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The Effectiveness of Computer-Assisted Instruction for Teaching Mathematics to Students with Specific Learning Disability

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Using computers to teach students is not a new idea. Computers have been utilized for educational purposes for over 80 years. However, the effectiveness of these programs for teaching mathematics to students with specific learning disability is unclear. This study was undertaken to determine if computer-assisted instruction was as effective as other methods of instruction that do not use computers for teaching mathematics to these students. A two-week experimental research study with 36 male and 22 female participants was conducted to determine if a difference existed in the learning of high school students with specific learning disability who were taught using either computer-assisted instruction or instruction using teacher-directed activities. Since there is sparse educational research regarding the effectiveness of using computer-assisted instruction for teaching mathematics to students with specific learning disability, the results of this study provide a starting point for future research on this subject.

keywords: Computer-Assisted Instruction, CAI, Mathematics, High School, Specific Learning Disability, SLD

Using computers to teach students is not a new idea. Computers have been utilized for educational purposes since 1924 (Pressey, 1926). However, the effectiveness of these programs for teaching mathematics to students with specific learning disability is unclear. This study was undertaken to determine if computer-assisted instruction was as effective as other methods of instruction that do not use computers for teaching mathematics to high school students with specific learning disability.

Students with Specific Learning Disability

Students with specific learning disability (SLD) are the single largest group of individuals with special needs in the classroom today (Pierangelo & Giuliani, 2002). The Individuals with Disabilities Education Act (IDEA) defined SLD as:

a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations, including conditions such as perceptual dis-

abilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include learning problems that are primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage. (34 CFR §300.7(c)(10)) (p. 13)

Students with SLD represent nearly half of all students in special education programs (Mercer & Pullen, 2009; National Center for Learning Disabilities, 2013). These students have unique learning characteristics and abilities that researchers must carefully consider when examining potential interventions.

The concept of SLD, as discussed in IDEA, stipulates that students should have average or above-average intelligence to receive this diagnosis. Because of their intelligence scores, students diagnosed with SLD are increasingly being placed in mainstreamed classrooms along with their nondisabled peers (McLeskey, 2007). Today, students with SLD are mainstreamed at a greater rate than any other group of students in special education (Gargiulo & Metcalf, 2010). The inclusion of these students contributes to the lack of research that specifically focuses on the efficacy of teaching methods for this population of students.

Mathematics Instruction and Students with SLD

The importance of understanding basic mathematical concepts is well documented (Kortering, deBettencourt, & Braziel, 2005; McKenna, Hollingsworth, & Laura, 2005; Montague & Jitendra, 2006). Without these skills, individuals will not be able to hold gainful employment or manage their daily finances. This is especially true for those with disabilities or those who

cannot afford to hire someone to assist them with managing their finances.

Students with SLD tend to fall behind their nondisabled peers in mathematics as they enter high school (Kortering et al., 2005; Montague & Jitendra, 2006). It is during these years that many students learn vocational skills to prepare them for their careers after they leave school. Unless the educational needs of students with SLD in mathematics classes are addressed, these students will often not be able to obtain gainful employment and will enter a cycle of failure that will trap them in low-paying jobs and lower socioeconomic statuses (Raskind, Goldberg, Higgins, & Herman, 2002).

Computers in the Classroom

Computers, whether in the form of traditional personal computers, notebook computers, or tablet devices, are becoming more common in the classroom. Nearly every American student has access to computers and the Internet, and over half of all students use it during the school day (Kleiner & Lewis, 2004; Saine, 2012). The popularity and increased usage of computer-based methods of instruction have largely been a function of the number of computers available to students. According to Wilson and Notar (2003), the student-to-computer ratio in American schools in 2003 was 5 to 1. This was more than five times better than the ratio in 1993, which was 26 to 1. In addition, current projections indicate that the student-to-computer ratio will be near 1 to 1 by the end of 2013 (Gulek & Demirtas, 2005). This is already the case in a growing number of American schools where students are being assigned their own notebook computers or tablet devices for use in the classroom (Bean, O'Brian, & Fang, 2012; Saine, 2012).

However, schools in rural areas or those with high populations of students in poverty are lagging behind other school

districts in the number of computers available for student use (Wells & Lewis, 2006). This perceived inequity in computer availability has led educational planners and politicians to push for increased funding for computers in the public school system. While this is an admirable goal, it does not answer the question of whether instruction that uses computers is as effective as traditional teacher-directed instruction for core subjects such as mathematics.

Defining Computer-Assisted Instruction

To answer this question, it is helpful to provide a working definition of computer-assisted instruction (CAI). Frenzel (1980) described CAI as “the process by which written and visual information is presented in a logical sequence to a student by a computer” (p. 86). This term is still used today when referring to the use of computers for educational purposes.

In theory, CAI reduces the need for in-person trainers by allowing for programmed responses to student actions. It offers a dual benefit of giving instantaneous feedback to students and continually adjusting the material that the student is being taught (Baroody, 1986; Mastropieri, Bakken, & Scruggs, 1991). These items help to maximize student learning.

Types of Computer-Assisted Instruction

Modern CAI programs have varying degrees of complexity in their design and operation and can be used to teach a variety of subjects. Most CAI programs can be classified as either drill-and-practice or game-type designs.

Drill-and-Practice

The first CAI programs had drill-and-practice designs (Molnar, 1997). They focused specifically on repeatedly reviewing information with the students to allow them to work on specific areas of weakness. The primary limitation of the drill-and-practice method of CAI was that it may not be able to hold the attention of some students,

especially younger students or those with attention deficits (Bahr & Rieth, 1989; Okolo, 1992). Recently, adaptive learning systems, built primarily on the drill-and-practice model, have been developed to provide personalized education for students and detailed statistical analysis of student performance to their teachers (Webley, 2013). However, those systems are in their developmental stage and have yet to provide substantive support regarding their effectiveness and protection of student privacy (Pereira, Baranauskas, & da Silva, 2013).

Game-Type

Game-type programs provide an alternative to drill-and-practice systems. These programs utilize various elements that are commonly found in a video gaming environment such as high-resolution graphics, sound effects, and changing backgrounds or settings to teach the material to the students (Okolo, 1992). They can assist in keeping the attention of the students for a longer period of time. This can lead to increases in student learning and student enjoyment of the learning process (Bahr & Rieth, 1989; Okolo). Many of the CAI programs that are used in the classroom today for younger students or those with attention problems have a game-type design because of its advantages over the drill-and-practice design.

Importance of Best Practices

The Individuals with Disabilities Education Act (IDEA) and the No Child Left Behind Act (NCLB) require that students in special education programs receive instruction using research-based best practices. Without an adequate body of research, it is impossible for teachers to know which teaching methods are the most effective. While some have debated the merits of focusing only on quantitative research to evaluate educational practices (Gallagher, 1998; Hammersley, 2001), it is

clear that the use of quantitative research for determining best practices for special education programs is essential (Heward, 2003; Mostert, 1999-2000; Vaughn, Klingner, & Hughes, 2000).

A great deal of quantitative educational research has been conducted to identify the best interventions for students in special education programs. However, there are gaps in the current body of research. This is especially true in the area of mathematics instruction for high school students with SLD, where the existing body of literature is inconclusive. These research gaps have led many classroom teachers to rely on anecdotally preferred educational practices rather than ones that have substantive support from educational research (Heward, 2003; Mostert 1999-2000).

Along with reading, mathematics is a fundamental skill that all students must possess for academic and professional success. The two most common methods of mathematics instruction that are currently in use in special education classes are instruction using teacher-directed activity and computer-assisted instruction (Westwood, 2000; Xin & Jitendra, 1999). However, additional research examining the efficacy of these teaching methods might assist classroom teachers to refine their preferences.

Research Question and Null Hypothesis

This study addressed the following question: Is there a difference between computer-assisted instruction and instruction using teacher-directed activity for teaching high school students with SLD to multiply and divide simple and mixed fractions?

Variables

The independent variable was the method of instruction: computer-assisted instruction (CAI) versus instruction using teacher-directed activity (TDA). The dependent variable for the study was the

amount of overall student learning as measured by the Brigance Comprehensive Inventory of Basic Skills – Revised. Student pretest scores on the testing instrument were selected to serve as the baseline assessment (i.e., the covariate).

Research Procedure

A before-after two-group design was utilized to examine the two different types of instruction (Judd, Smith, & Kidder, 1991; Miller & Salkind, 2002). The participants were randomly assigned to one of two groups and given pretests. Next, they were taught using either CAI or TDA. Finally, the participants completed posttests at the end of the study.

Setting

The public high school where the study was conducted had a student enrollment of 1,085. In addition, nearly 20% of the students enrolled in the school had been diagnosed with a disability and were receiving full-time or part-time assistance via special education programs. The largest disability diagnosis among these students was SLD.

The faculty members of the high school had an average tenure of 15.5 years. The special education faculty members had an average tenure of 8.2 years. In addition, nearly all of the teachers at the school had at least one graduate degree.

Approval and Permission

The study was conducted after all necessary agencies. A total of 73 student guardians were contacted to request their informed consent. Informed consent was provided by 59 of the 73 guardians. This was an overall response rate of 81%. The response rate for male students was 72%, while the rate for female students was 100%. One of the students for whom informed consent was received was unable to participate in the study due to a disciplinary issue at the school, so the remaining 58 students participated in the study.

Study Participants

The participants in the study were drawn from the total population of students with SLD in a special education classroom at the high school for whom informed consent was received. Thirty-six of the study participants were male, and 22 were female. A review of the Individualized Education Program (IEP) for each of the participants was conducted to confirm that each participant had been identified as having SLD in accordance with the definition of

SLD provided in IDEA and that they were currently receiving mathematics instruction in a self-contained special education classroom.

The 58 participants were initially divided by gender. There were 36 males and 22 females. This allowed for an even number to be randomly assigned to each group. Table 1 provides a summary of the pertinent information of the participants in the two groups.

Table 1
Data Regarding TDA and CAI Groups

Characteristics	TDA Group	CAI Group
Gender: Male	18	18
Female	11	11
Average Grade	9.9	10.2
Average Chronological Age	16.0	16.6
Average Time in Special Education	3.1 Years	3.5 Years
Average State Achievement Test Ratings in Mathematics for Latest Testing Cycle	Novice	Novice
Average IQ Score	88.5	88.9

Instructional Procedures

The primary investigator taught the lessons to the TDA group and gave guidance to the CAI group on using the computerized instructional program. A second investigator, who was the participants' regular classroom teacher, served three purposes. First, he observed the work of the primary investigator to make certain that the curriculum for both groups was administered correctly. In addition, he assisted in the management of the classroom by taking attendance, assisting in the administration of the pretests and posttests, and ensuring that students in the CAI group stayed on task when working on the computers. Finally, since the second investigator was the regular classroom teacher for the students, his presence in the classroom helped to relieve any anxiety that the students may have

experienced from working with a different instructor.

Curriculum

The curricula that were used to teach the students in the two groups were closely matched to the instructional goals and objectives established by the department of education in the state where the study was conducted. The primary focus was on mathematical operations involving simple and mixed fractions. This area of mathematics was chosen for three primary reasons: (a) it was identified by the special education teachers at the school as a general weakness among the students; (b) it had low student performance on the latest state achievement tests; and (c) the skills covered would be utilized in other courses such as algebra, geometry, and various types of

vocational training in which the students would enroll in the future.

In addition, the constructed response method of answer completion was utilized in the independent practice problems for both groups. This method paralleled the response type of question in the pretest and posttest of the testing instrument.

TDA Group Instruction

The participants in the TDA group received instruction using (a) direct instruction, (b) guided practice that involved students working out problems on the whiteboard with the assistance of the teacher, and (c) the use of paper-pencil exercises and quizzes. In addition, the students were required to successfully complete 70% of their assigned problems before moving on to the next topic area. The participants received all instruction in their regular classroom and did not use computerized instruction in mathematics during the study.

The course material utilized to teach the students in the TDA group was drawn from the mathematics textbooks provided by the county school system with particular attention given to ensuring that the material taught to these students had the same content taught to students in the computer-assisted instruction group. This was accomplished by reviewing the material provided by the computer-assisted program and then finding corresponding items from the textbooks and workbooks that had been provided for the students.

CAI Group Instruction

The participants in the CAI group were taught in their regular classroom using notebook computers. The Basic Math Competency Skill Building program for Fractions (BMCSB) was installed on the computers used by the study's participants. Each participant was provided with his or her own computer to use during the study

period and headphones to wear while working with the program. Each student worked at his or her own pace to complete each lesson, tutorial, practice problems, and quiz associated with each topic area. The BMCSB was chosen because it has a record of success in the classroom and because it was well-suited for the ages of the participants. The four modules associated with multiplying and dividing fractions were utilized in this study.

Content Validity of the Methods

Three mathematics education professionals supported the content validity of the instructional methods. One of the individuals was a professor of mathematics at a mid-sized university in the Middle Atlantic region of the United States, and the other two individuals were mathematics teachers in the public school system where the test site was located. The instructional methods were assessed to ensure that the lessons were on the same grade level and that they utilized the same types of practice/reinforcement activities.

The reviewers were given access to the computerized instructional program and the materials to be utilized in the classroom and then asked to respond to eight statements regarding the validity of the two methods of instruction using Likert-scale responses ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The level of agreement between the reviewers was 91.7%, and all reviewers concluded that the two methods were equivalent.

Length of the Study

All participants in the study were taught during 10 sessions conducted during the fall semester of the school year. Each session lasted 90 minutes. Table 2 summarizes the topics covered and the amount of instructional time that was spent on each item.

Table 2
Percentage of Instructional Time Spent on Each Topic Area

Topic Area	TDA Group	CAI Group
Review Concepts and Applications of Fractions	20%	20%
Multiplying Simple Fractions	20%	20%
Multiplying Mixed Fractions	20%	20%
Dividing Simple Fractions	20%	20%
Dividing Mixed Fractions	20%	20%

The participants received a total of 900 minutes of instruction over the 10 days of the study. The length of the study was primarily influenced by the curriculum that was chosen. The curriculum was designed to last only 8-10 days.

Testing Instrument

The Brigance Comprehensive Inventory of Basic Skills – Revised (CIBS-R) was utilized to measure student learning under each of the instructional methods. The CIBS-R consists of both individually administered and/or group administered

pretests, posttests, readiness tests, and overall assessments in 23 different subject areas ranging from learning readiness to using metrics (Glascoe, 1999). The participants completed the entire pretest and posttest subtests for multiplying and dividing fractions during the study to assess their learning of these skills. These tests consisted of 32 questions each that specifically focused on multiplying and dividing simple and mixed fractions by other fractions or by whole numbers. Table 3 lists the number of questions by type.

Table 3
Number of Questions by Type for Pretest and Posttest

Question Type	Number of Questions
Multiplying Simple Fractions	8
Multiplying Mixed Fractions	8
Dividing Simple Fractions	8
Dividing Mixed Fractions	8
Total	32

Statistical Analysis Methodology

Student learning and the effectiveness of each method of instruction were measured by examining the participants' pretest and posttest scores and then analyzing them using statistical analysis. Analysis of covariance (ANCOVA) was initially selected to test the research question and related null hypothesis for the study. Unfortunately, the normality of the pretest scores of the CAI and TDA groups, as measured using the standardized skewness and standardized kurtosis for each group,

could not be assumed. Therefore, the use of ANCOVA was rejected. Instead, an independent samples *t* test was used.

Results

Both groups completed pretests to establish a baseline and, at the completion of the study, all participants completed a posttest. The mean scores and standard deviations (S.D.) for each group are listed in Table 4. Independent samples *t* tests were performed with the participant posttest scores serving as the dependent variable for

analysis. Performing the independent samples t test was a two-stage process: (a) examine the homogeneity of the variances of

the dependent variable and (b) calculate the t value for the equality of the means of the dependent variable.

Table 4
Group Mean Scores and Standard Deviations

Group	Mean Pretest Correct Responses	Pretest S.D.	Mean Posttest Correct Responses	Posttest S.D.
TDA	1.72	2.95	12.97	10.04
CAI	1.76	2.62	11.72	6.44

The homogeneity of the variances of the posttest scores was examined to test the intermediate null hypothesis of no difference between the variances of the CAI and TDA groups. The results of this test ($p = .006$) indicated that this null hypothesis could be rejected and that the variances of the two groups could not be assumed to be equal.

Once the homogeneity of the variances was evaluated, the t test could be completed to examine the null hypothesis for the study that there is no difference between the skill acquisition of high school students with SLD who are receiving either CAI or TDA in multiplying and dividing simple and mixed fractions. The resulting t value was not statistically significant, $t(47.699) = -.560, p = .578$.

Therefore, the null hypothesis for the study could not be rejected. This led to the conclusion that there was no statistically significant difference between the CAI and the TDA groups. While the participants who received TDA experienced a greater gain in their test scores than those who received CAI based on the descriptive statistics of group means, the difference between the groups was not statistically significant.

Finally, the effect size (ES) for the method of instruction was calculated using the standard formula discussed by Wolf (1986) that utilized the mean scores of the two groups and their pooled standard deviation used as the denominator for cal-

ulation. The resulting ES value was .148. This extremely low ES for method of instruction supported the conclusion of the independent samples t test of no difference between the two groups.

Post Hoc Analysis

Despite the findings of the analyses that no statistically significant difference existed between the groups, there was a large amount of variability in the standard deviations of the two groups. While the standard deviation amounts for the TDA and the CAI groups on the pretest were close (i.e., 2.95 and 2.62, respectively), the standard deviation amounts on their posttest scores were much more distant (i.e., 10.04 and 6.44, respectively). This variability indicates that other factors may have interacted with the method of instruction to produce the increase in the variability of the test scores.

The two groups were determined to be comparable on several factors including pretest scores, IQ, age, grade, and years in special education. However, the standard deviations for the posttest scores of the TDA and CAI groups were quite different. This increase in the variability of the participant scores led to the conclusion that other factors, such as gender, socioeconomic status, and memory, may have been present in the TDA group. Since the participants in the TDA group received instruction from an actual person instead of using a self-paced

computer program, several explanations for the increased variability are possible.

First, the interaction of the instructor with the participants in the TDA group during the two-week period that the study was conducted may have developed a positive emotional connection with some of those participants. Since the researcher was from a similar cultural background with many of the participants and because the researcher has been working in the school system for 12 years, it is possible that some of the participants were more willing to try to learn the material than those who were faced with only an impersonal computer program. Villegas and Lucas (2007) suggested that student academic performance will improve if their teachers are more culturally sensitive to the students. This is a possible explanation for some of the increased variability in the participant scores in the TDA group.

Next, the interaction between the researcher and students allowed the researcher to determine when the students were becoming frustrated with a topic and allowed the researcher to restate a question in a way that students could understand or apply a concept to a topic to which they could relate (e.g., using fractions to determine the square footage of the classroom). The CAI was not able to do this because it is not designed to sense emotional responses or nonverbal cues from the participants that would allow for faster modification of the instruction.

Another potential reason for the variability in the student performance related to the interaction of the researcher with the students was the efficiency with which the class could be conducted. If the research could identify a particular area of weakness in a participant's processing (e.g., struggling with dividing numbers), then the classroom material could be modified to address that issue. This may have slightly

improved the efficiency of the TDA group instruction.

A difficulty with reading instructions with some of the participants in the CAI group may have slowed their progress. Since it is necessary to read the directions for each step of the process when using the CAI program, it is possible that a few of the participants did not completely understand the instructions that they were given by the program. One of the reasons that the BMCSB was chosen for this study was its lack of extensive reading requirements. However, it is possible that a few of the students still struggled with this area. This problem could be easily overcome in the TDA class by asking the researcher to restate the question, but it would not have been as easy for those in the CAI group.

Finally, it is possible that some of the students in the CAI group were unfamiliar with using a computer for this type of instruction. According to DeBell (2005), about 10% fewer students with disabilities regularly use computers at school than do their nondisabled peers. None of the participants in the CAI group indicated to the researcher that they were inexperienced with using a computer, but it is possible that they were not acclimated to using one for mathematics instruction. While none of these potential reasons for the increased variability in participant performance were able to be confirmed with the current test data, it is important that these potential factors be considered when applying these findings in the classroom and when preparing future research.

Relationship to Previous Studies

Previous educational research findings that examined the effectiveness of CAI in various environments concluded that it was as effective as other methods of instruction (Christmann, Badgett, & Lucking, 1997; Mann, Shakeshaft, Becker, & Kottkamp, 1999; Watkins, 1991).

However, a direct comparison of the findings of this study with those previous findings is difficult because of differences in either participant characteristics or study design.

In addition, most of the previous studies that focused on students with SLD did not exclusively use high school students as participants. Only two of the studies in the current body of literature (Howell, Sidorenko, & Jurica, 1987; Wilson, 1993) focused on high school students with SLD. While both of those studies concluded that CAI was effective for these students, neither utilized a non-CAI comparison group.

Since no difference was found between the CAI and TDA groups, the initial conclusion would be that the two methods of instruction are equally effective. However, the increased variability in the posttest scores points to other potential sources of interactions between the two groups, which should be examined before arriving at this conclusion.

Recommendations for Teachers

The design and participant composition of this study provide practical insight for classroom teachers, especially those at the high school level. According to these findings, the learning of the participants in both the TDA and CAI groups were statistically similar. However, a one-size-fits-all approach to educational planning is not in the best interest of students. Other factors, such as gender, socioeconomic status, and memory, can influence the effectiveness of an intervention. The scope of this study was not broad enough to examine these factors. Therefore, classroom teachers should consider this study's findings along with individual student characteristics when planning classroom activities and preparing IEPs.

Recommendations for Future Research

Although the present study revealed no statistically significant difference between the two instructional methods investigated, future research on the effectiveness of CAI for high school students with SLD may produce additional insights. Recommendations for future research may include:

1. Replicate the study in a different geographic region with a more diverse student population. This might provide greater insight into the relative effectiveness of CAI and TDA for students with varying ethnic, socioeconomic, and cultural backgrounds.
2. Design a study that will last for a longer period of time to see if the effects of the method of teaching changed with a longer study. This might assist with long-term planning for students with SLD.
3. Test other covariates, such as gender or computer literacy, along with method of instruction to determine if an interaction between these additional covariates and method of instruction exists. The sample size of this study ($n = 58$) was not large enough to lend itself to this type of analysis. However, a larger sample using these covariates might help to isolate the cause of the variability in student learning that was identified by this study.
4. Use the study design to test the effectiveness of the two methods of instruction for different areas of mathematics, such as geometry or algebra. It is possible that a study that examined another area of mathematics could yield different results.
5. Add a hybrid method of instruction that blended CAI and TDA to the study design. Neither the sample size

nor the testing environment of the current study permitted this type of analysis. However, the addition of the third method of instruction might address the assertion by Schmidt, Weinstein, Niemiec, and Walberg (1985-1986) that adding computers to lecture-style instruction would provide significant gains for students with SLD.

6. Test other types of CAI programs, such as game-type CAI, against TDA for high schools students with SLD. While game-type programs are not generally suited for older students (Bahr & Rieth, 1989; Okolo, 1992), these programs require less reading and processing than drill-and-practice programs. This type of CAI program might produce different results for this population of students.
7. Use a single-case design for a student with SLD whose specific learning disability is matched to the design features of CAI.

Summary

This study found that no statistically significant difference existed between CAI and TDA for teaching mathematics to high school students with SLD, $t(47.699) = -.560$, $p = .578$. Due to the limitations of the study and the fact that it is the first of its kind in the current body of literature, additional research should be conducted to confirm these findings.

Students with SLD deserve to receive an education that utilizes the most efficient and effective teaching methods. Even though these results may seem to indicate that the use of CAI is a cost-effective alternative to TDA, they provide only a starting point for future research and not a destination for educational planners.

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