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An Examination of Hand-held Computer-assisted Instruction on Subtraction Skills for Second Grade Students with Learning and Behavioral Disabilities

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The effect of a mathematic flashcard application on a hand-held computing device was examined across three individual second grade students with learning and behavioral disabilities. All of the students improved their subtraction scores by an average of 17% as measured by the district-created, curriculum-based assessment. The results of this study suggest that practice on a mobile computing device with a mathematic flashcard application can improve subtraction skills in second grade students with disabilities.

Mathematics plays a key role in many aspects of daily living, such as managing money for basic necessities, simple measurement for cooking and navigation, and recreation. As a result, mathematics is an essential content area for all students, including those with disabilities. Recognizing the value of mathematical knowledge involved in everyday functioning, the No Child Left Behind (NCLB) Act created mandates to increase participation and accountability in math instruction by requiring that all students be tested annually in Grades 3–8, and once in high school (Billingsly, Scheuermann, & Webber, 2009; Bouck & Flanagan, 2009).

Mastery of lower level math skills such as addition and subtraction is necessary before students can move on to higher level math (Wu, 1999). However, many students with disabilities do not master these lower level skills (Fuchs et al., 2006; Sayeski & Paulson, 2010). To be successful with mathematical computation, students must have adequate short-term memory, good organization skills, and strategies to facilitate learning (McLoughlin & Lewis, 2007). Unfortunately, students with learning disabilities often have problems with short-term memory, language, reasoning, and metacognition (Hallahan, Kauffman, & Pullen, 2009). In addition, they use inadequate strategies for problem solving and completing other math tasks (Geary, 1990; Kroesbergen & Van Luit, 2003). As a result, students with learning and behavioral disabilities typically perform one to two grades below their peers on all measures of mathematical functioning (Bouck & Flanagan, 2009; Hallahan et al., 2009; Trout, Nordness, Pierce, & Epstein, 2003; Vaughn & Bos, 2009).

Research has demonstrated that students with disabilities who struggle with math often lack automaticity with basic math facts (Edyburn, 2003; Geary & Brown, 1991; Mazzocco, Devlin, & McKenney, 2008), and they are more likely to rely on finger counting and other inefficient strategies when doing basic computing (Sayeski & Paulson, 2010). When students lack automaticity with number facts, they have difficulty with estimation, identifying multiples when working with fractions, performing algebraic equations, and performing mental math (Woodward, 2006). To compensate for these deficits, special education teachers need to find additional strategies to infuse fluency instruction into daily routines (Sayeski & Paulson, 2010).

One strategy to increase math fluency instruction is to integrate technology into the curriculum (Fuchs, et al., 2006). The National Council of Teachers of Mathematics (NCTM, 2000) identified six principles and 10 standards to ensure that all students have access to rigorous, high-quality mathematics instruction. The last of the six principles identified by NCTM addresses the importance of infusing technology into mathematics instruction. Specifically, the technology principle states that students with disabilities may benefit from increased opportunities to learn mathematics by interacting with newly developed technologies. Educators have become more aware of the potential benefits of using technology; according to the National Center for Education Statistics, by 2003, 82% of all students with disabilities were using computers (NCES, 2005). However, O'Dwyer, Russell, Bebell, and Tucker-Seeley (2008) found that despite increased access to computers, technology use in the classroom was not impacting students' math achievement, partially because the technology was not being utilized adequately. In their study, they discovered that the average classroom utilizes computers only nine times per year, and almost never for mathematic applications (O'Dwyer et al., 2008).

A number of studies have demonstrated the value of using technology to improve social and academic outcomes for students with disabilities (Blackhurst, 2005). However, there is limited research about the benefits of using technology to improve mathematic outcomes for these students (Bouck & Flanagan, 2009; Edyburn, 2003). In a comprehensive review of research on the use of technology in mathematics for students with high-incidence disabilities, Bouck and Flanagan found only 17 articles published between 1996 and 2007 that addressed technology and mathematics instruction. Six of those articles were by the same author, investigating the same intervention.

One of the more frequently studied approaches for using technology to facilitate mathematic instruction for students with disabilities is the use of computer-assisted instruction (CAI) (Hughes & Maccini, 1997; Vaughn & Bos, 2009). Computer-assisted instruction refers to computer software programs that provide reinforced practice, tutorials, or problem-solving simulations that can be done independently or as part of teacher-directed instruction (Ulman, 2005). For students with learning and behavioral disabilities, CAI has been strongly encouraged in mathematics (Vaughn & Bos, 2009) and is used typically to provide drill and practice or as a supplement to teacher-directed instruction (Yell, Meadows, Drasgow, & Shriner, 2009). As cited in Bouck and Flanagan (2009), some of the earliest research on the use of CAI for students with disabilities revealed an increase in accumulation of math facts, increased automaticity, and increased motivation. However, in a pilot study to examine the impact of CAI software on number skill combination with 33 at-risk first graders, Fuchs et al. (2006) found improved student performance on addition, but not subtraction. Nonetheless, despite some encouraging early research, there has been a decreased emphasis in research on CAI and math for students with disabilities, as only six articles were published from 1996–2007 (Bouck & Flanagan, 2009). Given the tremendous advances in technology during the past 15 years, the lack of research on CAI and mathematics for students with disabilities represents a significant research gap. There also is a need for additional research to explore the effects of CAI on subtraction number problems for students with learning and behavioral disabilities (Fuchs et al., 2006).

One of the most critical aspects to improving math fluency is providing students with adequate practice opportunities that include a systematic review of previously learned facts (Yell et al., 2009). Unfortunately most math curricula do not provide sufficient practice opportunities, and fact fluency is often overlooked (Stein, Kinder, Silbert, & Carnine, 2006). Research has demonstrated that children without disabilities are able to learn a new task without prompts or assistance after two to three trials. However, a child with a disability may require 20 to 30 trials to learn the same task (Hallahan, Kauffman, & Pullen, 2009). In mathematics, flash cards, which aid memorization of basic math facts by way of spaced repetition, are a frequent strategy for improving fact fluency (Vaughn & Bos, 2009).

One strategy for increasing practice opportunities with basic math facts is to use a flashcard application on a mobile computing device such as the Apple iPod Touch. The Apple iPod Touch is a hand-held media player, personal digital assistant, and Wi-Fi enabled computing device. While the iPod Touch is not marketed as a computer, it has the ability to run a variety of software applications in the same way a computer does. Practicing math facts on an iPod Touch may hold several advantages over traditional paper flashcards because it can alter

the presentation and response mode for practicing math facts, provide immediate feedback, and track student performance. However, there is a lack of evidenced-based research on how to use technology to facilitate learning (Blackhurst, 2005; Gersten & Edyburn, 2007). More research on how to use technology to improve mathematic outcomes for students with disabilities is needed (Bouck & Flanagan, 2009; Fuchs et al., 2006).

Methods

The purpose of this study was to examine the use of a mathematic flashcard application on an Apple iPod Touch to improve subtraction skills for second grade students with learning and behavioral disabilities. A single-subject, multiple-baseline design across students was used.

Participants

The participants in this study were three second grade students (Sarah, John, and Jacob) from a large metropolitan community. Sarah and John met state and federal criteria to receive special education services for learning disabilities. They were both identified to receive special education services through the district response to intervention (RTI) criteria. Their primary disability was in the area of reading, but they also were eligible to receive special education services for mathematics. According to her individualize education program (IEP), Sarah scored in the average range for intelligence as determined by an overall standard score of 89 on the Otis Lennon School Ability Test, Eight Edition (OLSAT-8), and she scored in the 7th percentile on the math procedures subtest of the School Achievement Test, Tenth Edition (SAT-10). The math procedures subtest of the SAT-10 measures a student's ability to apply rules of arithmetic to problems that require mathematic solutions. John scored in the low average range for intelligence as determined by his standard score of 70 on the OLSAT-8, and scored in the 15th percentile on the math procedures subtest of the SAT-10.

Jacob met state and federal criteria to receive special education services for behavioral disorders and was identified to receive special education services through the district referral system for behavior problems. Jacob began receiving these services after he was diagnosed with attention deficit hyperactivity disorder (ADHD). According to his IEP, Jacob scored in the average range for intelligence as determined by an overall standard score of 93 on the OLSAT-8, and scored in the 56th percentile on the math procedures subtest of the SAT-10. In spite of his average ability, Jacob had difficulty in school because of problems with impulse control, aggression, and off-task behavior.

The students were selected for participation in this study because they were performing significantly below the district criteria for subtraction mastery, as measured by the district-created, curriculum-based timed test for subtraction. As documented in their IEP, all of the students were taking some classes in the general education setting and spent 0–20% of their day in a resource room to receive special education services for mathematics and other academic subjects as needed. The age range of the students was 7–8, with a mean age of 7.45. Each of the students was identified as needing special education services to help with subtraction, as noted on their IEP objectives. All of the students attended the same urban elementary school in the Midwest, which was a Title 1 school with 58% of the students on free or reduced price lunch. The school served 313 students, and 42% of the population was identified as being of minority status. Approximately 10% of the students received special education services, and another 14% of the students were English language learners.

Dependent Variable

The dependent variable for this study was the percent of correctly answered subtraction problems on the Nebraska Abilities Math Test (N-ABLES). The N-ABLES is a district-created, curriculum-based mathematic assessment that is aligned with the state standards for math proficiency. It is a five-minute timed test with 100 problems designed to assess specific math fluency in the areas of addition, subtraction, multiplication, and division. Students throughout the district are required to take the N-ABLES at least once per quarter for their designated grade level. By the end of second grade, students are expected to complete 95 of 100 subtraction problems correctly within five minutes as measured by the N-ABLES. Each of the students in this study was scoring consistently below 25 on the subtraction form of the N-ABLES when they were selected for this study.

Validity of the N-ABLES was established by the district. Validity was met through content and curriculum based on state and district standards. Subtraction problems on the N-ABLES were selected randomly from the pool of all possible problems as defined by state and district standards. For example, students in the second grade are to have mastered subtraction of two-digit numbers from 0–20. All problems used the numbers 0–20, and they were checked against the curriculum to ensure that all were found in work available to second grade students. The 100 problems were selected randomly from the pool for the N-ABLES as a representative sample of items with which students are to be familiar. Similar validity checks have been conducted with addition, multiplication, and division. Reliability of the N-ABLES also was established by the district and has shown stable results through time. Test items are related to each other and test for the same mathematical concept.

Independent Variable

The independent variable for this study was a software application called Math Magic©, which is copyrighted by anusen.com. The Math Magic application was downloaded from the Apple iTunes Web site and loaded onto an Apple iPod Touch device. The Apple iPod Touch is a hand-held computing device that allows users to interact with a touch screen interface that supports a variety of software applications. The iPod Touch can play a variety of application software available through the Apple iTunes store. Currently, the Apple iTunes store has more than 100,000 applications ranging from games, to music, to education, and so on. Approximately 300 of the applications are related to mathematical concepts.

Math Magic uses a simple interface on the iPod Touch device that is designed to teach children between the ages of 3 and 8 basic addition, subtraction, multiplication, and division facts. Users are allowed to customize the difficulty level and set the maximum number of problems the students need to complete. Users also can set a timer to see how many problems can be completed in a specific time frame. Math Magic presents students with one problem at a time, and provides a choice of four answers from which to choose. Students choose the answer by touching the screen. If a student chooses the correct answer, a green check mark is displayed and tallied in the upper right hand corner of the screen, and the next problem is displayed. If the answer is incorrect, a red X is displayed and tallied in the upper right hand corner of the screen. If a student chooses the incorrect answer, he or she may continue to try to get the correct answer; however, it will not change the tallied score. For the purpose of this study, the Math Magic application settings were programmed to display two-digit subtraction problems from 0–20 for 10 minutes.

Procedures

To determine the effect of 10 minutes of practice, three times a week, on 0–20 two-digit subtraction problems on the Math Magic application, a multiple baseline across students research design was implemented. During baseline, students did their normal routine, which consisted of working on their math homework in the resource room and receiving help from support staff as needed. For the purpose of this study, the students were administered the 0–20 two-digit subtraction form of the N-ABLES on Fridays. There were three different versions of the subtraction form of the N-ABLES in which the order of the equations was rearranged. As required by the district, students were given five minutes to complete as many of the 100 subtraction problems as possible.

All of the students in this study went to their resource room daily to receive assistance with math and other academic subjects. During the intervention on Mondays, Wednesdays, and Thursdays, the students spent 10 minutes practicing subtraction facts using the Math Magic application on the iPod Touch. Using the Math Magic application, students practiced two-digit subtraction facts from 0–20 for 10 minutes. After 10 minutes, the resource teacher recorded the percentage of problems answered correctly out of the number attempted as recorded by the Math Magic application.

Students were trained on how to use the Math Magic application on the iPod Touch during their first day of intervention. Training consisted of a step-by-step demonstration of how to interact with the iPod Touch interface and the application. These steps included how to turn on the iPod Touch and touch the screen to open the Math Magic application. The application immediately opened to the subtraction practice problems, so the next step was to teach the students how to touch the screen to choose the answer to the subtraction problems as they presented themselves on the screen. Students then did

a 10-minute practice with teacher supervision to check for understanding. Once the students demonstrated that they knew how to operate the iPod Touch with the Math Magic application, they proceeded to practice on their own. Total training time took no longer than 20 minutes. On Fridays, students were administered the 0–20 two-digit subtraction form of the N-ABLES, just as during baseline.

Baseline data, using the subtraction form of the N-ABLES, were collected for at least three weeks on all three students. After the initial three data collection points, one student began the intervention using the Math Magic application on the iPod Touch while the other students continued at baseline. After collecting three additional data points, a second student was introduced to the intervention while the final student continued at baseline. After collecting an additional three data points, the third student began intervention. The final four data points were collected once all four students had started intervention. In addition to the data collected during baseline and intervention, one follow-up data point was collected before school let out for summer, after the intervention had been discontinued for two weeks for all of the students.

Reliability

The resource teacher monitored student use of the Math Magic application on the iPod Touch every time they practiced. To ensure fidelity of implementation, the resource teacher and a second person observed each student using the Math Magic application once every three trials. This resulted in seven reliability checks out of 21 opportunities. Reliability checks consisted of making sure the students worked on the application for 10 minutes without restarting the program and making sure the number of problems completed correctly and the number of problems attempted was recorded accurately. Interobserver agreement was 100% during the course of the seven reliability checks.

The second type of reliability check was on the grading of the N-ABLES subtraction test. Fifty percent of the N-ABLES tests were graded by a second person to assess the reliability of the grading. Only three items were discussed as being correct or incorrect because of difficulty in determining the answer based on how the student wrote the number.

Analysis

The improvement rate difference (IRD) was calculated to produce a quantitative index of the effect of the intervention. As cited in Parker, Vannest, & Brown (2009), IRD is the difference in the improvement rate of the intervention minus the improvement rate during baseline. The highest IRD score that can be calculated is 1.00, in which 100% of the intervention phase data points would exceed all baseline scores. Suggested benchmarks for IRD include .50 and below as very small to questionable, .50–.70 as moderate, and greater than .70 rated as large effects (Parker et al., 2009).

Results

Results from the IRD calculations are presented in Table 1. Additionally, Figure 1 shows the visual representation of the baseline and intervention performance of the students as measured by the weekly N-ABLES and the average weekly practice scores during intervention. The results suggest that when the students practiced 0–20 two-digit subtraction facts for 10 minutes, three days a week, using the Math Magic application on the iPod Touch, their N-ABLES subtraction time test scores improved. During three weeks of baseline testing, Jacob's scores had a little variability, but they ranged from 23–28, with an average of 23.3 (4.5 SD). After 10 weeks of the intervention, Jacob averaged 42.1 (11.8 SD) problems correct. His lowest score during the intervention phase was 25, which he received the first week of intervention. His highest score of 62 was scored during Week 9 of the intervention. The IRD calculation for Jacob was .57, which demonstrates that 57% of the intervention data points exceeded all baseline scores. This would suggest a moderate effect of the intervention on his performance. Upon visual inspection of Jacob's performance, we can see that in spite of some variability, there was a steady upward trend on the N-ABLES during intervention. Two weeks after the intervention had concluded, Jacob scored a 57 on the N-ABLES. His weekly average practice scores were consistently above 90 percent.

During six weeks of baseline testing, Sarah's scores were fairly consistent, ranging from 14–22, with an average of 16.6 (SD 3.3) problems correct on the N-ABLES. Her final three scores during baseline were a consistent 14. After seven weeks of the intervention, Sarah averaged

Table 1

Summary of Improvement Rate Difference

		Intervention		
Subject	**Baseline IR**	**IR**	**IRD**	**90% CI**
Jacob	.33	.90	.57	.09–1.0
Sarah	.16	.71	.55	.17–.92
John	.11	.75	.64	.24–1.0

Note. IR = improvement rate; IRD = improvement rate difference; CI = confidence interval.

28.8 (SD 8.7) problems correct on the N-ABLES. Her lowest score during the intervention phase was 22, and her highest score on the last day of testing was 41. The IRD calculation for Sarah was .55, which demonstrates that 55% of the intervention data points exceeded all baseline scores. This would suggest a moderate effect of the intervention on her performance. Upon visual inspection of Sarah's performance, we can see that during the intervention phase she showed a slow but gradual improvement in her performance with little variability. Two weeks after the intervention, she scored a 35 on the N-ABLES. Her average practice scores were somewhat variable, and ranged from 65–97% accuracy.

During the nine weeks of baseline testing, John's scores were fairly consistent, ranging from 18–30, with an average of 22 (SD 3.5) problems correct on the N-ABLES. After four weeks of the intervention, he averaged 40.5 (SD 8.5) correct on the N-ABLES. John's lowest score during the intervention was 28, which he recorded on the first test. His highest score was 47, which he received on the third week of the intervention. The IRD calculation for John was .64, which demonstrates that 64% of the intervention data points exceeded all baseline scores. This would suggest that the intervention had a moderate effect on his subtraction performance. Upon visual inspection of John's performance, we can see that during the intervention phase he showed a rapid improvement in his performance with little variability across four data points. Two weeks after the intervention, John scored a 46 on the N-ABLES. His average practice scores were somewhat variable, ranging from 74–95 correct.

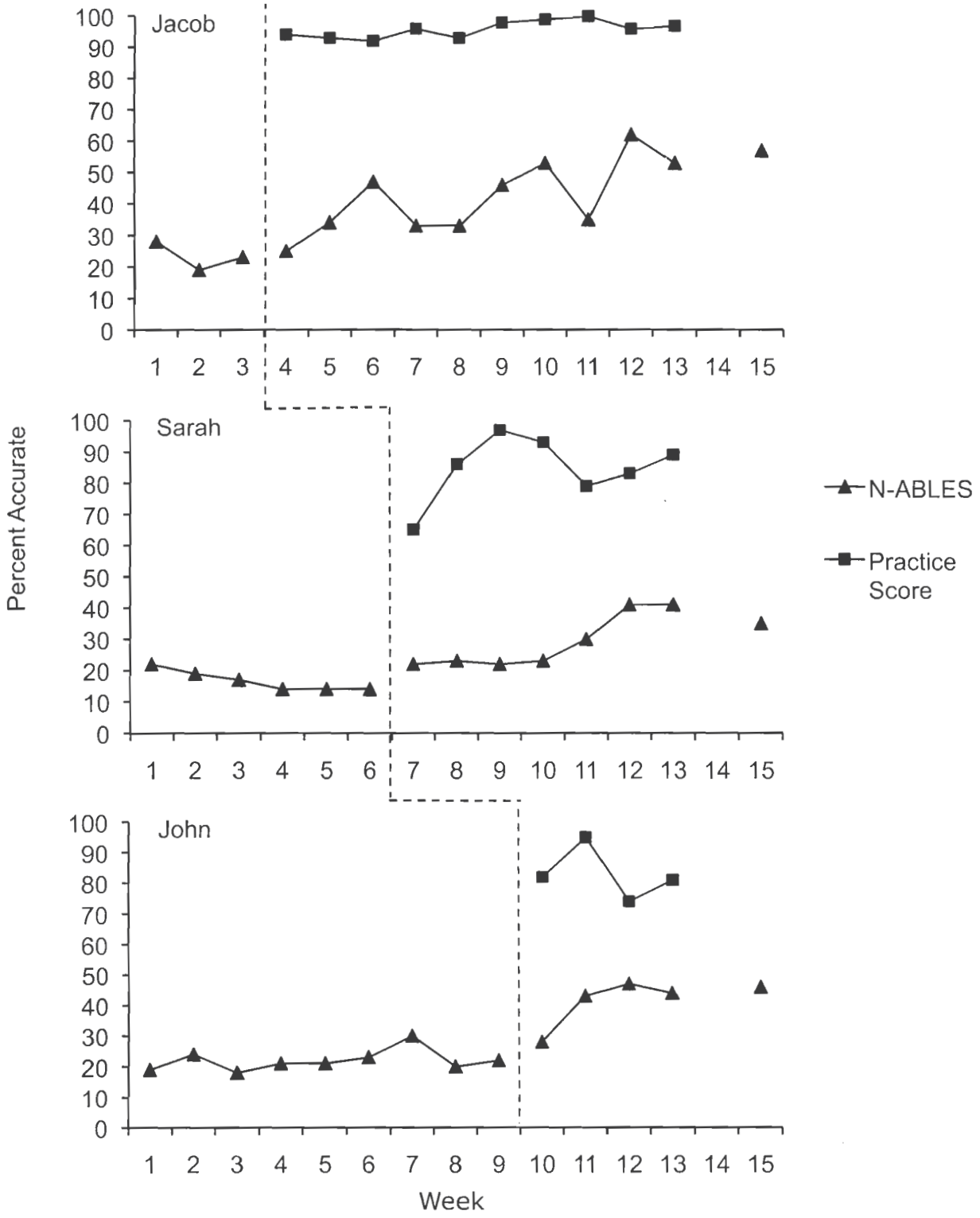
Discussion

The results from this study demonstrate that CAI can be used to improve subtraction skills in elementary students with disabilities. The results also support the use of new technologies such as the Apple iPod Touch as an assistive technology device that can be used effectively to support learning. Each of the students in this study benefitted from practicing 0–20 two-digit subtraction facts using the Math Magic application on the iPod Touch for 10 minutes, three days a week. While none of the students was able to meet the district criteria of 95% correct, the average test score on the N-ABLES improved by 17%. The overall average IRD score for the intervention was .59, which suggests that the intervention had a moderate effect on their performance.

The baseline test scores remained consistent throughout the progression of the study as scores during intervention improved. This would suggest that merely taking the N-ABLES test more frequently without the additional practice on the iPod Touch would not be sufficient to improve test scores. It also supports the conclusion that the intervention had a positive effect on student performance. The average practice scores taken from the Math Magic application suggest that the students were able to answer a high percentage of the problems correctly during practice, in comparison to their scores on the N-ABLES. This was not surprising, as the Math Magic application provides the students with multiple-choice answers on a touch screen, whereas the N-ABLES is open ended and requires students to write the correct answer independent of choices. Nonetheless, for the purpose of drill and practice, the students seemed to benefit from the multiple-choice format of the Math

Figure 1

Percent Correct and Math Magic© Practice



Magic application. Future research should examine the relationship between practice accuracy and N-ABLES performance as well as the impact of alternative response modes, such as touch screen versus hand written answer, on student performance.

Social Validity

The teacher reported that the intervention was well received by the students and that they enjoyed the opportunity to practice math on the iPod Touch device. She also emphasized, that when they were working on the iPod Touch, students were motivated to be on task and displayed no behavior problems. The teacher stated that the touch screen utility of the iPod Touch was easy to use and the students liked the interactive features of the Math Magic application. In addition, the application made it easy for students to track their performance, allowed them to try problems that they had gotten incorrect again, and provided additional opportunities to learn.

According to the teacher, one major outcome of this study was student willingness to accept help in the resource room. The students enjoyed working on the iPod Touch device so much that they came to the resource room with great enthusiasm. This enthusiasm translated to them finishing their work promptly in other academic subjects so that they could practice on the iPod Touch. According to the resource teacher, "Accepting help is the first form of self-advocacy that we strive to teach our students with disabilities. Anything that enhances this process by making resource services more inviting is a lasting benefit to our students. The iPod Touch proved to be an excellent educational tool for motivating students to accept help from the resource room."

Limitations and Future Research

There are several limitations to consider with the present study that offer opportunities for future research. First, when a student engages in consistent practice that is targeted toward a specific skill, one would expect to see an improvement in performance. However, the quality and quantity of practice will have an effect on that performance. In this study, for example, increased practice on the N-ABLES alone did not result in improved student performance. Future research should compare methods of practice and instruction to determine which methods are most effective. For instance, future research should compare student performance using the Math Magic application on the iPod Touch verses traditional paper flashcards or other technologies.

Second, as with any single-subject research design, our sample size was small for this pilot study. Replication of the intervention used in this study should be conducted with a larger, diverse sample to support the conclusions and to examine its use with other populations.

Third, there was limited use of this intervention during the school year. For example, John only received the intervention for four weeks, but improved his N-ABLES score by 18.5%. Future research would be needed to determine if the amount of time a student participates with the intervention has a significant impact on performance. Because we were able to collect only one follow-up data point before the end of the school year, future research is needed to examine the lasting impact of the intervention on student performance.

Fourth, while we were encouraged by the moderate IRD for each subject, those findings must be tempered with the recognition of the wide confidence intervals for each participant. While such large confidence intervals are not unusual in single-subject research (Parker et al., 2009), less variability and more data points may result in a narrower confidence interval. Finally, this study only examined student performance on subtraction skills. Future research should examine the utility of other flashcard applications with other mathematic equations. Research also is needed to evaluate the utility of educational software for the iPod Touch and other devices that may improve the academic and social performance of students with disabilities.

Implications

The results from this study support the use of a handheld computing device with flashcard software to improve math fluency skills in students with learning and behavioral disabilities. With the ongoing development of new software and hardware technologies, it is incumbent upon researchers to continue to investigate the viability of these technologies for improving academic and social outcomes for students with disabilities. In addition, there is a need to bridge the gap between research and practice by identifying efficient strategies

that are cost effective and easy to implement. The Apple iPod Touch device used in this study was approximately $230, and the Math Magic application was 99 cents. That is considerably less than the cost of a computer and accompanying software. Furthermore, the time used to train students on how to use the application on the iPod Touch was less than 20 minutes. This demonstrates that there are cost-effective and efficient ways to integrate technology into the instructional routines of students with disabilities that also can have a positive effect on academic outcomes.

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