2002; Salerno, 1995; Shirvani, 2010; Tienken & Maher, 2008; Tienken & Wilson, 2007; Wenglinsky, 1998), it was impossible to ascertain what mathematics skill was the primary objective of the study due to a lack of comprehensive descriptions of the content targeted by the investigators. Some of the ambiguous skills were described as addition, subtraction, multiplication, and division skills without any specification (i.e., the quantity of digits, whether regrouping was required, the range of facts). Lacking such pertinent data makes it difficult to replicate the study or justify the study's results.

Treatment fidelity. Studies in this review typically reported fidelity of implementation by using independent observers who collected data via logbooks, field notes, and reliability checks. Despite addressing that treatment fidelity was conducted, some of the investigators (Bottge, 1999; Bottge et al., 2001; Bottge et al., 2003; Bottge et al., 2006; Salerno, 1995; Tienken & Maher, 2008; Tienken & Wilson, 2007) were not explicit about their fidelity information (i.e., interobserver agreement, frequency of observations, degree to which appropriate procedures were observed). Overall, 33% of the studies (Beal et al., 2007; Funkhouser, 2002; Koedinger, 2010; Okolo, 1992; Page, 2002; Shiah et al., 1995; Shirvani, 2010; Wenglisky, 1998) did not provide any indication that the study was implemented with fidelity, thus making it difficult to confirm that the independent variable was implemented as intended. The absence of treatment fidelity was further evidenced in the aforementioned studies' failure to ensure the equivalency of instructional conditions (i.e., content, difficulty level, opportunities to respond, feedback, procedures) when comparing CAI to traditional instruction. Without this information, it was not clear whether any students' outcomes found in these studies were attributed to different instructional variables, which were not controlled.

Social validity. Out of 24 of the studies, 38% (Billingsley et al., 2009; Bottge & Hasselbring, 1993; Fuchs et al., 2006; Koedinger, 2010; Page, 2002; Salerno, 1995; Tienken & Maher, 2008; Tienken & Wilson, 2007; Wilson et al., 1996) did not include information regarding social validity. Considering that 79% of the reviewed studies involved participants with disabilities or at-risk for disabilities, addressing the social importance or practicality of these studies' interventions would have been very beneficial. Further research should include such information.

Maintenance. Follow-up procedures after implementing an intervention helps further validate positive improvements found during the intervention phase. Fifty-eight percent (Beal et al., 2007; Fuchs et al., 2006; Funkhouser, 2002; Koedinger, 2010; Laffey et al., 2003; Mautone et al., 2008; Okolo, 1992; Ota & DuPaul, 2002; Page, 2002; Salerno, 1995; Shirvani, 2010; Tienken & Maher, 2008; Tienken & Wilson, 2007; Wenglisky, 1998) of the studies in this review did not include a maintenance phase. The absence of this phase makes it difficult to determine whether any improvements were maintained across time. Such information is vital especially since deficits of some students with disabilities or at-risk for disabilities can either remain stable or worsen over time (Anderson et al., 2001).

Chapter 3: Methodology

Research is scarce regarding the effectiveness of CAI on the math proficiency of students with EBD. This study sought to examine the extent to which a technology-based intervention was effective in improving math achievement for students with EBD. A single-subject, multiple-probe design was employed to address the following questions:

1. What is the effect of CAI on basic skills in mathematics?
2. What is the effect of CAI on problem-solving skills in mathematics?
3. What is the effect of CAI on task engagement in mathematics?

Design of the Study

A multiple-probe design across participants was selected for this study to determine the effects of CAI on the math achievement and task engagement of students with EBD. The multiple-probe design demonstrates the effect of treatment by showing the occurrence of change of a particular behavior when an intervention is introduced and this change is replicated across participants. This procedure does not require baseline observations throughout the course of a study, thus its use is beneficial when continuous measurement is not feasible due to impracticality or the potential for reactivity (Poling, Methot, & LeSage, 1995). Since reticence was a characteristic of this study's participants, it was not logical to submit the participants to repeated assessment prior to implementing the treatment. Instead, quick probes were employed during the baseline phase to rapidly evaluate the participants' behavior preintervention. Probes are discrete measurements of a target behavior often conducted intermittently to verify that the participants still cannot perform the target behavior or to record any behavior changes before the intervention (Morgan & Morgan, 2009).

Once baseline levels are deemed stable, the intervention is implemented with the first participant while the other participants continue to receive intermittent probes. When the first participant reaches a predetermined performance criterion, one or more probe sessions are conducted on all of the participants. The intervention is then implemented with the second participant, while postcheck probes are conducted with the first participant to establish that his/her behavior change is being maintained. Baseline probes continue with the other participants until the second participant reaches the established criterion. Once again, one or more probes sessions are conducted. This procedure will continue until all participants are involved in the intervention and then data collected during the treatment phase can be compared with the probe measures collected during the baseline phase to determine the treatment's effect on the behavior (Morgan & Morgan, 2009). To ensure sufficient replication upon which to evaluate the functional relation between this study's intervention and behavioral effects, six students were selected for the study.

Setting and Participants

This study was conducted in a high school mathematics classroom in a private residential treatment facility located in a metropolitan area in the Southeastern United States. The facility, which served approximately 84 students, specialized in treating adolescents with emotional and behavioral issues triggered by trauma. The adolescents were admitted to the facility for emotional, behavioral, psychiatric and/or psychological problems. These adolescents were not only taught the coping skills necessary to make the transition back into the community, but they also received academic instruction to return to a standard classroom. The school in which the residents attended was an accredited member of the Virginia Association of Independent Specialized Education Facilities and licensed by the Virginia Department of Education to offer both general and special education services. General and special education teachers worked closely with the students' home school divisions in continuing the appropriate course work needed for their graduation.

As part of Virginia Commonwealth University's (VCU) policy, this study was reviewed by the university's Institutional Review Board (IRB) prior to the recruitment of participants. After approval was obtained from the IRB, a formal request to conduct the study was submitted to the facility's Chief Administrative Officer and the Education Director of the school. Once permission was granted, a memorandum of understanding was devised and potential study participants were considered. Students were considered as eligible participants of the study based on the following criteria: a) identified as having EBD substantiated via school records, b) recently administered (i.e., no more than a year old) standardized tests indicated deficit skills in basic math and problem-solving, c) an additional standardized measure of math achievement specifically indicated a low average (i.e., standard score range of 80-89) functioning level in calculation and applied problems, and d) to avoid the possibility of attrition, at the time of the study, potential participants' projected length of stay at the facility had to be at least six months. Based on these eligibility criteria, written information conveying the purpose of this study along with consent forms were sent to the homes of the eligible students. Once consent was received, assent was sought from the students. After assent had been obtained, six of the lowest performing eligible students were selected as participants and the study was then implemented by the mathematics teacher, who was also the researcher of the study.

Classroom. The mathematics classroom in which the study was conducted was set up like a traditional classroom. Upon entering the room, the teacher's desk was to the immediate right and a large whiteboard was to the immediate left. Fifteen desks were in rows and they all faced the whiteboard in front of the room. A medium table was in the back the room and designated for the paraprofessional. Two large windows were on one side of the room and they were covered with blinds. Walking space was adequate and although there were 15 desks, during the study the teacher to student ratio was 1:10. The course provided in the classroom during the study was Algebra I and was taught during the last of 6 periods that met each day of the week. The participants of the study sat in assigned seats around the classroom. The teacher established a daily routine that began with a warm-up activity, followed by whole-group instruction and guided practice, and ended with independent practice and individual assistance.

Participant profiles. The six lowest performing students selected for the study were all 9th grade high school males ranging from ages 14 to 17. In order to meet the study's participation criteria, these participants were receiving special education services under the classification of EBD and documentation of previous and recent administered standardized tests indicated deficit skills in basic math and problem-solving (see Table 1). To identify the participants' specific deficit skill areas in basic math and problem-solving, a diagnostic test was administered from the *I CAN Learn* software package. There were a range of deficits in each individual's competencies. Diagnostic scores revealed that each participant experienced difficulty with fractions, specifically adding and subtracting fractions with different denominators and simplifying answers to lowest terms. Therefore, this common deficit skill was selected as the target skill for all participants throughout the duration of the study.

Table 1

Demographics of Participants

Participant	Age/Grade	Race	*SS (WIAT-III) Basic Math/ Problem-Solving (within the last year)	*SS (WJ-III) Basic Math/ Problem-Solving (onset of the study)
David	15/9th	African American	82/85	82/83
Mitchell	15/9th	Caucasian	89/87	87/85
Kyree	16/9th	African American	85/86	85/84
Trenton	14/9th	Caucasian	83/87	83/85
Andre	17/9th	African American	81/80	83/81
Zeik	15/9th	African American	84/82	83/80

**Standard Scores*

David. David was a 15-year-old, African American student who had been receiving special education services under the classification of EBD since the 5th grade. David's school records indicated many issues with truancy, disrespect to authority, and academic troubles. His standard scores on the Wechsler Individual Achievement Test-Third Edition (WIAT-III) indicated deficit skills in basic math and problem-solving. David scored an 82 in basic math and an 85 in problem-solving. At the time of the study, he had a 65 average in his math class. At the onset of the study, David was administered the Woodcock Johnson III Tests of Achievement (WJ-III). His standard scores of 82 and 83 substantiated his deficits with basic math and problem-solving respectively.

Mitchell. Mitchell was a 15-year-old, Caucasian student who was identified as a student with EBD while in the 2nd grade. Mitchell's school records indicated difficulty interacting socially with his peers, substance abuse, and displays of covert aggression. His standard scores on the WIAT-III indicated deficit skills in basic math and problem-solving. Mitchell scored an 89 in basic math and an 87 in problem-solving. At the time of the study, he had a 79 average in his math class. At the onset of the study, Mitchell was administered the WJ-III. His standard scores of 87 and 85 substantiated his deficits with basic math and problem-solving respectively.

Kyree. Kyree was a 16-year-old, African American student who had been receiving special education services under the classification of EBD since kindergarten. Kyree's school records indicated many issues with truancy, possession and distribution of drug paraphernalia, and physical aggression toward authority figures. His standard scores on the WIAT-III indicated deficit skills in basic math and problem-solving. Kyree scored an 85 in basic math and an 86 in problem-solving. At the time of the study, he had an 88 average in his math class. At the onset of the study, Kyree was administered the WJ-III. His standard scores of 85 and 84 substantiated his deficits with basic math and problem-solving respectively.

Trenton. Trenton was a 14-year-old, Caucasian student who was identified as a student with EBD while in the 5th grade. Trenton's school records indicated many issues with homicidal and suicidal ideations. His standard scores on the WIAT-III indicated deficit skills in basic math and problem-solving. Trenton scored an 83 in basic math and an 87 in problem-solving. At the time of the study, he had a 50 average in his math class. At the onset of the study, Trenton was administered the WJ-III. His standard scores of 83 and 85 substantiated his deficits with basic math and problem-solving respectively.

Andre. Andre was a 17-year-old, African American student who had been receiving special education services under the classification of EBD since kindergarten. Andre's school records indicated many issues with defiance and opposition. His standard scores on the WIAT-III indicated deficit skills in basic math and problem-solving. Andre scored an 81 in basic math and an 80 in problem-solving. At the time of the study, he had a 50 average in his math class. At the onset of the study, Andre was administered the WJ-III. His standard scores of 83 and 81 substantiated his deficits with basic math and problem-solving respectively.

Zeik. Zeik was a 15-year-old, African American student who had been receiving special education services under the classification of EBD since the 5th grade. Zeik's school records indicated many issues with depression and social isolation. His standard scores on the WIAT-III indicated deficit skills in basic math and problem-solving. Zeik scored an 84 in basic math and an 82 in problem-solving. At the time of the study, he had a 70 average in his math class. At the onset of the study, Zeik was administered the WJ-III. His standard scores of 83 and 80 substantiated his deficits with basic math and problem-solving respectively.

Instrumentation

Different measures were used to address the various research questions of this study. These measures included software developed curriculum-based math probes and a task engagement inventory.

Curriculum-based math probes. Developed by the software publisher, these probes were used to monitor the participants' progress in the acquisition of individually targeted basic math and problem-solving skills. All participants were given multiple math probes of varying degrees of difficulty to determine their skill level regarding the objectives covered in the intervention. Each probe consisted of 10 questions that pertained directly to the lessons in the intervention. See Appendix A for a sample probe. The skill assessed in each probe remained constant throughout the study. Individual problems were changed from probe to probe to preclude potential practice effects. Students had to obtain a grade of 80% or higher in order for their target skill to be considered at a level of mastery.

Inter-scorer agreement. To ensure consistency in the scoring of the probes, inter-rater reliability data were gathered for 25% of the sessions. During these sessions, the study's investigator and a trained classroom assistant independently scored and calculated the total percentage correct on administered probes using provided answer keys. Participants' answers were compared to the correct answers on the answer keys. There was no partial credit when scoring, each correct answer was worth 10 points, and answers had to be correct in their entirety (i.e., proper use of math symbols) to obtain a correct score value. See Appendix B for a sample answer key.

After scores were calculated, the investigator and the second rater's scores were compared to determine the percent of agreement. The following formula for calculating inter-scorer agreement was used: Agreements/ (Agreements + Disagreements) x 100.

Task engagement inventory. According to Walker and Severson (1990), academic engaged time is the amount of time an individual is appropriately involved in an academic task. For this study, participants were considered actively engaged on their academic tasks if their eyes were focused on the activity (e.g., teacher, computer, assignments) and/or they were appropriately responding to questions (e.g., raising hand, selecting answers with the computer's mouse, completing assignments). The study's behavioral criteria of academic engagement are described in Table 2.

Table 2

Behavioral Criteria for Academic Engagement

Eye Contact	Appropriately Responding
The student is.......	The student is.......
focusing on the teacher during a lesson.	taking notes.
focusing on the computer program.	completing an assignment.
reading his/her textbook.	answering questions verbally.
asking questions pertaining to the lesson.	completing problems on the whiteboard.
asking questions about an assignment.	answering questions on the computer.
using a calculator to complete an assignment.	working with a peer on an assignment.

Throughout this study, the participants' engagement was measured by calculating their percentage of academic engaged time. Following Walker and Severson's (1990) procedures, which were normed on a large national sample of children (n = 4,500) and reported to have an inter-rater reliability of .96, a stopwatch was used to record the duration of time that each participant was engaged during observational sessions. A sampling of each participant's academic engagement time was collected by conducting randomly ordered, five minute observations of each participant for a total of 10 minutes. Collection of classroom observation data for each participant occurred over a period of two 5-minute sessions. During these sessions, the stopwatch was started when the session began and was stopped whenever the observed participant disengaged. The stopwatch was restarted when his/her engagement resumed. After a total of five minutes, the next participant was observed using the aforementioned procedures and this observation process continued until each participant was observed twice for five minutes. Data were recorded on the task engagement collection form (see Appendix C). The percentage of academic engaged time for each participant was calculated by dividing the sum of each participant's final time, in seconds, displayed on the stopwatch by the total observed time.

Inter-scorer agreement. To ensure consistency in the measuring of the participants' task engagement, agreement data were taken for 25% of the observational sessions. This was accomplished by having a trained classroom assistant and a second rater simultaneously record participants' engagement time. After observational sessions, both raters' final recorded engagement times were compared. Inter-scorer agreement was calculated by dividing the smaller amount of time (in seconds) by the larger amount of time.

Intervention

I CAN Learn is a computer program distributed by JRL Enterprises. The system is comprised of both hardware and software packages that are designed to deliver a series of interactive lessons on a one-on-one basis. The curricula are aligned with the NCTM standards and can be customized to meet state standards. This software program allowed students to study math concepts at their own pace. Each lesson consisted of a pretest, a review, the lesson, a cumulative review, and comprehensive tests. Problem-solving skills were targeted with challenging problems embedded in the software that required students to solve multi-step application problems throughout provided lessons. If students did not pass the comprehensive tests, they had to repeat the entire lesson until they received a certain degree of mastery. All diagnostic and assessment scores were maintained for the teacher's review, thus making it easy to determine where additional assistance was needed. The U.S. Department of Education's *What*

Works Clearinghouse awarded this program its highest rating of "Positive Effects" (U.S. Department of Education, 2010).

Treatment fidelity. To ensure that implementation of the CAI intervention was standardized across all sessions and participants, treatment fidelity was monitored via a fidelity checklist and inter-rater reliability data were gathered for 25% of the observational sessions (Appendix D). Using the checklist, the raters ensured the CAI intervention focused directly on the participants' identified deficit skills, followed the lesson sequence (e.g., warm-up, lesson presentation, review, and assessment) as described by the software publisher, and lasted for a duration of 20 minutes each session. On the checklist, raters were provided with detailed descriptions of what each section in the lesson sequence entailed. Raters either placed a check mark or a zero next to each step on the checklist to indicate if the step was observed. At the end of the checklist, spaces were provided for the independent observers to mark the total occurrence of observed steps. This number was divided by the total number of steps on the checklist and then multiplied by 100.

After the percentage of observed steps was calculated, the raters' scores were compared to determine the percentage of agreement. An agreement occurred if both observers recorded the presence of a completed step. The number of agreements divided by the number of agreements plus disagreements multiplied by 100 produced percentage reliability of the observations.

Social validity. In order to examine the practicality of the CAI intervention, a social validity survey was administered to the participants at the beginning and end of the study. The survey specifically measured the participants' attitudes toward mathematics and technology-based instruction and consisted of a five-point Likert scale ranging from *5 = strongly agree* to *1 = strongly disagree* (Appendix E). The survey had three subscales that were designed to assess students' attitude toward computer use (i.e., "I enjoy doing things on a computer"), attitude toward mathematics (i.e., "I am sure of myself when I do math"), and attitude toward CAI (i.e., "I enjoy lessons on the computer"). The subscales had 4, 9, and 5 items respectively (see Table 3). The 18-item scale (Nguyen, Hsieh, & Allen, 2006) was reported to have pre-assessment and post-assessment reliability of .87 and .93, respectively and the survey was said to demonstrate high internal consistency on all subscales. In efforts to isolate students' math attitudes and to prevent subject effects, the researcher of this study added 18 additional items assessing the students' attitudes toward history, English, and science. The survey was administered by the trained classroom assistant.

Table 3

Subscales and Corresponding Statements on Attitude Survey

Computer Use	Mathematics	CAI
I enjoy doing things on a computer.	I enjoy mathematics courses.	I concentrate on a computer when I use one.
	I feel at ease in mathematics.	
I feel comfortable working with a computer.	Knowing mathematics will help me earn a living.	I would work harder if I could use computers more often.
I think that working with a computer is enjoyable and stimulating.	I study math because I know how useful it is.	I enjoy lessons on the computer.
I have a lot of self-confidence when it comes to working with computers.	I am sure of myself when I do math.	I know that computers give me opportunities to learn many new things
	I know I can do well in math.	
	I think I could handle more difficult math.	I believe that the more teachers use computers, the more I will enjoy school.
	I enjoy mathematics problem-solving.	
	I will need mathematics for my future work.	

Procedures

This study was conducted during the 2013-2014 school year, for a duration of 12 weeks. Various procedures took place throughout this study. This section explains the training, data collection and recording, data analysis, baseline, intervention, and maintenance procedures that occurred.

Training procedures. Before the study began, individuals who agreed to assist with the study signed a confidentiality disclosure requiring them to keep the names, identities, and any identifying information regarding the participants in the study confidential. In this study, the investigator's classroom paraprofessional and a special education teacher at the study's setting served as data collectors. Both individuals had more than three years of experience conducting classroom observations. To ensure rating consistency between these two raters, a two-week training took place until a minimum of 80% agreement between the two independent observers was reached. According to Kazdin (1982), 80% agreement is considered acceptable for interobserver agreement.

The raters were systematically trained by the researcher of this study for 30 minutes a day. During the first training week, the raters were given an overview of the study and detailed information on the selected measures. Training objectives included: a) operationally defining and distinguishing target behaviors for classroom observations and b) practicing collecting and recording procedures. The raters were required to memorize the behavioral criteria for academic engagement (see Table 2). Once the observers verbally understood the observational codes, they were introduced to the collecting and recording procedures. After the introduction of these procedures, the raters simultaneously practiced the procedures by observing videotaped mock classroom sessions. As a group, the raters and the researcher discussed examples and non-examples of events that occurred during the videotaped sessions. The observers then independently scored video examples and recorded their data on the provided forms (Appendix C). Their data were analyzed to estimate the extent to which they were in agreement. During the second week of training, the raters conducted in vivo coding of behavioral observations of selected nonparticipants by simultaneously observing them in class three times over the week. It was expected that their inter-scorer agreement would be at or above .80 during these observational sessions. If reliability was not acceptable, coders continued practicing until .80 was reached on three consecutive sessions.

Also during the second week, the raters learned how to administer the attitude survey and the curriculum-based math probes. They practiced scoring the math probes with prefilled answered probes. Using provided recording forms (see Appendix A), they independently scored and calculated the total percentage correct on the mock probes. After scores were calculated, they were compared to determine the percent of agreement. It was expected that their inter-scorer agreement would be at or above .80. If reliability was not acceptable, coders continued practicing until .80 was reached on three consecutive sessions. Following the training period, periodic retraining occurred throughout the study to discuss and address any observational concerns from the researcher and/or the raters and to minimize the occurrence of observer drift.

Data collection and recording procedures. Data collection began after the two observers completed the interobserver agreement training, successfully reaching 80% on the curriculum-based math probes and the task engagement collection and recording procedures. Using direct observation and onsite recording, data were collected and recorded as often as four times a week by the second raters and the researcher of this study. The assisting paraprofessional was the primary data collector of the participants' academic engagement time, while the assisting special education teacher simultaneously collected data during 25% of these observational sessions. The researcher of the study was the primary scorer of the administered curriculum-based math probes, while the assisting paraprofessional scored 25% of the probes to ensure inter-rater agreement.

At the end of each observation period, the researcher of the study obtained the information recorded on the provided recording forms (see Appendices B & C) and then kept track of the information in a Microsoft Excel spreadsheet. The information inserted in the spreadsheet was used to automatically construct multiple-probe design graphs, which were updated and analyzed each recording session. In addition, the information obtained from the administered pre and post social validity survey was coded and entered into a separate computerized database, using SPSS software, for storage and analysis.

Data analysis techniques. Throughout this study, visual and descriptive analyses were conducted to analyze the data. Specifically, when analyzing the participants' academic engagement time and progress on the administered curriculum-based math probes, the researcher of the study conducted visual graphic inspections of the multiple- probe design graphs created in Microsoft Excel. Certain characteristics of the plotted data within and across the baseline, intervention, and maintenance conditions were examined in order to judge the effectiveness of the intervention. These data characteristics included: a) trend, b) variability, c) level, d) immediacy of effect, and e) overlap.

Evaluation of the data's trend and variability were conducted in the early stages of the study to monitor when the intervention should be implemented for the first participant. Trend refers to the tendency for the data to show systematic and consistent increases or decreases over time (Alberto & Troutman, 2003; Kazdin, 1982). It was assessed by calculating a least-squares regression coefficient of the first participant's baseline data and a trend line was entered on the graph to better represent that trend. Variability, which is the degree to which the plotted points deviate from the overall trend (Kennedy, 2005), was evaluated by examining the distribution of the points to the trend line. When the first participant's baseline probes indicated an absence of a trend, slight variability, or a decreasing trend, the participant was introduced to the intervention.

Level refers to the magnitude and direction of change from the end of one phase to the beginning of the next (Alberto & Troutman, 2003; Kazdin, 1982). In order to assess the level of data, the difference between the values of the last plotted point in the baseline condition and the first plotted point in the intervention condition was calculated to discern whether the intervention produced reliable effects upon initial implementation. An intervention's impact is considered powerful if a large level change occurs immediately after the treatment is introduced (Alberto & Troutman, 2003; Kazdin, 1982; Kennedy, 2005).

Immediacy of effect refers to how quickly data points change from baseline to intervention conditions. If plotted points show a quick versus a gradual change between conditions, there is a greater demonstration of the strength of the intervention (Alberto & Troutman, 2003; Kazdin, 1982; Kennedy, 2005). This was evaluated by examining marked changes in the level of the data.

Another indicator of an intervention's impact is the percentage of overlap of data. The lower the percentage of overlap, the stronger the impact of the intervention and the more convincing of the study's methodological strength (Alberto & Troutman, 2003). The percentage of overlapping data points was calculated for each adjacent condition. This was accomplished by determining the range of the data points in the baseline condition, counting the number of data points plotted in the intervention condition, counting the number of these points that fall within the range of values of the baseline condition, and finally dividing the number of data points that fell in the range of the baseline condition by the total number of data points in the intervention condition. To convert to a percentage, this value was multiplied by 100.

Overall, data collected in this study regarding the participants' academic engagement time and progress on the administered curriculum-based math probes were regularly reviewed for patterns that assisted the researcher in drawing conclusions regarding the participants' responses during the baseline, intervention, and maintenance phases. Conversely, data collected from the pre and post social validity survey were only analyzed at the beginning and end of the study via descriptive statistics. Participants' responses were described using frequency distributions and measures of central tendency (i.e., mean, median, and mode) to make comparisons between responses before and after the implementation of the intervention.

Pre-baseline procedures. In order to identify the participants' specific skill areas that became targets of instruction during the study, instructional levels were determined based on math assessment scores obtained on an administered standardized math assessment and diagnostic scores from the *I CAN Learn* software package. After target skills were identified, curriculum-based math probes were generated by the *I CAN Learn* system.

Baseline procedures. At the beginning of this condition, participants were administered the attitude survey to assess their perceptions of math and CAI before treatment implementation. Throughout this condition, the participants received typical classroom instruction, which included either small or large group mathematics instruction. Simultaneously, the participants' task engagement was measured. The participants did not receive remedial instruction in any of the target skills that were presented to them during the intervention phase and none of the participants received CAI for mathematics tasks during the baseline phase. The participants were administered curriculum-based probes on the specific skill areas identified as deficits during the pre-baseline procedures. Baseline observations occurred during mathematics instructional time.

In keeping with the recommendations made by Horner and Baer (1978), a minimum of three baseline probes were conducted with each participant and an additional baseline probe was added for each successive participant. At the start of the study, an initial baseline probe was conducted with each participant. Three consecutive sessions of probe data were collected for the first participant while intermittent probes were conducted with the other participants. When the first participant's baseline probes indicated an absence of a trend (i.e., percentage of correctly answered problems do not fluctuate), slight variability (i.e., percentage of correctly answered problems fluctuates with no more than 10 data points between probes), or a decreasing trend (i.e., percentage of correctly answered problems declines per probe), based upon visual analysis, the participant was introduced to the CAI intervention.

Intervention procedures. After baseline performance was established for the first participant, the *I CAN Learn* intervention was implemented while the other participants continued to receive intermittent probes. The *I CAN Learn* software was used four times a week for 20 minutes. The participants worked on lessons specifically targeting skill deficits. Lesson presentations were composed of video and graphic segments which offered the participants guided practice on their target skills. In addition, computer generated questions were given to assess comprehension and how much the participants retained. For questions answered incorrectly, the software provided guidance based on the nature of the errors. Consecutive sessions of probe data were conducted until the participant reached at least 80% proficiency of his/her targeted skill. Observations continued per probed session. If the participant reached the 80% mastery level immediately after receiving the CAI intervention, two consecutive probes were conducted to ensure stable mastery. Once the first participant reached the 80% level of mastery, one probe session was conducted on all of the participants. Following this probe session, the intervention was implemented with the second participant and a postcheck probe was conducted with the first participant to establish that his/her mastery level was being maintained. Intermittent probes continued with the other participants until the second participant reached 80% mastery on his/her targeted skill. Another probe session was conducted and this procedure continued until all participants were involved in the intervention.

As a caveat, it was possible that once the intervention was introduced to a participant he/she may not reach the predetermined criterion thus precluding the subsequent participants from being introduced to the treatment. If this occurred after six consecutive sessions, that participant's plotted data points were visually inspected via the aforementioned data analysis techniques to examine whether a functional relation between the independent and dependent variables was demonstrated. The strength of the demonstration that the intervention was responsible for the participant's change in performance rather than extraneous events was based on the trend and variability of the baseline data and the level and immediacy of effect in behavior once treatment was applied. As long as the effects of the intervention were demonstrated when the intervention was introduced and not before, the next participant received the treatment.

If effects of the intervention were not demonstrated with a participant but were demonstrated with others, that participant's performance was considered an exception. In a multiple-baseline design, it is possible to have one of the baselines not change after treatment implementation. If this occurs in a design that has many (e.g., six) baselines indicating clear effects of the intervention, a baseline that does not show a treatment effect will not interfere with drawing causal inferences about the ultimate effect of the intervention (Kazdin, 1982). Thus, in this study, if effects of the intervention were not demonstrated for a participant after six consecutive sessions during the treatment condition, the successive participant was introduced to the intervention.

Maintenance procedures. Two weeks after the intervention phase concluded, three intermittent probes were conducted with all participants. These probes were conducted to see whether the participants maintained their 80% mastery level in their targeted skill. Observations of task engagement took place during the maintenance probe sessions and the post attitude survey was administered.

VCU IRB

Before any actual data collection began, the researcher of this study received approval by the VCU IRB (HM20000469_CR1).

Delimitations

Several delimitations exist within this study. They are as follows: a) the study was conducted in a private residential treatment facility opposed to a public school; b) all of the participants in the study receive special education services under the classification of EBD; and c) the classrooms at the study's site consisted of small teacher to student ratios (e.g., 1:10).

Chapter 4: Results

This chapter analyzes the academic and engagement measures that were used to investigate the effectiveness of CAI on the math proficiency of students with EBD. Dependent measures to assess academic performance included curriculum-based math probes used during baseline, intervention, and maintenance conditions. Engagement data were also analyzed. Results relative to the study's research questions are reported in this chapter and interobserver agreement, treatment fidelity, and social validity results are provided. The research questions were as follows:

1. What is the effect of CAI on basic skills in mathematics?
2. What is the effect of CAI on problem-solving skills in mathematics?
3. What is the effect of CAI on task engagement in mathematics?

Research Question #1

The first research question explored the effects of CAI on basic skills in mathematics. Overall, visual analysis of the graphs on the curriculum-based math probes' scores of all participants showed that levels increased for 83% of the participants from baseline to intervention phases. The increases ranged from 20% to 100% with a mean increase of 60% (*SD* = 37.42). Upon initiation of the intervention, five of the participants showed moderate to high immediacy of response to the intervention. An immediate level change occurred for all participants except for Andre. All data continued an upward trend or ceiling effect following the introduction of the *I Can Learn* intervention. During the baseline session, all participants earned a mean score of 0% on the curriculum-based math probes, thus indicating a stable baseline with zero level, trend, and variability.

David. With a rapid immediacy of effect, David's scores during the intervention phase showed an improved change in level of 100 and continued throughout the intervention phase with low variability and a lack of overlap in data points. The mean of data scores in the intervention session was 98.18 and the scores ranged from 80% to 100%. The trend line for David was flat. During the maintenance session, David's curriculum-based math scores depicted a decayed level and an accelerating trend after dropping from 100% to 80% between the treatment and maintenance phases. Mean performance during the maintenance condition was 86.67% (*SD* = 11.55), a phase difference of 11.51. Scores during the maintenance phase also ranged from 80% to 100%. Figure 1 illustrates the percentage of David's scores throughout the baseline, intervention, and maintenance sessions.

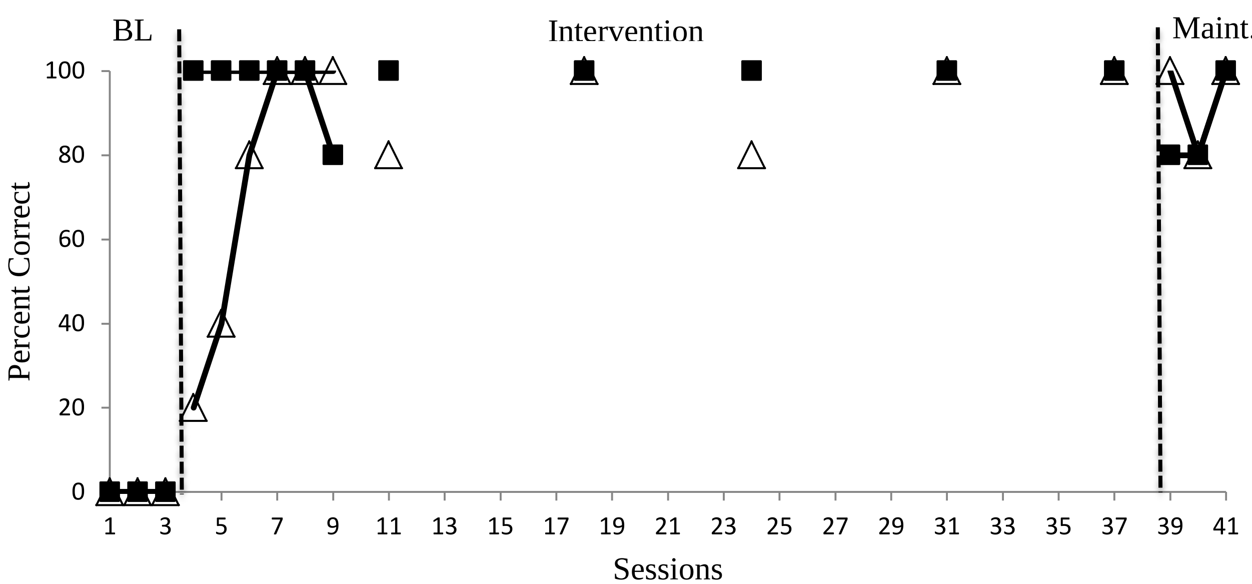

Figure 1. David's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Mitchell. Mitchell's scores, with an abrupt immediacy of effect, revealed an improved change in level of 100% without an overlap in data points. Scores remained at 100% throughout the intervention and maintenance conditions. Thus, during both of these phases (*M* = 100.00), the trend and level of the data were analyzed as visually flat without variability and 100% of overlap in data points. Figure 2 illustrates the percentage of Mitchell's scores throughout the baseline, intervention, and maintenance sessions.

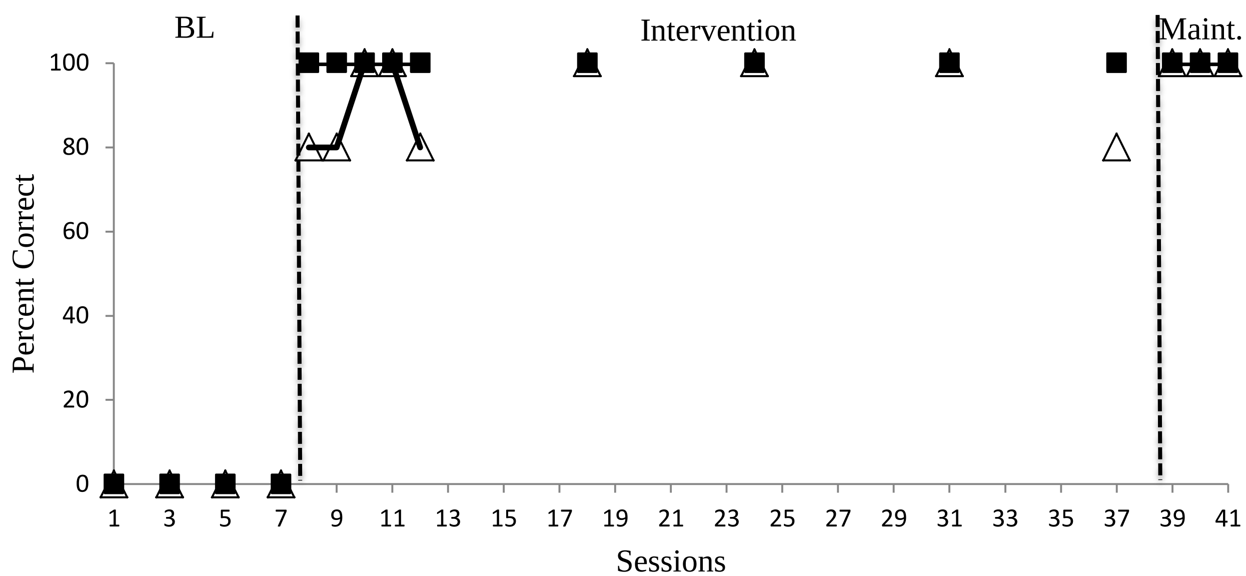

Figure 2. Mitchell's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Kyree. With a rapid immediacy of effect, Kyree's scores during the intervention phase showed an improved change in level of 40% without an overlap of data points. Scores on this participant's math probes revealed an upward trend with moderate variability (*M* = 69.09, *SD* = 25.87). Scores during this phase ranged from 40% to 100%. Kyree did not reach the predetermined criterion of 80% until the sixth session of the intervention phase. During the maintenance condition, the level also showed an improved change (*M* = 80.00, *SD* = 20.00);

however, there was a decelerating trend with moderate variability. Scores during this phase ranged from 60% to 100%. Figure 3 illustrates the percentage of Kyree's scores throughout the baseline, intervention, and maintenance sessions.

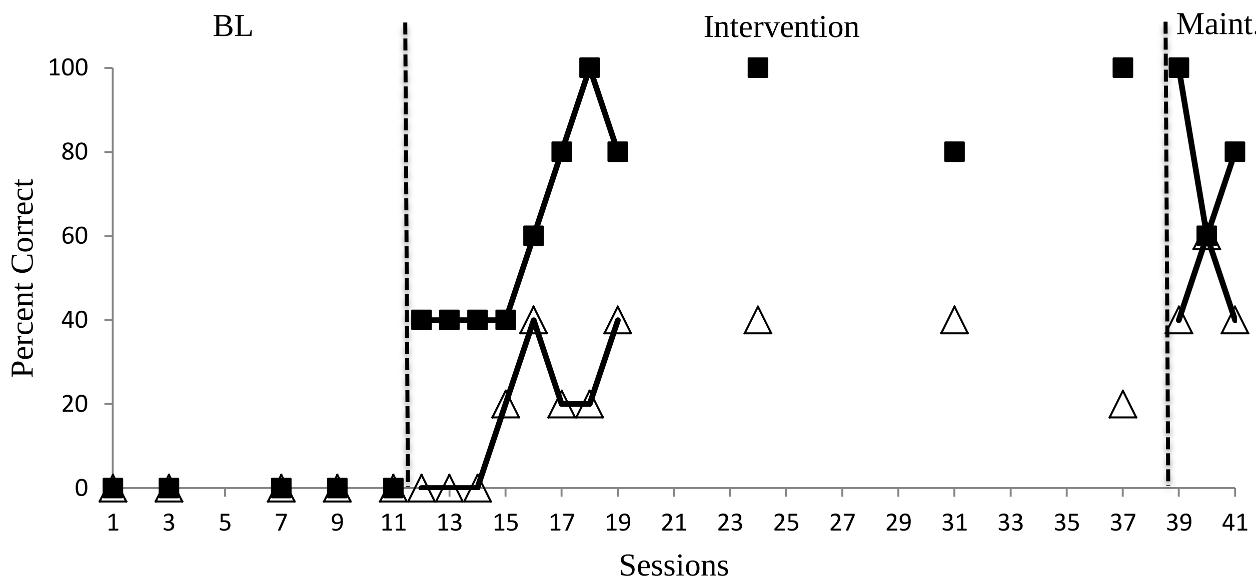

Figure 3. Kyree's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Trenton. Trenton's scores, with a gradual immediacy of effect, revealed an improved change in level of 20% without an overlap in data points. Scores throughout the intervention phase (M = 66.67, SD = 36.06) showed an accelerating trend with moderate variability. Scores during this condition ranged from 20% to 100% and the predetermined criterion was not reached until the fifth session of this phase. During the maintenance phase, the trend and level of the data were flat (M = 93.33, SD = 11.55) with low variability. Throughout the three maintenance sessions, scores ranged from 80% to 100%. Figure 4 illustrates the percentage of Trenton's scores throughout the baseline, intervention, and maintenance sessions.

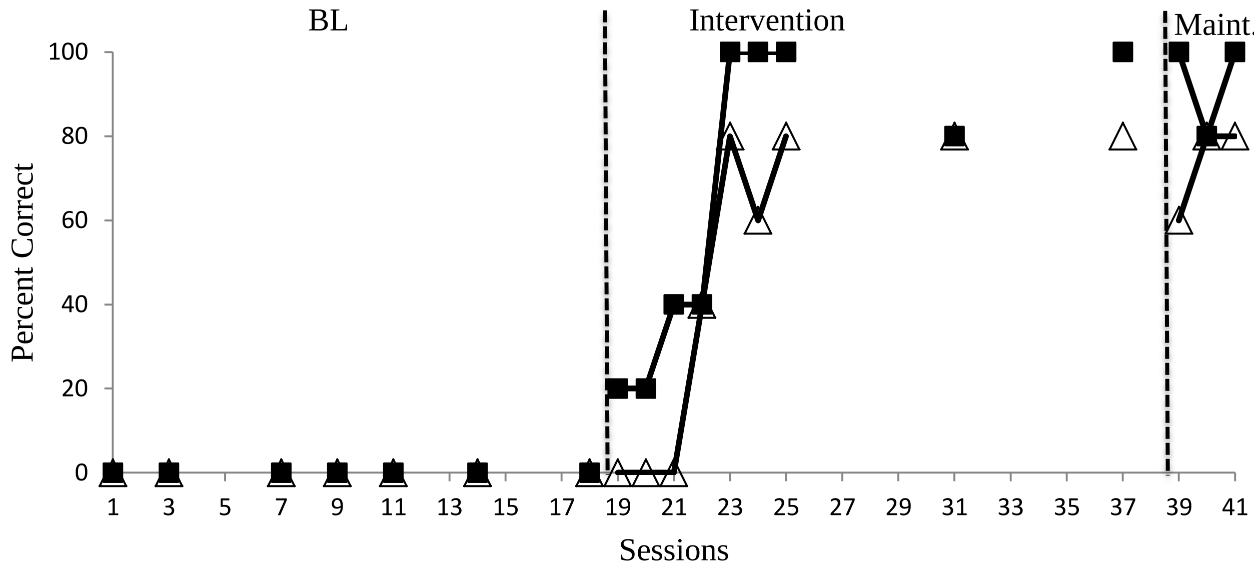

Figure 4. Trenton's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Andre. Upon initiation of the intervention, Andre's curriculum-based math scores did not display an immediate level change until the second session of the phase. The percentage of overlapping data points between the baseline and intervention phases were 11%. Gradually, intervention scores increased (*M* = 40.00, *SD* = 24.49) revealing an upward trend with moderate variability. Scores during this phase ranged from 0% to 80%. Andre did not reach the predetermined criterion until the eighth session of the intervention condition. Scores during the maintenance phase showed an improved change in level (*M* = 66.67, *SD* = 11.55), with a decelerating trend. Scores during this condition ranged from 60% to 80%. Figure 5 illustrates the percentage of Andre's scores throughout the baseline, intervention, and maintenance sessions.

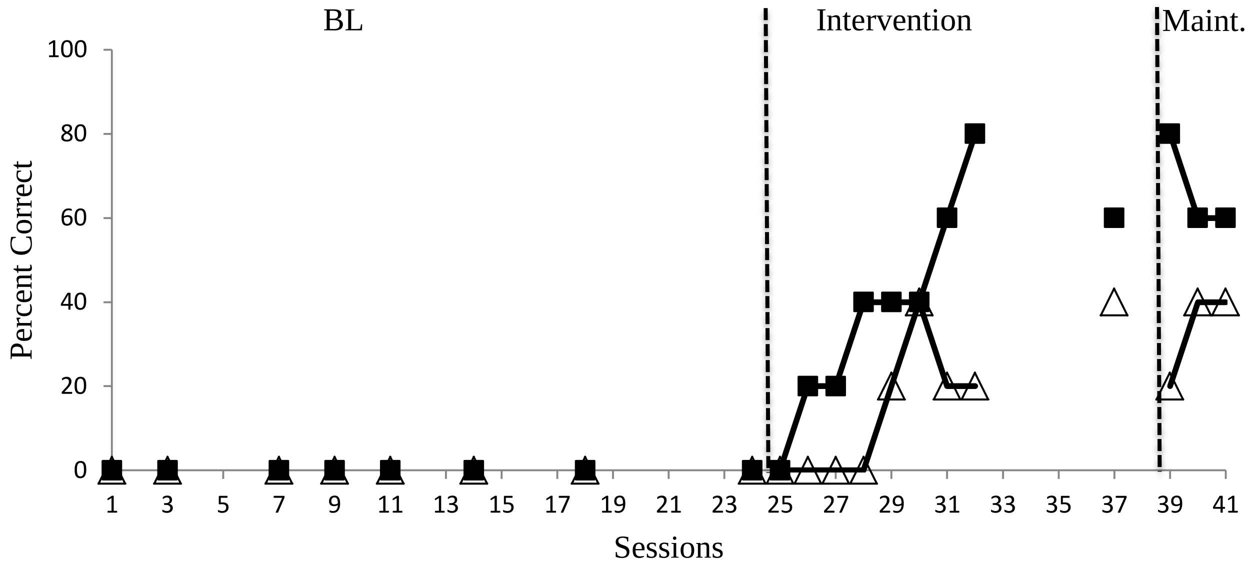

Figure 5. Andre's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Zeik. Zeik's scores, with a quick immediacy of effect, revealed an improved change in level of 40% without an overlap in data points. Scores throughout the intervention phase (*M* = 74.29, *SD* = 25.07) showed an accelerating trend with moderate variability. Scores during this condition ranged from 40% to 100%. Zeik met the predetermined criterion on the third session of the intervention phase. During the maintenance phase, the trend and level of the data were analyzed as visually flat (*M* = 86.67, *SD* = 11.55) with low variability. Scores ranged from 80% to 100%. Figure 6 illustrates the percentage of Zeik's scores throughout the baseline, intervention, and maintenance sessions.

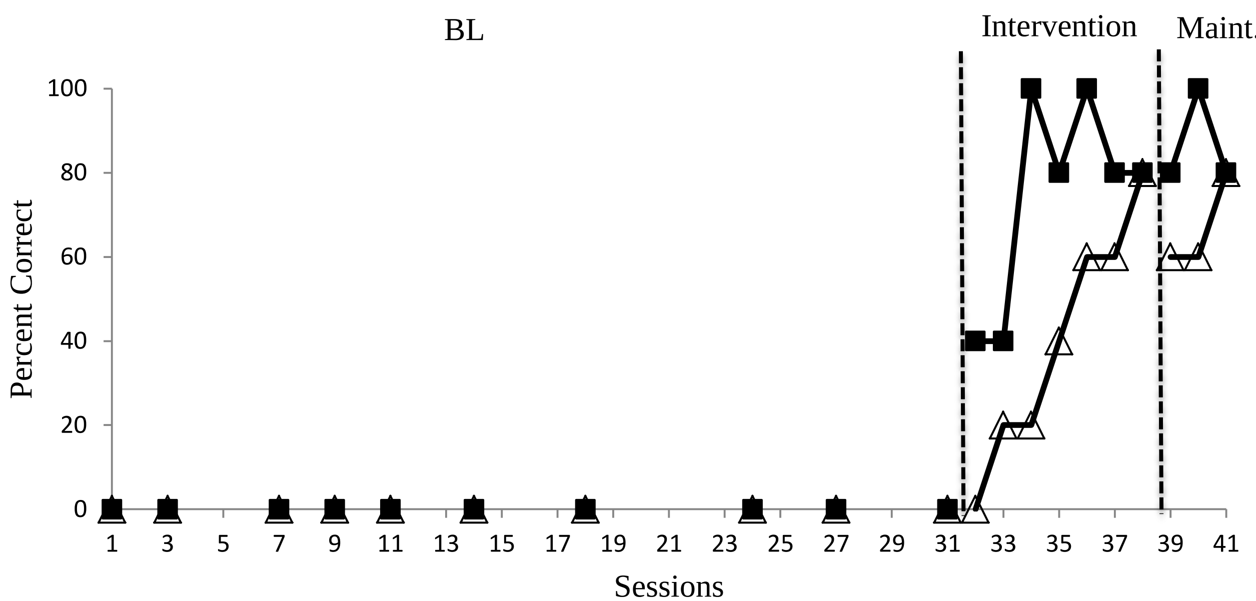

Figure 6. Zeik's Basic Math (squares) and Problem-solving (triangles) Probe Scores

Research Question #2

The second research question explored the effects of CAI on problem-solving skills in mathematics. During the baseline session, all participants earned a mean score of 0% on the curriculum-based math probes, thus indicating a stable baseline with zero level, trend, and variability. After the introduction of the intervention, an immediate level change occurred for only two participants, David and Mitchell.

David. With a gradual immediacy of effect, David's scores during the intervention phase showed an improved change in level of 20%. With a lack of overlap in data points, scores during the intervention condition revealed moderate variability (M = 81.82, SD = 27.50) with an accelerating trend. Scores ranged from 20% to 100% and the predetermined criterion was met during the third session of the intervention phase. During the maintenance condition, David's curriculum-based math scores indicated an improved level and a flat trend with low variability.

Mean performance during the maintenance condition was 93.33 (*SD* = 27.50), a phase difference of 11.51. Scores during this phase ranged from 80% to 100%. Figure 1 illustrates the percentage of David's scores throughout the baseline, intervention, and maintenance sessions.

Mitchell. Mitchell's scores, with an abrupt immediacy of effect, revealed an improved change in level of 80%, thus immediately reaching the established criterion. With low variability, scores during the intervention phase revealed a slight upward trend and a flat level (*M* = 91.11, *SD* = 10.54). Scores during this phase ranged from 80% to 100%. During the maintenance condition, scores were consistent at 100% throughout the condition. Thus, the trend and level of the data were flat without variability. Figure 2 illustrates the percentage of Mitchell's scores throughout the baseline, intervention, and maintenance sessions.

Kyree. Upon initiation of the intervention, Kyree's curriculum-based math scores did not display an immediate level change until the fourth session of the phase. The percentage of overlapping data points between the baseline and intervention phases were 27%. Gradually, intervention scores increased (*M* = 21.82, *SD* = 16.62) revealing an upward trend with moderate variability. Kyree did not meet the predetermined criterion of 80% during the intervention phase. Scores ranged from 0% to 40%. During the maintenance phase, scores showed an improved change in level (*M* = 46.67, *SD* = 11.55), with a flat trend. Scores during this phase ranged from 40% to 60%. Figure 3 illustrates the percentage of Kyree's scores throughout the baseline, intervention, and maintenance sessions.

Trenton. After the introduction of the intervention, Trenton's scores did not show a change in level until the fourth session of the treatment phase and the predetermined criterion was not met until the fifth session. Scores range between 0% and 80%. The percentage of overlapping data points between the baseline and intervention phases were 33%. Mean performance during the intervention condition was 46.67 (*SD* = 37.42), with an accelerating trend and moderate variability. This pattern of the data continued during the maintenance condition with improvements in the level (*M* = 73.33, *SD* = 11.55) and trend. Scores during the maintenance phase ranged from 60% and 80%. Figure 4 illustrates the percentage of Trenton's scores throughout the baseline, intervention, and maintenance sessions.

Andre. Andre's scores did not depict an abrupt immediacy of effect upon initiation of the intervention. A change in the level was not revealed until the fifth session of the intervention phase and the participant did not meet the predetermined criterion. The percentage of overlapping data points between the baseline and intervention phases were 44%. Gradually, intervention scores increased (*M* = 15.56, *SD* = 16.67) revealing an upward trend with moderate variability. Scores during this phase ranged from 0% to 40%. During the maintenance phase, scores showed an improved change in level (*M* = 33.33, *SD* = 11.55), with a visually depicted accelerating trend. Scores during the three maintenance sessions ranged from 20% to 40%. Figure 5 illustrates the percentage of Andre's scores throughout the baseline, intervention, and maintenance sessions.

Zeik. Upon initiation of the intervention, Zeik's curriculum-based math scores did not display an immediate level change until the second session of the phase. The percentage of overlapping data points between the baseline and intervention phases were 14%. Gradually, intervention scores increased (*M* = 40.00, *SD* = 28.28) and ranged from 0% to 80%, revealing an upward trend with moderate variability. Scores during the maintenance phase showed an improved change in level (*M* = 66.67, *SD* = 11.55), with a visually depicted upward trend. Scores during the maintenance condition range from 60% to 80%. Figure 6 illustrates the percentage of Zeik's scores throughout the baseline, intervention, and maintenance sessions.

Research Question #3

The third research question explored the effects of CAI on task engagement. Each participant's task engagement throughout all phase conditions is discussed below.

David. During the baseline condition, David's task engagement results depicted an upward trend with scores ranging from 71% to 100%. Mean performance during this phase was 89.33 (*SD* = 15.95). After implementation of the intervention, there was a gradual immediacy of effect. The percentage of overlapping data points between the baseline and intervention phases were 100%. The level during the intervention phase improved slightly (*M* = 91.36, *SD* = 7.46) and scores ranged from 73% to 100%, depicting a flat trend with low variability. This data pattern continued during the maintenance phase (*M* = 91.67, *SD* = 1.15), with a slightly decelerating trend and scores ranging from 91% to 93%. Figure 7 illustrates the percentage of David's scores throughout the baseline, intervention, and maintenance sessions.

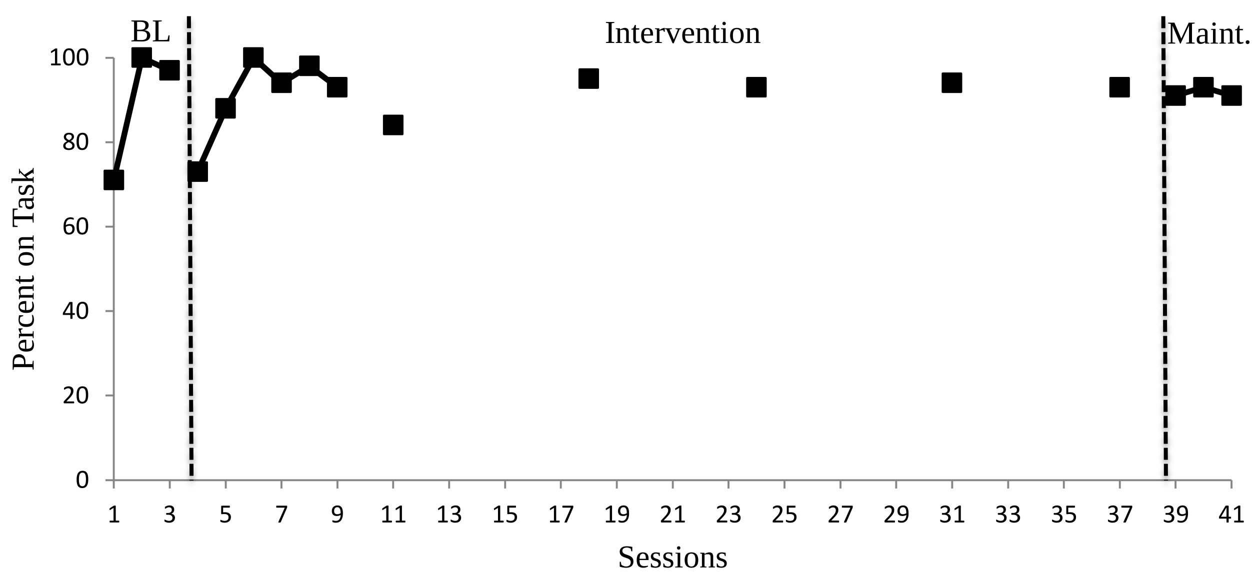

Figure 7. David's Task Engagement Probe Scores

Mitchell. With high variability, Mitchell's baseline scores revealed an upward trend and a mean performance of 23.25 (*SD* = 27.73). Scores during this condition ranged from 0% to 55%. After the introduction of the intervention, scores displayed an improved level (*M* = 84.00, *SD* = 20.07) and a trend line with very high variability. The percentage of overlapping data points between the baseline and intervention phases were 13%, scores during the intervention phase ranged from 38% to 100%. During the maintenance sessions, scores depicted a slightly elevated level (*M* = 85.67, *SD* = 3.79) with scores ranging from 83% to 90% and a slightly decelerating trend line. Figure 8 illustrates the percentage of Mitchell's scores throughout the baseline, intervention, and maintenance sessions.

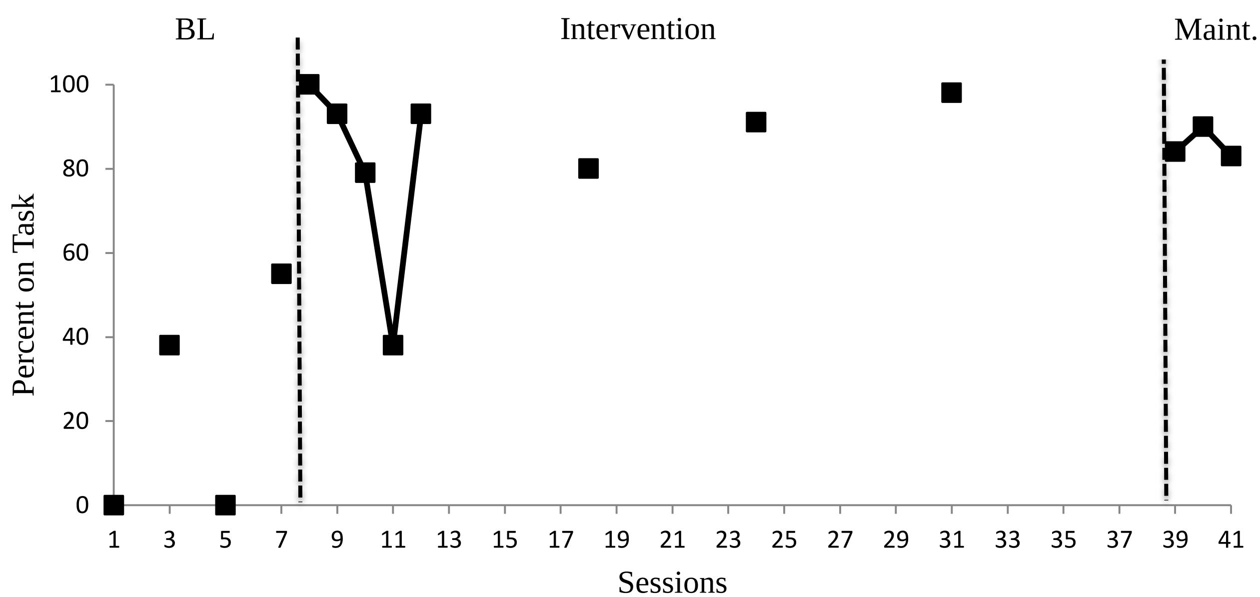

Figure 8. Mitchell's Task Engagement Probe Scores

Kyree. During the baseline condition, Kyree's task engagement results depicted a gradual decaying trend with scores ranging from 92% to 98%. Mean performance during this phase was 95.40 (*SD* = 2.19). Upon initiation of the intervention, there was a gradual immediacy of effect. The percentage of overlapping data points between the baseline and intervention phases were 55%. The level during the intervention phase elevated slightly (*M* = 95.82, *SD* = 4.51) and scores ranged from 85% to 100%, depicting a visually decelerating trend and low variability. This data pattern continued during the maintenance phase (*M* = 92.00, *SD* = 5.57), with scores ranging from 86% to 97%. Figure 9 illustrates the percentage of Kyree's scores throughout the baseline, intervention, and maintenance sessions.

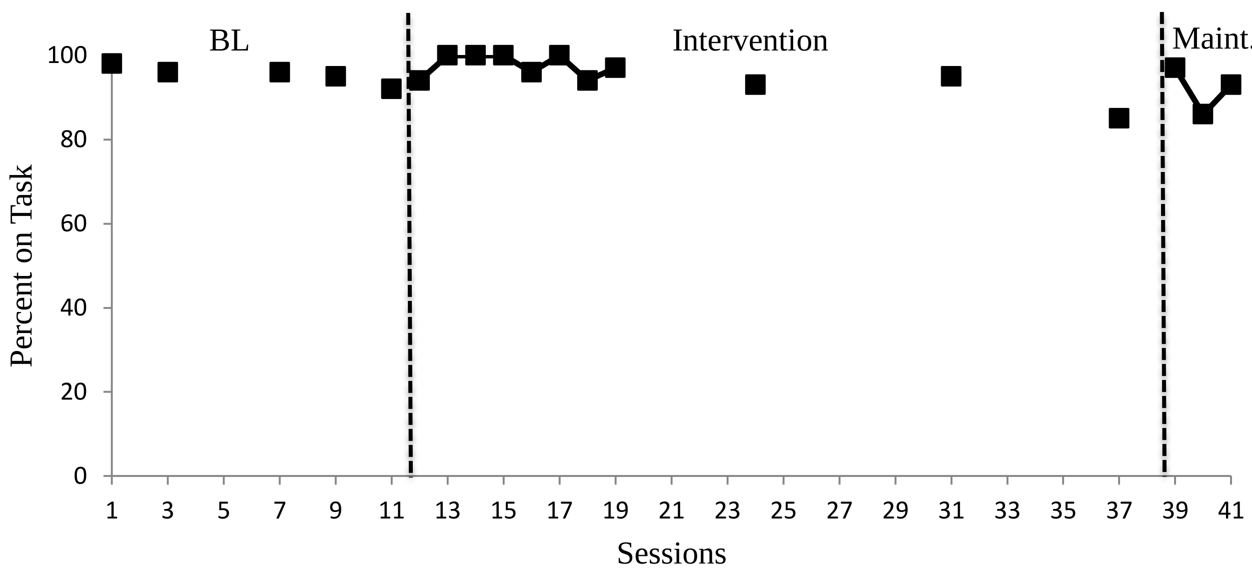

Figure 9. Kyree's Task Engagement Probe Scores

Trenton. With high variability, Trenton's baseline scores revealed a downward trend and a mean performance of 90.86 (*SD* = 8.47). Scores during this condition ranged from 77% to 99%. After the introduction of the intervention, scores displayed an improved level (*M* = 95.00, *SD* = 5.68) and a downward trend line with low variability. The percentage of overlapping data points between the baseline and intervention phases were 56%. Intervention scores ranged from 85% to 100%. During the maintenance sessions, scores depicted a decreased level (*M* = 79.00, *SD* = 1.00) with scores ranging from 78% to 80% and a slightly accelerating trend line. Figure 10 illustrates the percentage of Trenton's scores throughout the baseline, intervention, and maintenance sessions.

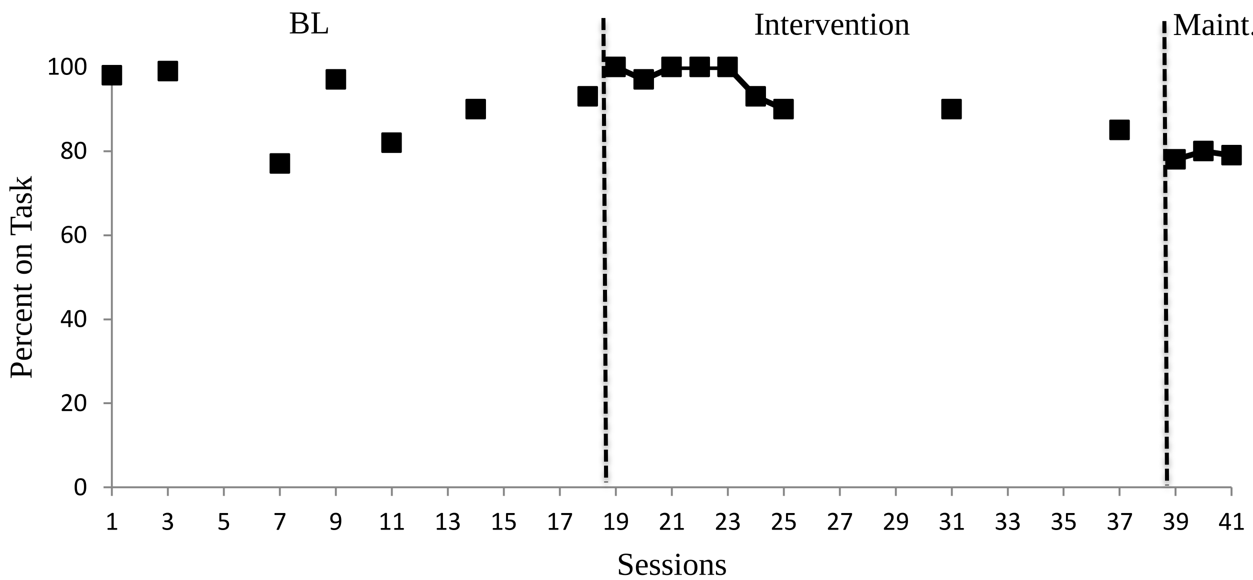

Figure 10. Trenton's Task Engagement Probe Scores

Andre. Andre's scores displayed high variability and a gradually accelerating trend during the baseline condition. Mean performance was 8.33 (*SD* = 12.18) with scores ranging from 0% to 33%. Upon initiation of the intervention, scores displayed an improved level (*M* = 64.67, *SD* = 21.82) and downward trend with moderate variability of scores ranging from 24% to 91%. The percentage of overlapping data points between the baseline and intervention phases was 11%. During the maintenance phase, scores depicted a decreased level (*M* = 20.33, *SD* =

4.04) with scores ranging from 16% to 24% and a continued downward trend. Figure 11 illustrates the percentage of Andre's scores throughout the baseline, intervention, and maintenance sessions.

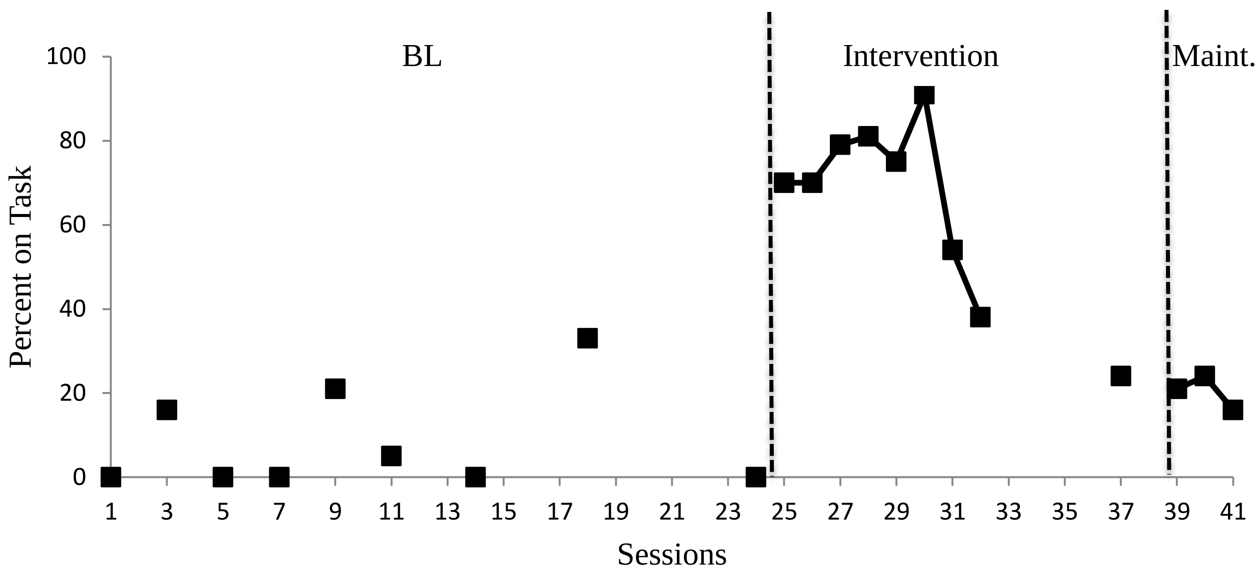

Figure 11. Andre's Task Engagement Probe Scores

Zeik. During the baseline condition, Zeik's task engagement results depicted a gradual decaying trend with scores ranging from 0% to 99%. Mean performance during this phase was 27.18 (*SD* = 29.40). After the introduction of the intervention, there was an improved level (*M* = 64.43, *SD* = 21.88) with scores ranging from 33% to 89%. These scores depicted a decelerating trend with moderate variability. Mean performance of task engagement during the maintenance condition was 34.33 (*SD* = 7.51), with scores ranging from 27% to 42% and a continued downward trend. Figure 12 illustrates the percentage of Zeik's scores throughout the baseline, intervention, and maintenance sessions.

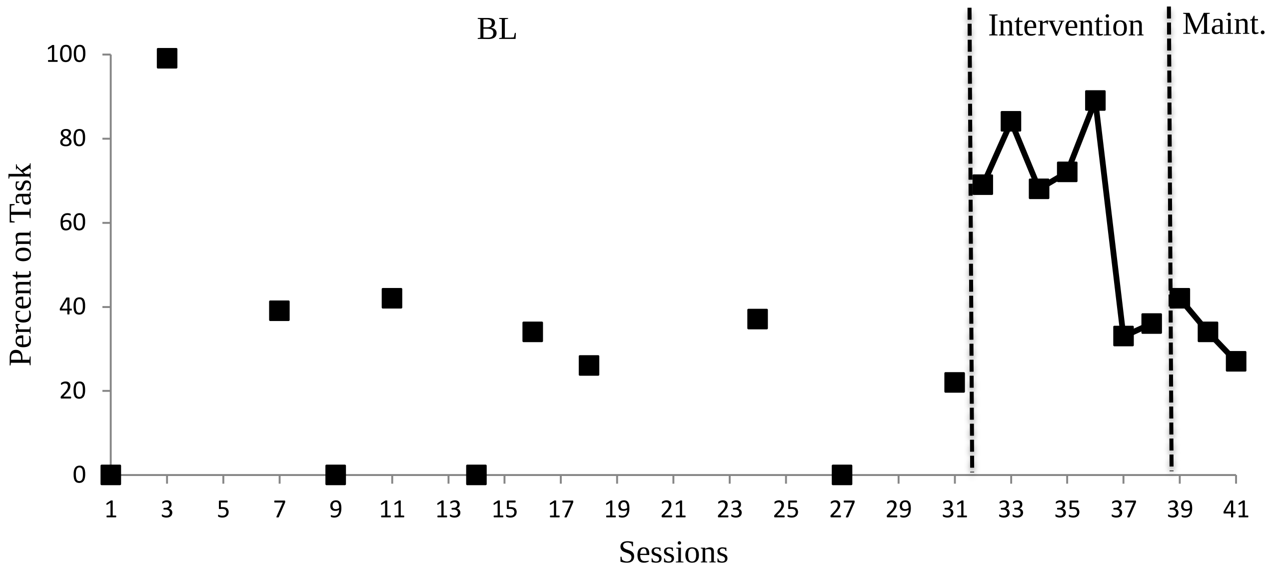

Figure 12. Zeik's Task Engagement Probe Scores

Interobserver Agreement and Treatment Fidelity

Interobserver agreement on the results of the participants' curriculum-based math probes and task engagement was determined from 25% of the observational sessions. Probes and task engagement for each participant were randomly selected and scored by a second rater. Interobserver agreement was 100% for each participant's curriculum-based math probes, thus indicating that agreements were perfect across all items for each check. Interobserver agreement for the participants' task engagement was 98% (range 95% - 99%). Interobserver agreement for treatment fidelity was evaluated using a checklist for a total of 25% of the observational sessions for each participant. Fidelity was 100% for each participant, also indicating that agreements were perfect across all items for each check and each software component (e.g., warm-up, lesson presentation, review, and assessment) in the instructional lessons occurred for each participant during each observation. In the study, the "Agreements/(Agreements + Disagreements) x 100" formula was used for analysis of the reliability data between the observers and of the treatment's implementation.

Social Validity

Information obtained from the administered pre and post social validity survey was analyzed at the beginning and end of the study. The results of the participants' attitudes toward mathematics and technology-based instruction are discussed below. Evident shifts in responses between the pre and post survey are displayed in Tables 4 and 5.

Table 4

Shifts in Survey Responses Regarding Attitudes toward Mathematics

Item	David	Mitchell	Kyree	Trenton	Andre	Zeik
			Pre & Post Survey Responses			
I enjoy mathematics courses.	3, 5	N/A	3, 4	4, 3	2, 1	5, 4
I feel at ease in mathematics.	3, 5	4, 3	N/A	4, 3	2, 1	4, 5
I am sure of myself when I do math.	3, 5	3, 2	N/A	3, 2	2, 1	4, 5
I know I can do well in math.	3, 5	4, 3	N/A	3, 2	2, 3	4, 5
I think I could handle more difficult math.	3, 4	3, 4	3, 4	3, 2	N/A	4, 3
I enjoy mathematics problem-solving.	3, 4	N/A	N/A	N/A	1, 2	N/A
I will need mathematics for my future work.	N/A	N/A	4, 5	N/A	N/A	N/A
I study math because I know how useful it is.	N/A	N/A	4, 5	N/A	N/A	N/A
Knowing mathematics will help me earn a living.	3, 4	3, 5	4, 5	3, 4	5, 4	N/A

Table 5

Shifts in Survey Responses Regarding Attitudes toward Technology-based Instruction

Item	David	Mitchell	Kyree	Trenton	Andre	Zeik
	Pre & Post Survey Responses					
I concentrate on a computer when I use one.	3, 4	3, 4	N/A	3, 5	N/A	4, 3
I would work harder if I could use computers more often.	3, 5	3, 5	N/A	4, 5	5, 4	3, 4
I know that computers give me opportunities to learn many new things.	3, 5	N/A	4, 5	N/A	N/A	4, 5
I enjoy lessons on the computer.	3, 5	N/A	N/A	N/A	4, 3	N/A
I believe that the more teachers use computers, the more I will enjoy school.	3, 4	3, 4	4, 5	N/A	N/A	N/A

David. David's responses regarding his attitude toward mathematics on the pre survey (*M* = 3.33, *SD* = 1.00) revealed strong disagreement with 11.1%, neutrality with 33.3%, and agreement with 55.6% of the statements on the survey. After the conclusion of the study, David's responses (*M* = 4.11, *SD* = 1.27) revealed strong disagreement with 11.1%, agreement with 44.4%, and also strong agreement with 44.4% of the statements on the same survey. Regarding technology-based instruction, David's responses on the pre survey (*M* = 3.00, *SD* = 0.00) revealed 100% neutrality with the statements on the survey. After the conclusion of the study, David's responses (*M* = 4.60, *SD* = 0.55) revealed agreement with 40% and strong agreement with 60% of the statements on the same survey.

Mitchell. Mitchell's responses regarding his attitude toward mathematics on the pre survey (*M* = 3.67, *SD* = 0.50) revealed neutrality with 33.3% and agreement with 66.7% of the statements on the survey. After the conclusion of the study, Mitchell's responses (*M* = 3.56, *SD* = 0.88) revealed disagreement with 11.1%, neutrality with 33.3%, agreement with 44.4%, and strong agreement with 11.1% of the statements on the same survey. Regarding technology-based instruction, Mitchell's responses on the pre survey (*M* = 3.20, *SD* = 0.45) revealed neutrality with 80% and agreement with 20% of the statements on the survey. After the conclusion of the study, Mitchell's responses (*M* = 4.00, *SD* = 0.71) revealed neutrality with 20%, agreement with 60%, and strong agreement with 20% of the statements on the same survey.

Kyree. Kyree's responses regarding his attitude toward mathematics on the pre survey (*M* = 3.78, *SD* = 0.44) revealed neutrality with 22.2% and agreement with 77.8% of the statements on the survey. After the conclusion of the study, Kyree's responses (*M* = 4.33, *SD* = 0.50) revealed agreement with 66.7% and strong agreement with 33.3% of the statements on the same survey. Regarding technology-based instruction, Kyree's responses on the pre survey (*M* = 4.00, *SD* = 0.00) revealed 100% agreement with the statements on the survey. After the conclusion of the study, Kyree's responses (*M* = 4.40, *SD* = 0.55) revealed agreement with 60% and strong agreement with 40% of the statements on the same survey.

Trenton. Trenton's responses regarding his attitude toward mathematics on the pre survey (*M* = 3.22, *SD* = 0.44) revealed neutrality with 77.8% and agreement with 22.2% of the statements on the survey. After the conclusion of the study, Trenton's responses (*M* = 2.78, *SD* = 0.67) revealed disagreement with 33.3%, neutrality with 55.6%, and strong agreement with

11.1% of the statements on the same survey. Regarding technology-based instruction, Trenton's responses on the pre survey (*M* = 3.60, *SD* = 0.55) revealed neutrality with 40% and agreement with 60% of the statements on the survey. After the conclusion of the study, Trenton's responses (*M* = 4.20, *SD* = 0.84) revealed neutrality with 20%, agreement with 40%, and strong agreement with 40% of the statements on the same survey.

Andre. Andre's responses regarding his attitude toward mathematics on the pre survey (*M* = 2.67, *SD* = 1.58) revealed strong disagreement with 22.2%, disagreement with 44.4%, agreement with 11.1%, and strong agreement with 22.2% of the statements on the survey. After the conclusion of the study, Andre's responses (*M* = 2.44, *SD* = 1.59) revealed strong disagreement with 44.4%, disagreement with 11.1%, neutrality with 11.1%, agreement with 22.2%, and strong agreement with 11.1% of the statements on the same survey. Regarding technology-based instruction, Andre's responses on the pre survey (*M* = 4.60, *SD* = 0.55) revealed agreement with 40% and strong agreement with 60% of the statements on the survey. After the conclusion of the study, Andre's responses (*M* = 4.20, *SD* = 0.84) revealed neutrality with 20%, agreement with 40%, and strong agreement with 40% of the statements on the same survey.

Zeik. Zeik's responses regarding his attitude toward mathematics on the pre survey (*M* = 4.44, *SD* = 0.53) revealed agreement with 55.6% and strong agreement with 44.4% of the statements on the survey. After the conclusion of the study, Zeik's responses (*M* = 4.56, *SD* = 0.73) revealed neutrality with 11.1%, agreement with 22.2%, and strong agreement with 66.7% of the statements on the same survey. Regarding technology-based instruction, Zeik's responses on the pre survey (*M* = 4.00, *SD* = 0.71) revealed neutrality with 20%, agreement with 60%, and strong agreement with 20% of the statements on the survey. After the conclusion of the study, Zeik's responses (*M* = 4.20, *SD* = 0.84) revealed neutrality with 20%, agreement with 40%, and strong agreement with 40% of the statements on the same survey.

Chapter 5: Summary, Discussion, Limitations, and Recommendations

The purpose of this study was to examine the extent to which a technology-based intervention was effective in math instruction for students with EBD. In addition, to address the social/behavioral issues typically prevalent in students with EBD, students' task engagement was also examined and a social validity survey was used to examine their attitudes toward mathematics and technology-based instruction. This chapter will provide a summary, discussion, limitations, and recommendations of the entire study.

Summary

Numerous studies have demonstrated various achievement benefits of using CAI over traditional instruction when teaching mathematics to general education students (Funkhouser, 2002; Huntley & Greever-Rice, 2007). Some of these benefits include fluency of basic mathematics computation skills, increased scores on annual state assessments, higher class grades, and a deeper understanding of problem-solving. There is a dearth of research focusing on the effects of CAI and the mathematics achievement of students with EBD. The paucity of research in this area makes it difficult to draw definitive conclusions about the effectiveness of CAI for these students. Since students with EBD often experience greater difficulty in mathematics than their peers with and without disabilities, it is instructive to further investigate the effects of CAI on students with EBD.

In the current study, the *I CAN Learn* intervention was implemented in a high school mathematics classroom to examine its effects on the mathematics achievement and task engagement of six adolescent students with EBD. The overall results of the study indicated that the *I CAN Learn* intervention improved the adolescents' mathematics achievement, but findings revealed that the intervention was more effective with some participants than others. In addition, results indicated that the intervention may not be associated with the participants' task engagement. The study's social validity survey showed that the participants had varying attitudes toward mathematics and CAI at the end of the study.

The study used a single-subject, multiple-probe design in which the participants' baseline conditions served as the control and the intervention conditions served as the experiment (Horner & Baer, 1978). Experimental control of the study was provided to find any increase in positive responses among the participants when the target skill was instructed. However, no considerable change occurred in skill acquisition when the participants were not taught. Participants initially were monitored in the baseline condition.

The first participant, David, was monitored consistently throughout the baseline phase, while the other participants were monitored intermittently. Specifically, during the baseline condition the participants received Algebra instruction in the routine of a warm-up activity, followed by whole-group instruction and guided practice, and ended with independent practice and individual assistance. Simultaneously, the participants' task engagement was measured. During independent practice, the participants of the study were administered curriculum-based math probes on target skills that would be presented to them during the intervention phase.

When the intervention phase was implemented, the participants used the *I CAN Learn* software during independent practice and worked on lessons specifically targeting skill deficits. The software administered curriculum-based math probes similar to the probes administered during the baseline condition. Following each session of the phases, scores were recorded and graphed. Visual analysis of the graphs helped to examine whether a functional relation between the independent and dependent variables was demonstrated.

Discussion

What is the effect of CAI on basic skills in mathematics. The data indicated that all participants made gains in basic skills in mathematics, specifically on the target skill of adding, subtracting, and simplifying fractions with different denominators. Initial performance on the curriculum-based math probes revealed that the participants had an absence of understanding of fraction computation. The means from the baseline condition to intervention increased for all six adolescents. Although some increases in scores were larger than others, results from these findings indicate that the instructional components of the *I CAN Learn* software program were effective in helping the participants improve their fraction computation. Yet it is interesting to note, two weeks after the implementation of the intervention, during the maintenance phase, half of the participants' scores did not sustain as expected. For example, David, who surpassed the predetermined criterion upon being introduced to CAI and for the most part consistently scored above the criterion, decreased in scores during the maintenance phase until the last probed session. Conversely, Kyree and Andre increased their mean scores between the two conditions, but graphs of performance for the two participants showed a decelerating trend of data during the maintenance phase.

Follow-up procedures after implementing an intervention undoubtedly help further validate positive improvements found during the intervention phase (Anderson et al., 2001); it is not clear as to what caused the aforementioned results. Perhaps, the repetitiveness of completing the same concept was a factor. While fraction computation is a skill that needs repetition and practice, it appears that after the participants carried out multiple iterations of the concept, they developed a sense of overfamiliarity which may have resulted in boredom thus impacting their motivation. Literature shows that once something has become routine, revitalization may be required to counteract monotony (Bryant & Carless, 2010; Carless, 2005). This may be particularly true for students with EBD whose learning is often impeded by affective issues and factors associated with the EBD disability, such as low expectations of success, disinterest in academic work, decreased self-confidence, chronic truancy, and high rates of school dropout (Blackorby, et al., 2003; Bottge et al., 2006).

Consistent repetition and assessment of math skills throughout the curriculum is of course imperative in maintaining learned skills (NCTM, 2000). Since students with EBD tend to struggle in mathematics more than their peers with and without disabilities, specifically with attaining and retaining basic and computational math skills sets, prolonged exposure to mathematics topics is crucial for long-term positive outcomes (Maccini & Gagnon, 2002; McLaughlin, 1999; Wagner et al., 2006). Yet, the literature consistently suggests that students with EBD continue to make very little progress and at times even fall further behind over the course of an academic year (Anderson et al., 2001; Lane, Wehby, Little, & Cooley, 2005; Mattison, Hooper, & Glassberg, 2002). If tedium, as a result of repetition of concepts, is impacting motivation in mathematics and consequently the achievement of students with EBD in the subject, it is recommended that future research focus on concepts that last several days or weeks and include multiple sequences of related activities. Such research may counteract practices that some students with EBD find laborious.

What is the effect of CAI on problem-solving skills in mathematics. Results indicated that all six participants experienced greater difficulty with problem-solving skills than basic math skills when introduced to the *I CAN Learn* intervention. Across phases, all mean scores improved, thus indicating that CAI was an effective teaching strategy for adolescents with little or no previous knowledge of the target skill. Although improvements were evident for all participants, two participants, Kyree and Andre, never reached the predetermined criterion. If the intervention's instructional components can possibly be attributed to the participants' gains in basic math skills, why does the same not reflect when targeting problem-solving skills? Perhaps the intervention did not provide enough explicit instruction in enhancing the participants' problem-solving development. This assumption is supported by the percentage of overlapping data revealed across the baseline and intervention phases. The percentage of overlap of data is an indicator of an intervention's impact (Alberto & Troutman, 2003). Four participants', (Zeik, Kyree, Trenton, and Andre), percentage of overlap was 14%, 27%, 33%, and 44% respectively, suggesting that the impact of the intervention was not strong when teaching problem-solving skills. These results are consistent with other studies which assessed the effects of CAI on the acquisition of basic math and problem-solving skills (Fuchs et al., 2006; Shiah et al., 1995).

Although the study's intervention embedded challenging problems in the software and required students to solve multi-step application problems throughout provided lessons, it is possible that the participants in the current study were unable to transfer fraction computation to application problems because they lacked higher order capacities for organizing and interpreting information. Solving word problems is undoubtedly distinct from computation (Fuchs, Fuchs, Stuebing, Fletcher, Hamlett & Lambert, 2008). Though word problems require accurate computation, they also require students to be able to identify and organize essential information (NCTM, 2000; Xin, Jitendra, & Deatline-Buchman, 2005). Whether the intervention allotted enough time to explicitly teach the participants of the study how to structure the information provided in word problems is unclear.

What is the effect of CAI on task engagement in mathematics. Findings revealed that the CAI was initially effective with participants who originally had low task engagement scores during the baseline condition. These participants included Mitchell, Andre, and Zeik and their gains ranged from 37% to 61%. Unfortunately, these gains eventually decreased as the students interacted with the intervention. Similarly, Trenton's scores decreased after the fifth session of using CAI. These decreasing trends in engagement perhaps suggest initial performance gains were attributed to a novelty effect of interacting with the *I CAN Learn* computer program.

A novelty effect can occur when a new intervention is introduced. Instances of novelty effect and CAI have been corroborated in the literature (Hur & Oh, 2012). It has been suggested that technology accessibility in the classroom can act as extrinsic motivator, thus providing an initial motivation boost that wanes after time has passed. Although today's generation of students may not find computers a novelty, incorporating them into class as a new learning tool can potentially have such an effect.

Even more noteworthy is the discrepancy between some of the participants' scores on the curriculum-based math probes and their decreasing trends in engagement. While some participants' scores indicated no significant gains or very minimal changes in task engagement, Andre and Zeik, who made slow and moderate gains in basic and problem-solving tasks, decreased in engagement. An influencing factor could be the participants' individual characteristics or learning styles (Finn & Rock, 1997; Fredericks, Blumenfeld, & Paris, 2004). Their characteristics could provide an understanding of how their individual differences relate to their engagement tendencies. For example, maybe some of the participants in the study did not prefer or react well to some of the instructional components (e.g., three-dimensional graphics, audio presentations, etc.) embedded in the software. Perhaps their learning styles catered to rote but not higher order thinking tasks. Since student characteristics may be a decisive factor for student engagement, further research should carefully take student characteristics into account.

Social validity. Interestingly, many unfavorable shifts in attitudes toward mathematics occurred at the conclusion of the study. According to survey findings, half of the participants' initial perceptions of mathematics showed a decrease in attitude when asked about the subject. Although these findings are similar to other studies' results (Funkhouser, 2002), there seems to be a discrepancy between the positive results of performance data in the current study and the participants' perspectives. For example, upon implementation of the CAI intervention, Mitchell met and exceeded the predetermined criterion when assessed on the study's target skill in basic and problem-solving tasks. However, his mean scores decreased from pre- to post-survey. Specifically, Mitchell's responses to statements such as "I feel at ease in math; I am sure of myself when I do math; and I know I can do well in math" (see Table 4) all decreased. Similarly, Trenton and Andre, who made slow and moderate gains on basic and problem-solving tasks, also decreased in attitude.

Although the literature has revealed that some students who receive CAI make gains in acquiring math concepts but do not tend to develop more positive attitudes toward mathematics (Funkhouser, 2002; Okolo, 1992), one would assume that pre- and post-survey responses would at least remain the same for such students. Perhaps unaccounted internalizing factors caused the aforementioned results (Gresham & Kern 2004). For example, **i**nternal feelings (i.e., moods, stress levels) can significantly impact students' judgments or self-efficacy about their math capabilities (Pajares & Valiante, 2001).

Bandura (1997) proposed four primary sources that affect self-efficacy beliefs. These sources are mastery experiences, vicarious experiences, social persuasion, and physiological responses. In the current study, the participants whose scores revealed diminishing attitudes toward math after the intervention could have been affected by vicarious experiences and physiological responses. In terms of vicarious experiences, through daily observations, most students are keenly cognizant of how their peers perform in math and they may base their own performance on the success or failures of their peers. By observing the achievement of others, one's self-efficacy can either increase or decrease (Bandura, 1997; Pajares, 2003; Pajares & Valiante, 1999). Participants in the current study were vocal about their performances during the intervention. This may have had a direct effect on the participants' self-efficacy beliefs.

In regards to physiological responses, the most prevalent physiological reaction that adversely impacts students' self-efficacy is apprehension (Pajares, 2003). Apprehension toward math can be the result of lack of experience, negative expectations, and anticipated perceptions. Physiological responses are largely a predictor of self-efficacy and have a direct effect on math apprehension. Overall, physiological factors can considerably affect self-efficacy beliefs.

Although one would assume the mastery experiences that the participants encountered in the study would suggest that their self-efficacy would improve, research indicates that ultimately the impact of academic performance attainments on efficacy beliefs depends on what students make of their performances (Bandura, 1997; Usher & Pajares, 2006). The participants in the current study knew that 80% was considered the mastery level of their target skill. Perhaps some of the participants desired or expected to perform higher than this criterion or their actual scores. Their perceptions of mastery or lack thereof could have affected their self-efficacy and attitude toward mathematics. Bandura (1997) noted that "the same level of performance success may raise, leave unaffected, or lower perceived self-efficacy depending on how various personal and situational contributions are interpreted and weighted" (p. 81). In addition, sometimes only one source (e.g., mastery experiences, vicarious experiences, social persuasion, and physiological responses) may prove to alter a student's self-efficacy (Usher & Pajares, 2006). Because students with EBD often encounter different educational experiences (e.g., expulsion from school, placement in restrictive settings, stigma from disability, etc.), it is important to examine self-efficacy.

Data revealed that all participants, except Andre, increased in attitude regarding technology-based instruction. This is particularly interesting because despite the decreasing of some of the participants' engagement scores, they still preferred receiving technology-based instruction. This preference could simply be due to the prevalence of technology today. Much of the literature on technology (Harrington & Loffredo, 2010; McBrien, Jones, & Cheng, 2009) indicates that regardless of educational outcomes, this instructional practice is preferred due its convenience and abundance of use in everyday tasks. Although this preference is greater in higher education, it is believed that as school aged students continue to encounter technology in mundane tasks (i.e., communicating via smartphones, participating in social media platforms), they too will prefer this instructional practice over traditional instruction.

Limitations

This study was conducted in a single classroom with students in a highly specific environment (i.e., a self-contained classroom in a residential treatment facility); therefore it is imperative that the findings in this study be interpreted conservatively. Related to this is the limited sample size of six participants which impacts the generalizability of the study's findings. Given that the sample included all students with EBD, the findings are not expected to generalize to students without the disability. In addition, the participants in this study were solely identified as having a low average (i.e., standard score range of 80-89) functioning level in calculation and applied problems; thus, it is not clear how the findings would generalize to students with EBD and lower functioning levels. In light of the study's findings, the participants' self-efficacy may be instrumental in understanding their engagement and attitude data in mathematics and CAI. Not measuring efficacy at the onset of the study may have limited the researcher's ability to interpret revealed discrepancies of the two constructs.

Overall, replication studies are recommended to improve the external validity of this study. For further research, this study can be replicated with students of different ages and levels, and for teaching different math skills. The following recommendations for practice and research are suggested.

Recommendations

The results of this study support the use of the CAI intervention to improve basic math and problem-solving skills of students with EBD; however, based on the findings of this study, it is recommended that CAI supplement traditional instruction. In light of the decreased attitudes toward mathematics in this study, the overwhelming preference for technology use in instruction supports the need of examining why the CAI instructional practice would still be preferred over traditional instruction.

Since CAI is a multicomponent intervention, it can only be speculated which of the components affected the outcomes in this study. Aspects of the representational content embedded in this study's CAI intervention could have adversely impacted some of the participants' achievement, engagement, and attitudes. For example, participants' non-receptiveness to the intervention's interactive media content (i.e., instructors, reinforcement mechanisms, length of instruction) may have caused the discrepancies revealed between achievement and engagement data. In terms of the delivery approach provided in CAI, practitioners and researchers should take into account how material presented to students verbally (i.e., monologue-style speech, dialogue-style speech, personalized speech) and nonverbally (i.e., reinforcement, feedback, text pictures) can be perceived as more interesting than others. This could be accomplished by ensuring that instructional approaches used in CAI to attain and sustain students' engagement and motivation are developmentally appropriate. Based on this study's revealed findings, it appears that some media characteristics can affect learning and thus it is important to consider how the presence of such factors can promote or suppress learning. Future research is warranted to determine which of the components might be associated with mathematical, engagement, and attitude outcomes.

As inferred by some findings in this study, potential incompatibility between learning styles and CAI could possibly create conflicts that distress student achievement, affect, and engagement. When using or researching CAI, awareness of students' learning styles and self-efficacy will perhaps be beneficial in coupling well-suited CAI interventions that embed learning approaches and strategies that are readily accepted by the students. It is recommended that these interventions spend enough time explicitly teaching evidence-based mathematics instructional strategies, especially with instruction on problem-solving.

In addition to examining student profiles, since students with EBD may experience tedium when encountering the repetition of math concepts, it is recommended that future practice and research focus on instruction that includes multiple sequences of related activities. Doing such could prevent potential declines in motivation and achievement in the subject. Practitioners and researchers should consider instructional practices that last several days or weeks targeting a specific skill and incorporating rejuvenating tasks that mask obvious repetition.

As technology advances, CAI could possibly be used solely as an effective instructional practice if precisely tailored to an individual's academic profile. Overall, in order to ensure that students are provided with a personalized learning experience that may increase satisfaction and academic performance when experiencing CAI, future research directions include examining students' learning styles and self-efficacy beliefs and incorporating technology interventions that accommodate these characteristics and align with evidence-based mathematics instructional strategies to address the needs of the participants.

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Appendix A

Sample Curriculum-based Math Probe

Name: ______________________________ Date: _________________________

Directions: Subtract the following fractions. Simplify when possible.

1.) $\frac{7}{10} - \frac{2}{5} =$	**2.)** $\frac{11}{12} - \frac{1}{2} =$
3.) $\frac{5}{6} - \frac{5}{12} =$	**4.)** $\frac{4}{5} - \frac{7}{10} =$
5.) $\frac{9}{10} - \frac{4}{5} =$	**6.)** $\frac{3}{4} - \frac{1}{8} =$
7.) $\frac{11}{12} - \frac{2}{3} =$	**8.)** $\frac{3}{4} - \frac{5}{8} =$
9.) $\frac{5}{6} - \frac{2}{3} =$	**10.)** $\frac{7}{12} - \frac{1}{6} =$

Appendix B

Sample Probe Answer Key

Student: __________________ Scorer: ______________________ Date: ______________

Directions: Compare the student's answer with the key below. For each correctly answered item, circle 10 points under the correct column. For each incorrect answer, circle 0.

Item No. **Incorrect**	**Answer**	**Correct**	
1.	3/10	10	0
2.	5/12	10	0
3.	5/12	10	0
4.	1/10	10	0
5.	1/10	10	0
6.	5/8	10	0
7.	1/4	10	0
8.	1/8	10	0
9.	1/6	10	0
10.	5/12	10	0

TOTAL [ ]

PERCENTAGE [ ]

Appendix C

Task Engagement Data Collection

Observer: ________________

Date: ____________________

Time Started: _____________

Time Ended:________________

	Participants					
	#__	#__	#__	#__	#__	#__
1st 5-min (displayed time)						
	Participants					
	#__	#__	#__	#__	#__	#__
2nd 5-min (displayed time)						
	Participants					
	#__	#__	#__	#__	#__	#__
Total in seconds						
Total divided by 600 sec (10 min of observation)						
% of academic engagement						

Appendix D

Treatment Fidelity Checklist

Observer: ________________________________ Student: ___________________________
Date: ________________________

√ = occurred 0 = did not occur

Steps	√ **OR** 0
The participant's target skill was selected on the computer program.	
Before the interactive lesson began, the computer program presented the participant with 1 to 2 questions that covered prerequisite concepts of his/her target skill.	
The computer program provided a lesson presentation, composed of video and graphic segments, on the participant's target skill.	
After the lesson, as a review, the computer program presented several questions to assess how much information the participant retained from the lesson.	
For review questions answered incorrectly, the computer program provided hints and allowed the participant to resubmit his/her answer.	
For review questions answered incorrectly twice, the computer program provided step-by-step guidance on how to solve the presented problem.	
As a final assessment, the computer program presented the participant with 10 randomly chosen questions that pertained directly to the lesson.	
After the assessment was completed and graded, the computer program gave the participant an opportunity to review the solutions of the 10 questions and see illustrations on how incorrectly answered problems are properly worked out.	
The participant worked with the computer program for 20 minutes.	
Total Occurrence of Steps	
Percentage of Observed Steps	

Appendix E

Social Validity Survey

Name: ________________________________ Date: ___________________________

Directions: Rate your level of agreement/disagreement at the current time with the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I enjoy doing things on a computer.	5	4	3	2	1
I concentrate on a computer when I use one.	5	4	3	2	1
I would work harder if I could use computers more often.	5	4	3	2	1
I know that computers give me opportunities to learn many new things.	5	4	3	2	1
I enjoy lessons on the computer.	5	4	3	2	1
I believe that the more teachers use computers, the more I will enjoy school.	5	4	3	2	1
I feel comfortable working with a computer.	5	4	3	2	1
I think that working with a computer is enjoyable and stimulating.	5	4	3	2	1
I have a lot of self-confidence when it comes to working with computers.	5	4	3	2	1
I enjoy mathematics courses.	5	4	3	2	1
I feel at ease in mathematics.	5	4	3	2	1
I am sure of myself when I do math.	5	4	3	2	1
I know I can do well in math.	5	4	3	2	1
I think I could handle more difficult math.	5	4	3	2	1

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
I enjoy mathematics problem-solving.	5	4	3	2	1
I will need mathematics for my future work.	5	4	3	2	1
I study math because I know how useful it is.	5	4	3	2	1
Knowing mathematics will help me earn a living.	5	4	3	2	1
I enjoy science courses.	5	4	3	2	1
I feel at ease in science.	5	4	3	2	1
I know I can do well in science.	5	4	3	2	1
I will need science for my future work.	5	4	3	2	1
I study science because I know how useful it is.	5	4	3	2	1
Knowing science will help me earn a living.	5	4	3	2	1
I enjoy English courses.	5	4	3	2	1
I feel at ease in English.	5	4	3	2	1
I know I can do well in English.	5	4	3	2	1
I will need English for my future work.	5	4	3	2	1
I study English because I know how useful it is.	5	4	3	2	1
Knowing English will help me earn a living.	5	4	3	2	1
I enjoy history courses.	5	4	3	2	1
I feel at ease in history.	5	4	3	2	1
I know I can do well in history.	5	4	3	2	1
I will need history for my future work.	5	4	3	2	1
I study history because I know how useful it is.	5	4	3	2	1
Knowing history will help me earn a living.	5	4	3	2	1