Pentop Computers as Tools for Teaching Multiplication to Students with Mild Intellectual Disabilities

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Abstract: The effectiveness of a pentop computer when teaching multiplication facts to three middle school students with mild intellectual disabilities was examined. A multiple probe design was used to assess the students learning of one and two digit multiplication facts over a 2-3 week intervention period. During the intervention phase, students used a FLY™ Pentop Computer (LeapFrog©) to practice multiplication problems. Following intervention, students were assessed on their ability to solve multiplication problems without the tool. The results indicated that all three students improved in the percentage of correct math facts completed and support the use of the pentop computer when teaching multiplication to students with mild intellectual disabilities. Limitations and suggestions for future research are discussed.

Mathematics education is a high priority in the United States (Ellis & Berry, 2005). The majority of students in the third through eighth grades are now annually evaluated on their mathematical abilities under the requirements of No Child Left Behind (NCLB, 2002). Additionally, these students are expected to reach proficiency in this domain by the 2013–2014 school year (Yell & Drasgow, 2005). Research suggests that students in the United States perform worse than their international counterparts (Beaton, Mullis, Martin, Kelly, & Smith, 1996); as such, mathematics is considered an important and critical content domain for instruction and evaluation for students with and without disabilities. Yet, researchers and teachers document that many students with disabilities struggle with mathematics (Grise, 1980). These struggles can include skills ranging from computational fluency to knowing one’s basic facts as well as problem solving (Cawley, Parmar, Fley, Salmon, & Roy, 2001; Jitendra, DiPipi, & Per-
In their review of the literature on mathematics and students with intellectual disabilities, Butler et al. found only three studies that involved secondary students: two focusing on middle school students with mild intellectual disabilities and one that involved students with mild intellectual disabilities in elementary through high school. One study involved basic computation instruction and the other two focused on technology. In the computation study, Morin and Miller (1998) taught three middle school students with intellectual disabilities multiplication facts using the concrete-representational-abstract teaching method, along with mnemonic devices that were added during the abstract phase. The results indicated that all students learned their basic multiplication facts and improved from pretest to posttest.

Other recent research suggests that students with mild intellectual disabilities benefit from developing fluency in mathematical skills, such as multiplication (Cooke, Guzaukas, Pressley, & Kerr, 1993). Fluency can be defined as “the effortless, automatic ability to perform mathematical operations” (Houchins, Shippen, & Flores, 2006, p. 324). In other words, mathematical fluency refers to the speed, accuracy, and monitoring of errors that students have when completing mathematical problems. In addition, fluency with basic facts or basic operations assists students in problem solving, such as when solving word or story problems (Houchins et al.). Several strategies focused on increasing the mathematical fluency of students with developmental disabilities, such as mild intellectual disabilities, were examined: teaching via the concrete-representation-abstract method (Morin & Miller, 1998); using timed trials, including constant time delay (Mattingly & Bott, 1990; Miller, Hall, & Heward, 1995); use of a supplemental program (Jolivette, Houchings, Lingo, Barton-Arwood, & Shippen, 2006); and peer tutoring (Harper, Mallette, Maheady, Bentley, & Moore, 1995). In addition to these strategies, another way suggested to increase the mathematical fluency of students with mild intellectual disabilities was through the use of technology (Maccini & Gagnon, 2005).

Despite the increased emphasis of technology in the teaching and learning of students with disabilities and increased opportunities for technology in the area of mathematics, little research examined technology, mathematics, and students with mild intellectual disabilities. Although Mastropieri, Scruggs, and Shian (1997) called for increased attention in this area a decade ago, the focus on technology, mathematics, and students with mild intellectual disabilities never materialized. Within the research that does exist, Masteropieri et al. used a computer-assisted instruction (CAI) program to teach problem solving to four upper elementary students with mild intellectual disabilities. They concluded that these students improved their scores from pretest to posttest as well as reported enjoyment using the computer program.

Additionally, Horton, Lovitt, and White (1992) examined the use of calculators as compared to traditional paper-and-pencil method for solving subtraction with middle school students with mild intellectual disabilities. They concluded that students improved in their performance on the subtraction problems after they used calculators. The use of calculators was attributed to increased accuracy in the students. Jaspers and Van Lieshout (1994) also found benefits from integrating technology into mathematics instruction for students with mild intellectual disabilities across the span of elementary to high school. They found that allowing students to touch key words on a computer screen in a story problem was beneficial to students when they took paper-pencil tests.

**Smart Toys**

Prior research on technology and mathematics for students with mild intellectual disabilities is limited to more traditional forms of educational technology (i.e., calculators, CAI), and this field failed to take advantage of exploring more advanced technological ways to educate these students. One type of new technology includes **smart toys**. Smart toys are an innovative form of technology which has recently increased in popularity (Bouck,
Okolo, & Courtad, 2007). Smart toys are described as toys that are programmed to respond to a child though microprocessors that recognize and transmit input from the child (Roderman, 2002). An early example of a smart toy is the Furby, which is a toy that spoke English (Maine, 2004). Other examples of smart toys further incorporated computer technology and include: LEGO Mindstorms which are programmable bricks and Logo Turtles a robotic creature which could be programmed to perform commands (Papert, 1993). More recent smart toys include I-Dog a robotic dog which reacts to music; Share-A-Story from Care Bears where the bears read “children stories” aloud to the children (Gibson, 2005); and the FLY™ Pentop Computer from LeapFrog© (Pogue, 2005).

The FLY™ Pen is a pentop computer that provides auditory output and prompts users to complete a variety of tasks. The FLY™ Pen includes a variety of software options that can be used with the pen (Pogue, 2005). The different software options allow the pen to be used as a calculator, a calendar, a piano keyboard, a journaling assistance tool, a Spanish dictionary, as well as provide assistance with mathematics, social studies, science, spelling, and writing. Although this software is marketed for students to use with academic areas, little research explored its potential for assisting students. Furthermore, despite its potential, no research could be found that examines the impact of using this tool as a form of assistive technology for students with disabilities.

Research Project

Previous research illustrated that secondary students with mild intellectual disabilities experience a variety of difficulties at school in regards to learning their mathematics curriculum (Parmar et al., 1994; Van Luit & Naglieri, 1999). Additionally, there is a lack of research which focuses on ways to improve mathematics instruction for students with mild intellectual disabilities (Butler et al., 2001). The use of a pentop computer (i.e., the FLY pen) as a form of assistive technology may provide assistance in a uniquely beneficial way for students with mild intellectual disabilities who struggle with mathematics by improving the student’s fluency. Previous research that focuses on using assistive technology to improve math skills indicates that these students can benefit from similar types of interventions (Mastropieri et al., 1997; Horton et al., 1992). Yet, no studies could be found that analyzed the effects of the FLY™ Pen technology as an effective instructional strategy for teaching mathematics to students with mild intellectual disabilities. The purpose of the present investigation was to determine if students with mild intellectual disabilities who use the FLY™ Pen could improve their multiplication skills. It was hypothesized that instruction with the FLY™ Pen would improve the students’ abilities in learning to solve multiplication problems.

Method

Participants

Three middle school students, Diane, Joe and Sam, participated in this study. Each was selected to participate based on a) a mild cognitive level of functioning (IQ 55-70), b) similar chronological age, c) similar mathematics skill level, d) willingness to participate, e) absence of sensory disabilities, and f) no previous training or experiences in using the FLY™ Pen. All students were educated primarily in the same special education pull-out classroom, although all participated in “specials” within general education settings (i.e., art, music, physical education, and keyboarding). Table 1 provides information about the three participants.

Diane was a 12 year-old Hispanic female who was shy in her classroom and sought to please her teachers. At home, Diane primarily spoke Spanish. She was a diligent student and always tried to complete her work on time. She tended to be quiet and would only interact with her closest friends. All of Diane’s content areas were taught in the special education classroom and she was in general education for less than 40% of the day, where she was included in specials. At the start of the study, Diane was performing at a fourth-grade mathematics level and her assignments primarily included one- and two-digit addition and subtraction problems.

Joe was a 12 year-old Hispanic male who
enjoyed interacting with his peers whenever possible and was well liked by his classmates due to his good sense of humor. At times, however his sense of humor could become a distraction, as he would interrupt himself and others from completing work by talking to his classmates. Joe primarily spoke English at home. Like Diane, he was primarily served in a self-contained resource setting for more than 60% of the day and was only included in specials. He was also performing at a fourth-grade math level at the beginning of the study and his math work prior to the study included arithmetic and subtraction problems.

Sam was a 12 year-old Hispanic male who enjoyed playing sports, particularly soccer. At home, Sam spoke both Spanish and English. Sam was outgoing and was well received by his peers and teachers. He was typically a hard worker and enjoyed answering questions in class; however, at times he would allow himself to be distracted from his work. Sam participated in academic instruction in an inclusive classroom during more than 60% of the day including language arts and specials. He participated in the same special education math class as Diane and Joe. He was also performing at a fourth-grade math level with a focus on addition and subtraction problems prior to the start of the study.

**Settings**

All participants attended a self-contained mathematics class during the same class period and were provided mathematics instruction by their primary special education teacher. The students were taught their math lessons using the Saxon mathematics curriculum (grades 4/5) (Saxon Math, 2008). The class included six other students who were not included in the study, of which four participated in the same mathematics lessons as the target students. The other two students were taught separately with a paraprofessional. In the students’ classroom, the desks were arranged in rows with Sam and Joe seated next to each other in the back row and Diane seated in front of Joe. The students who were taught by the paraprofessional worked at a separate table which was sectioned off from the rest of the classroom.

The assessments for each of the phases (baseline, intervention, and maintenance) as well as the FLY™ Pen training sessions were conducted in a separate room (the school counselor’s room), which was across the hall from the self-contained classroom so the other students were not distracted. In the separate room, the students worked at a round table. The students were either seated next to each during times when the phases overlapped, or were assessed individually. Typically, only the researcher and the students were in the room during the assessments, however during some of the sessions the school counselor was in the room working at his desk which was placed behind the table where the students worked. During the intervention phase, the participants used the FLY™ Pen (with ear phones) during their regular math instruction as well as in the separate classroom.

**Independent and Dependent Variable**

The use of the FLY™ Pen as a mathematical instructional strategy was the independent variable for the study. After demonstrating mastery in how to correctly use the FLY™ Pen, students were instructed to use the pentop
computer for all multiplication problems that they worked on during their mathematics class. Students used the FLY™ Pen to complete assigned multiplication problems given on a worksheet designed by the teacher or assigned problems from their textbook.

The percentage of multiplication problems solved correctly during each assessment session was the dependent variable. Prior to the start of the study, all three of the students received instruction from their special education teacher on how to solve multiplication problems. Additionally, at the start of the study (and throughout the completion) the students’ understanding of basic multiplication facts was assessed through daily timed tests. A set of 57 random multiplication problems was created for the assessments. Of the 57 problems, 31 were basic multiplication facts (single digit numbers multiplied by single digit number, i.e., 3 × 4) and 26 were mixed problems (double digit numbers multiplied by a single digit number, i.e., 34 × 5). The problem set was developed based on the Saxon mathematics curriculum used by the students’ teacher. The set was generated through stratified random sampling to ensure that the multiplication problems included a wide range of numbers from 1-99. The researcher created the set by arbitrarily selecting non-sequential multiplication problems that used an assorted selection of digit combinations. Specifically, diverse problems such as 8 × 8, 2 × 7, and 6 × 5 were chosen for the set and sequential problems such as 8 × 8, 8 × 7, and 8 × 6 were intentionally omitted from the set. A variety of the basic and mixed problems totaling ten or fewer questions per assessment were randomly drawn from the set of problems during each phase of the study. During the baseline phase, four basic facts problems and three mixed problems were used. Initially, three, two digit times two digit problems (i.e. 42 × 63) were assessed during the baseline phase, however the students were not assigned problems like this to work on in class with the FLY™ Pen therefore these data were not included in the final data analysis. During the intervention and maintenance phases, the probes consisted of five basic facts problems and five mixed problems.

Materials

FLY™ pentop computer. The FLY™ Pen, a pentop computer developed by LeapFrog®, was used during the intervention phase. This pentop computer is a device slightly larger than a pen and uses special paper called FLY™ Paper. The FLY™ Pen writes as a pen, can assist students with calculations, and includes various games that support the pen’s use. In addition, educational software can be purchased for this device, such as software for spelling, multiplication and division, algebra, and writing. When the software cartridge is inserted into the top of the FLY™ Pen and used with the special FLY™ Paper, students have access to assistance in spelling activities, solving multiplication and division problems, and organizing one’s writing. The FLY™ Pen comes with a Launch Pad which provides instructions for the pentop computer and activities that can be done with the FLY™ Pen.

Multiplication and division software. This study used the FLY™ Pen multiplication and division mathematics software. The multiplication and division software included a software cartridge, the FLY™ Control Panel tablet, FLY™ Paper used to complete the math problems, and a manual with example problems and directions. The FLY™ Control Panel tablet contained 40 pages of the FLY™ grid paper for students to write multiplication or division problems following a format specified in the manual. This software required students to use specific steps while solving their multiplication or division problems. To ensure that steps were followed correctly, the FLY™ Pen provided auditory prompts about which functions needed to be completed before moving to subsequent steps. When each student started the intervention phase of the study, s/he was assigned a box with the study materials that were stored in a nearby cabinet for easy access during each math class.

Experimental Design

A multiple probe across students design was used to determine the effectiveness of a FLY™ Pen on the acquisition of multiplication skills. The multiple probe design was chosen since it provided a means to decrease the collection of data across the multiple baselines while at the
same time ensuring that no significant changes occurred before the introduction of the intervention. Additionally, the multiple probe design allowed the researchers to determine if a functional relationship existed between the intervention (practicing multiplication with the FLY™ Pen) and students improving their multiplication skills as measured by the assessments (Kennedy, 2007). A multiple baseline design is frequently used when academic learning is involved (Alberto & Troutman, 2006); as such, this design was selected because it best controlled for possible learning or carry-over effects as a result of student exposure to the FLY™ Pen.

Data Collection

Event recording was used to determine the number of multiplication problems solved correctly during each of the phases in the study. This method was selected because it provides simplicity and accuracy with discrete event data collection (Kennedy, 2007). Each assessment conducted provided a record of the student’s work when solving the assigned multiplication problems, which was used to analyze the effects of the FLY™ Pen.

Procedure

Baseline. Prior to intervention, students were assessed on multiplication facts learned through traditional instructional methods, two or three times per week for a minimum of two weeks. These assessments included a random selection of four basic math problems (single-digits multiplied by single-digit problems) and three mixed math problems (double-digit numbers multiplied by single-digit numbers) for a total of seven problems per assessment. The percentage correct out of seven was calculated for each baseline session. Students continued in the baseline phase based on the order they were selected to begin the intervention. The order of the students was based on the teacher’s suggestion. Diane began the intervention first while Joe and Sam continued in the baseline phase with the traditional instruction. Joe began using the FLY Pen second; Sam continued in the baseline phase using the traditional instruction and was the last student to begin the intervention. The students only began the intervention phase once baseline stability was established.

Pre-training. During the baseline period, students were introduced to the FLY™ Pen. Initially, students used the Launch Pad, an orientation booklet to the FLY™ Pen software. Launch Pad activities included selecting objects using the FLY™ Pen, responding to prompts, and playing various games. Students also operated the FLY™ Pen while completing multiplication activities using the FLY™ Pen math paper. During this time, students were taught how to properly use the FLY™ Pen to solve multiplication problems. Tasks included teaching the student how to hold the pentop computer to ensure the software recognized the numbers they wrote, teaching the students how to write the multiplication problems on the FLY™ Pen paper, and teaching the student how to use the buttons on the FLY™ Pen math tablet so they could enter and solve the multiplication problems (as well as use the hint button as needed). The pre-training phase also served as an opportunity for the students to ask questions about how to use the pentop computer. The pre-training phase was considered complete when each student was able to individually complete three practice multiplication problems using the FLY™ Pen.

Intervention. The intervention phase took place over a minimum of three weeks. During this phase, students participated in mathematics instruction using the FLY™ Pen, software, and worksheet materials for learning their targeted multiplication facts. During each mathematics lesson in their regular classroom, students were instructed to get their assigned FLY™ Pen and then use the pentop computer to solve the multiplication problems assigned for that day. Typical assignments included teacher made worksheets or problems assigned from the students’ textbook. These assignments provided an opportunity for the students to write and solve multiplication problems using the large grid FLY™ Pen paper.

When using the FLY™ Pen for their multiplication problems, students were first prompted to tap “start” so that the pen would recognize that the student was writing a problem. Next, the student pressed “Start Problem” in the FLY™ Control Panel tablet. As the student wrote the multiplication problem, the
software immediately repeated the numbers aloud. This allowed the student to hear what the FLY™ Pen interpreted from their writing. Students were then able to re-write the number if the FLY™ Pen misidentified a number or they were able to move on to the next step. After the pentop comptuer correctly recognized each number and operation (i.e., multiplication), students were prompted to confirm that the problem was correct and press the “Enter” button on the tablet. The student was then prompted to select “Yes” or “No” if the entire problem was read correctly. Additional assistance was provided only after the problem was read correctly and the student selected “Yes.”

As the students worked to solve the problems, they were required to complete the multiplication steps in the correct order, as specified by the FLY™ Pen, which allowed the software to recognize what the student had written. For example, when the problem involved the multiplication of two numbers, the student was first required to write the numbers in their answer from right-to-left placing the correct digit in the ones place prior to writing the number to be carried or before writing a number in the tens or hundreds place (i.e., When solving $12 \times 9$, first the student must multiply the 9 digit by the 2 digit and write the number eight or write the carried one before proceeding to write the zero in the tens place or the one in the hundreds place [$12 \times 9 = 108$]). As the student continued to solve the problem, the FLY™ Pen provided reinforcement (i.e., beeps) for correct responses, prompts for incorrect ones such as “switch your digits” or “remember to carry” hints, and page numbers for example problems in the Launch Pad. Once the student finished writing what they believed was the solution, the student tapped “Finish” and the pentop computer responded by indicating whether the solution was correct or incorrect. If the solution was incorrect, a specific hint about where the error was made was provided. For example, when solving $13 \times 4$ if the student put a 53 instead of a 52, a hint may have prompted the student to multiply $3 \times 4$ again.

During the intervention phase, students were required to use the FLY™ Pen and associated multiplication and division software for all multiplication problems. The materials used by the students during the intervention included the pen, multiplication and division software cartridge, earphones, FLY™ Pen Math paper, and the pen storage container. When each student started the intervention phase of the study, s/he was assigned a box with the study materials that were stored in a nearby cabinet for easy access during each math class.

Following their in-class practice with the pentop computer, students were then assessed on the multiplication facts acquired during instruction three or four per week. These assessments required the students to solve similar types of problems to what they had previously practiced; however, they were not allowed to use their FLY™ Pen during the assessment sessions. The assessment sessions included a random selection of five basic multiplication problems (single digits multiplied by single digits problems) and five mixed multiplication problems (double digit numbers multiplied by single digit numbers) for a total of ten problems per assessment. The percentage correct out of ten was calculated for each intervention session.

**Maintenance.** Following a minimum of a one week break from intervention, students completed a maintenance assessment in which their maintenance of the multiplication facts was determined. These assessments were conducted in the same format as the baseline and intervention assessments. Specifically, they included a random selection of five basic multiplication problems (single digits multiplied by single digits problems) and five mixed multiplication problems (double digit numbers multiplied by single digit numbers) for a total of ten problems per assessment. The percentage correct out of ten was calculated for each maintenance session.

**Social Validity**

Twice during this investigation—first following the pre-training phase and again after the intervention phase—students and their teacher were interviewed to determine the social validity of using FLY™ Pens for acquiring multiplication skills (see Table 2 for a list of the student and teacher pre and post social validity questions). Students and teachers were interviewed individually and were asked
about their likes and dislikes of the FLY™ Pen when learning multiplication. All students indicated that they liked the FLY™ Pen after using it during the pre-training phase. Additionally, all indicated that they liked that the pen gave audible hints about ways to solve math problems. After using the FLY™ Pen during the intervention phase, students indicated they enjoyed using it and felt it helped them learn their multiplication; however, there were some aspects of the tool that the students did not like. Specifically, Diane did not like using the pentop computer in front of the rest of the class because she believed it made her stand out and she was more comfortable using it in the separate room. Joe and Sam disliked that the FLY™ Pen required them to rewrite the multiplication problems on the FLY™ Pen paper. Typically, the teacher handed out worksheets with the problems already written on them so the students just had to solve the problems and not write them out. Both Joe and Sam felt that having to rewrite every problem slowed them down in completing their work.

When asked about her opinions of the FLY™ Pen, the teacher also expressed likes and dislikes about using it as an instructional

| TABLE 2 |
| Pre and Post Social Validity Questions |

| Student Interview Questions (pre intervention) |  |
| 1. What do you think about the FLY™ Pen? |  |
| 2. Do you think you will like using the FLY™ Pen to do your math or spelling? |  |
| 3. What do you like most about it? |  |
| 4. What do you like least about it? |  |
| 5. Do you think it is important to learn spelling or math skills? Why? |  |
| 6. How do you think the FLY™ Pen will help in learning spelling or math? |  |

| Student Interview Questions (post intervention) |  |
| 1. Did you like using the FLY™ Pen? |  |
| 2. Did the FLY™ Pen help you to learn writing skills? |  |
| a. If it did, how do you think it helped? |  |
| b. If it did not, why do you think it did not? |  |
| 3. What did you like most about the FLY™ Pen? |  |
| 4. What was the worst thing about the FLY™ Pen? |  |
| 5. Would you want your teacher to let you keep using the FLY™ Pen to do your writing? |  |
| 6. Would you like to use a FLY™ Pen for other school work like science or math? |  |
| 7. Would you like to use the FLY™ Pen in other classes? |  |
| 8. Did it help you learn? |  |

| Teacher Interview Questions (pre intervention) |  |
| 1. What do you think about the FLY™ Pen? |  |
| 2. Do you think the FLY™ Pen will assist students in acquiring and maintaining writing skills? |  |
| 3. What traits or characteristics of the FLY™ Pen do you think are useful in the learning process? |  |
| 4. Do you think that using the FLY™ Pen and its software will allow you as the teacher to be more efficient and effective in teaching? |  |
| 5. What are your concerns about using the FLY™ Pen with students for writing activities? |  |
| 6. What benefits do you foresee in using the FLY™ Pen for instruction? |  |
| 7. Do you think the FLY™ Pen is something you would use often with students? |  |

| Teacher Interview Questions (post intervention) |  |
| 1. Did you like the FLY™ Pen? |  |
| 2. Do you think it was helpful in teaching students writing skills? |  |
| 3. Do you think it was better, worse, or equivalent to traditional instruction? Why? |  |
| 4. What did you like most and least about the FLY™ Pen? |  |
| 5. What did you like most and least about the FLY™ Pen software? |  |
| 6. Would you use the FLY™ Pen again? |  |
| 7. Would you consider using the FLY™ Pen to teach or reinforce other academic skills if software were available? |  |
tool. Prior to the intervention, she believed that the pen would help the students learn multiplication because it provided audible hints and feedback to the students which she felt would help engage the students and be more fun. Following intervention, she believed that using the pen was helpful, particularly for Diane. She also stated that it did slow the students down in completing their work. Overall, the students and the teacher felt that using the FLY™ Pens was beneficial for learning multiplication.

Reliability

Interobserver agreement data were collected by a trained second observer. For Diane and Sam, reliability data were collected for 40% of the baseline sessions, 43% of the intervention sessions, and 50% of the maintenance sessions. For Joe, reliability data were collected for 43% of the baseline sessions, 43% of the intervention sessions, and 50% of the maintenance sessions. Interobserver agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements of the number of problems solved correctly and then multiplying this number by 100. Agreement was 100% for all three students in each of the phases of the study. When given the assessments, the students were asked to write each problem and answer legibly. These instructions helped ensure clarity in the students’ writing; thus, the second observer did not find any errors in the calculations conducted by the primary observer.

Treatment Integrity

A checklist was developed to assess treatment integrity during the intervention phase. The checklist included three steps to ensure that the teacher was instructing the students to use the FLY™ Pen to practice solving their multiplication problems in their mathematics class. Treatment integrity data were collected during 44% of the observations for Diane, 53% of the observations for Joe, and 66% of the observations for Sam. During each observation in which treatment integrity data were collected, the researcher assessed whether the teacher implemented each step as indicated. For Diane, treatment integrity was 100% for all of the sessions observed, for Joe, treatment integrity was 96%, and for Sam the treatment integrity was 100%. For Joe, the treatment integrity was lower because the teacher forgot to prompt Joe to get his FLY™ Pen and he had to be reminded by the researcher to get his pen. The teacher corrected this oversight during subsequent sessions.

Results

Results indicate that students demonstrated increases in the percentage of multiplication problems solved correctly from baseline. Each student showed relevant gains in correct performance between baseline and intervention and baseline and maintenance conditions. Figure 1 illustrates the percent of multiplication problems solved correctly while using the FLY™ Pen during each of the study conditions.

Diane

During Diane’s baseline, the mean percent of problems solved correctly was 11.4%. A visual analysis of data demonstrate that there was a considerable increase in the number of problems solved correctly during intervention with a mean performance score of 62.9%. The percentage of non-overlapping data between the baseline phase and intervention phase was 100% indicating that the intervention was effective for Diane. Similarly, the maintenance mean (75%) increased from both the baseline and intervention means. Additionally, the percentage of non-overlapping data between the baseline phase and maintenance phase was 100% showing that the results of the intervention were able to be maintained over time.

Joe

Joe’s mean percent of problems solved correctly during baseline was 30.6%. During intervention, he achieved a mean of 50.0%, indicating an increase over baseline levels. His mean performance score during the maintenance condition decreased slightly to 45%. Visual analysis indicated some variability in Joe’s performance; however, he did demonstrate a rapid increase in the number of problems solved correctly when the intervention
Figure 1. Percent of multiplication problems solved correctly for Diane, Joe, and Sam when using the FLYPen as a mathematical instructional tool.
was first introduced. Specifically, when comparing the last two sessions of at the end of the baseline phase and the first two sessions at the beginning of the intervention phase, there was an increase from 14.3% of the problems being solved correctly to 50% of the problems being solved correctly (an increase of 35.7%) indicating an immediate change of level for Joe.

Sam

During Sam’s baseline, the mean percent of problems solved correctly was 48.6%. The mean during the intervention phase was 74.3%, indicating an increase in the overall problems solved correctly. The mean for Sam’s maintenance phase was 70.0%, suggesting a slight decrease in the problems Sam solved correctly once the intervention ended. Visual analysis indicated that Sam demonstrated a high variability of performance during the baseline phase; however, less variability was observed during intervention. Additionally, the median for the baseline phase was 28.6% of the problems solved correctly and the median for the intervention phase is 100% of the problems solved correctly signifying an increase in the level during the intervention phase. There was also a rapid increase observed between the last session of baseline where the assessment score was 14.3% solved correctly and the first session of the intervention phase where the assessment score was 50.0% (increase of 35.7%), which reveals an immediate change of level.

Discussion

The purpose of this study was to examine the effectiveness of the FLY™ Pen when used as a mathematical instructional tool for students with mild intellectual disabilities. The results indicate an increase in students’ assessment scores on multiplication facts during the intervention phase; however, the extent of these results was variable among the students. The results suggest that all three participants experienced an immediate increase in the percentage of problems solved correctly when they initially began using the FLY™ Pen. These results support previous research that found technology may be beneficial when used to teach math skills to students with mild intellectual disabilities (Horton et al., 1992; Jaspers & Van Lieshout, 1994; Masteropieri et al., 1997).

Dihoff, Brosvic, Epstein, and Cook (2005) examined the improvement of mathematics abilities of students with mild disabilities. They found that students who received immediate feedback from an educator or from an Immediate Feedback Assessment Technique (IFAT) on mathematical assessments demonstrated reductions in errors and a greater retention of the material. The FLY™ Pen similarly provides students with immediate feedback through its beeps (indicating a correct number or answer was written) or prompts indicating an incorrect answer (i.e., the pen saying “not there yet, there’s more to do”). Dihoff et al. called for an instrument that can be used by students with disabilities that can not only assess correct answers but also provide feedback and correct misunderstandings of material. The audible output provided by the FLY™ Pen does this through the feedback given when a student answers a question incorrectly. The prompts assist students in identifying where errors are made and allow them to continue working on solving problems until a correct answer is obtained. A teacher who is working individually with a student typically would provide this type of one-on-one feedback. Since the pentop computer can provide this feedback instead, this may help to decrease the amount of time teachers spend working one-on-one with students.

While the FLY™ Pen does provide immediate feedback, there was variability in the students’ assessment scores and responses to the intervention. Diane, who expressed a dislike for using the technology in front of her classmates, demonstrated the most significant changes in her assessment scores during the intervention and maintenance phases. When Diane expressed discomfort in using the pentop computer in front of her classmates, she was accommodated by being allowed to use the FLY™ Pen in a separate room across the hall. Diane expressed an increase in motivation for learning her multiplication facts after using the FLY™ Pen. Although allowed to use a multiplication table (in addition to the FLY™ Pen) for her work, Diane tended to only use the FLY™ Pen. Following the inter-
vention phase, the teacher indicated that Diane received 100% on her daily timed tests. Diane tended to want to please her teachers and this motivation to demonstrate continuous improvements in her classroom assessments may have influenced her maintenance results. Diane had the longest break between the end of her intervention phase and the maintenance phase; however, of the three students, she received the highest average percent correct during the maintenance phase.

Joe’s variability in his assessments has a variety of possible explanations. Joe expressed dislike in having to rewrite the multiplication problems on the FLY™ Pen paper and experienced difficulty with his basic multiplication facts. In addition to using the FLY™ Pen, Joe also relied on using his multiplication tables when completing his mathematics worksheets in class. Joe was encouraged to only use the pentop computer and not the multiplication table; however, Joe was not always able to fully comprehend the auditory prompts provided by the FLY™ Pen resulting in him becoming frustrated with the tool. He would repeatedly tap the hint button to try to get different hints from the pen and then ultimately ask if he could use his table. Joe also had a secondary diagnosis of a communication disorder and this may have impacted his ability to accurately comprehend certain prompts provided by the pentop computer. Joe’s reliance on using the multiplication table and dislike of rewriting the problems possibly contributed to the variability of Joe’s assessment scores. The decreases in scores observed during Joe’s maintenance phase indicate a lack of retention in his ability to solve the multiplication facts. Additionally, the assessment during the maintenance phase where Joe scored 20%, although randomly drawn, included a majority of higher digit problems (problems with 7s, 8s, and 9s in them). These are the type of problems with which Joe tended to struggle and he would typically rely on his multiplication table to solve. The multiplication tables were not allowed to be used by students during the assessments conducted and this was possibly a factor in Joe’s low score.

Of the participants, Sam seemed to enjoy using the pen the most. However, like Joe, he expressed a dislike in having to rewrite every problem on the FLY™ Pen paper. During the intervention phase, there was less variability in Sam’s scores and this may be a reflection of Sam’s enjoyment in using the pentop computer. During one of the intervention assessments, Sam indicated that he was having a difficult time and even said, “I wish I had my FLY™ Pen, this is hard.” One notable finding was that Sam indicated he felt that sometimes the FLY™ Pen did not help him learn multiplication because, on occasion, it would just give him the answer. This made him not have to think about solving the problem because the pen would just say the answer without requiring the student to attempt to solve the problem. This would occur at times if a student continued to use the hint button before writing what they believed to be the answer down.

The results of this study have important implications for the use of smart toys in special education classrooms. The increased requirements for schools to demonstrate mathematical proficiency for all students, including those with disabilities, will continue to be an important topic in the field of special education (NCLB, 2002). One way to assist teachers and schools with this mandate may be through the use of assistive technology such as smart toys. This study found that there were gains made by all of the students in this study; however, these variable results may warrant teacher discretion when considering using a pentop computer as an assistive technology intervention, particularly if they have limited funds to spend on classroom supplies. Many smart toys can be rather expensive; the cost of the FLY™ Pen itself tends to be around $80 per pentop computer with an additional cost of $15–30 per software.

**Limitations and Future Directions**

One of the limitations in this study is that only three of the students in the classroom served as participants. If all of the students in the class were able to participate, the students who participated may have reported different perceptions of the FLY™ Pen. Specifically, Diane may not have felt like she stood out as much if all of the students in the class had been using the tool. Also, if all of the students were required to use the FLY™ Pen, Joe and Sam may not have felt like they were being slowed down
because all of the students would be required to rewrite the multiplication problems on the FLY™ Pen paper. Additionally, the teacher indicated that one dislike she had with using the technology was that she always had to remind the students to use their pentop computer. If all of the students in the class were able to use a FLY™ Pen then it was easier for the teacher to remind all of the students at once, instead of individual students. For this study, only three students in the classroom were selected as participants due to these students having the same disability classification and a similar math level; however, future studies may seek to examine the effects of using the FLY™ Pens in a classroom where all of the students have access to using the pens. Another limitation was the student’s access to using multiplication tables during the intervention phase. Future studies may want to examine the effect of the FLY™ Pens for learning multiplication with students who do not use multiplication tables as part of the class.

Future replication studies should be conducted to better assess the effects of the FLY™ Pen as an instructional tool in the area of mathematics for students with mild intellectual disabilities as well as for students with other types of disabilities. Only one student in the current study had a secondary disability (communication disorder), and it would be of interest to examine the effectiveness of FLY™ Pens between groups of students with different types of disabilities. Furthermore, LeapFrog developed a variety of software that can also be used as instructional tools with the FLY™ Pens. Future studies may want to examine how the FLY™ Pen can provide assistance in other academic areas or mathematical content areas for students with disabilities (i.e., spelling, writing, algebra, Spanish). In addition to future studies that focus on students with disabilities, it would be of interest to examine how this type of technology might be useful for students without disabilities in general education settings.

References


