Abstract: The effects of a fluency building math program on addition and subtraction computational skills were evaluated using a multiple probe across subjects design. Two students with developmental disabilities and one student with attentional difficulties participated in a supplemental intervention using the Great Leaps Math program. Analyses indicated all three students made gains in oral fluency of math facts, and one student made progress in written fluency and written fluency generalization as well. Results are discussed within the context of differential rates of student progress, graphing student progress, and changes in student academic and social behavior with implications for practice and future research.

The understanding and use of mathematics has implications for an individual on practical, civic, recreational, and professional levels (Bos & Vaughn, 1998; Mercer & Mercer, 1998). Mathematical knowledge is used daily to perform practical tasks such as developing a budget, calculating salary, and paying bills. As citizens, individuals apply mathematical concepts to interpret civic information related to public issues (e.g., taxation, health issues, and crime statistics). At a recreational level, mathematics may be used when participating in games requiring strategy or solving puzzles. Finally, mathematical knowledge and skills are needed to obtain and maintain employment on most jobs.

Unfortunately, while mathematics is important to individuals on numerous levels, it is estimated that 5-8% of school-age students have math disabilities (Geary, 2004). Much of their math difficulties are with recalling and using basic facts. Students who do not master foundational addition and subtraction skills in first and second grade, are then at a disadvantage when attempting to learn multiplication and division as well as more complex skills. In fact, Cawley and Miller (1989) suggest that elementary aged students with learning problems typically function at the first grade level for basic math facts. In addition, older students with learning problems typically make minimal progress each school year in basic math computation, especially if the foundational math facts are missing (Cawley, Parmar, Yan, & Miller, 1998). For these students, this can negatively affect not only their school mathematical performance but also their attitude toward math (Miller, Butler, & Lee, 1998).

Being fluent in math is essential if students are to be successful in school. According to Houchins, Shippen, and Flores (2004), mathematical fluency is the “effortless and auto-
matic ability to perform math operations” (p. 331). Mathematical fluency of basic facts involves both the rate (speed) and accuracy at which students answer problems (Rhymer, Dittmer, Skinner, & Jackson, 2000). A student who demonstrates math fluency makes high numbers of computations with few to no errors within a specified amount of time (e.g., one minute). In fact, basic math fact fluency is a significant predictor for future complex problem solving (e.g., word problems) (Zettall & Ferkis, 1993).

As the mathematical demands of the general education curriculum increases so does the assumption that the student can perform already learned math skills as a means to solve more complex problems. However, this assumption may negatively affect student performance in that students who cannot perform basic math skills fluently may have more difficulties performing more complex problems accurately and within an appropriate amount of time (Houchins et al., 2004). For example, a student who cannot fluently compute basic math facts but is expected to solve long division problems with borrowing may not perform as well as or as quickly as a student who can perform the basic math facts fluently. Such performance has implications for both mathematical instruction and student performance.

For students with developmental disabilities, becoming fluent in math computational skills is particularly difficult. Researchers suggest that students with developmental disabilities benefit from math instruction that is explicit, has sufficient drill-and-practice, and provides frequent corrective feedback (Butler, Miller, Kit-hung, & Pierce, 2001; Kroesbergen & Van Luit, 2003; Mastropieri, Bakken, & Scruggs, 1991). Specifically, researchers have suggested that using a concrete-representational-abstract (CRA) teaching method, one-minute time trials, and peer-tutoring all have the potential to improve the computational skills of students.

Morin and Miller (1998) examined the effectiveness of teaching multiplication facts using the concrete-representational-abstract (CRA) method in conjunction with a mnemonic strategy with three middle school students using a multiple baseline design. Results indicate students mastered basic multiplication computation skills. Constant Time Delay (CTD) also has been shown to be effective in teaching math computation to students with developmental disabilities. Constant time delay is a controlled, data-based method of using flashcards to instruct students. Whalen, Schuster, and Hemmeter (1996) demonstrated the use of CTD with the acquisition and maintenance of addition facts with two elementary students using a multiple probe design. Students mastered basic addition facts and recalled all the facts 22 weeks after instruction. Mattingly and Bott (1990) also demonstrated the use of CTD to teach two elementary students 30 multiplication facts using a multiple probe design. Students mastered and generalized the facts over time.

Researchers have used time as a factor to improve students’ math computational skills. Miller, Hall, and Heward (1995) demonstrated the effectiveness of one-minute time trials using an ABABC design. Eleven elementary students with developmental disabilities increased their math facts fluency when they used one-minute trials with self-correction and immediate feedback as compared to 10-minute work sessions. Instruction was considered to be both effective and efficient.

Researchers also have used peer tutoring. Harper, Mallette, Maheady, Bentley, and Moore (1995) studied the use of class-wide peer tutoring with three elementary students over a 10-week period to develop subtraction computational skills using an alternating treatment design. Peer tutoring was effective in increasing students’ accuracy, short-term retention, long-term retention, and rate of responding with basic subtraction facts. Fasko (1994) examined the use of peer tutoring to improve the multiplication fact retention of two elementary students using a multiple baseline design. Peers who were proficient in multiplication facts provided tutoring involving immediate feedback, praise, and drill-and-practice. Overall, the students with developmental disabilities increased their recall of multiplication facts.

Fluently being able to understand and use mathematics in everyday life is a critical skill. As such, a supplemental math program, Great Leaps Math (Mercer, Mercer, & Campbell, 2000), focused on basic addition, subtraction, multiplication, and division facts has been cre-
ated as a means to provide students with fluency difficulties instruction and corrective feedback. The purpose of the study was to determine if the Great Leaps Math Program (Mercer et al.) would positively effect the basic addition and subtraction fluency of facts for three elementary students with developmental disabilities and attentional difficulties.

Method

Participants and Setting

Three students were selected to participate in this study based on their common educational math goals: (a) to be engaged in and to pass the general education math curriculum; (b) to minimize math skill discrepancies (e.g., building mathematical foundation skills) between them and their same-age peers; (c) to teach and reinforce more efficient math strategy usage; and (d) to move from the acquisition stage of learning to the fluency stage with regards to basic math facts. Each student also had Individual Education Plan math calculation and fluency long- and short-term objectives. In addition to math instruction received as part of the general education curriculum, these students received additional math instruction in a resource classroom in a rural Southeastern elementary school. Sam was an 8-year-old African-American third grade student with developmental delays and attentional difficulties. On the Learning Accomplishment Profile that tested matching and counting skills, he scored a 76 (5th percentile). Bridget was a 7-year-old second grade Caucasian student with ADHD. On the Woodcock-Johnson Achievement Test, she had an age-equivalent score of 6-1 (47th percentile) for broad math, 5-11 (37th percentile) for math calculations, 5-3 (14th percentile) for math reasoning, and 3 (27th percentile) for math fluency. Carrie was an 8-year-old third grade Caucasian student with developmental delays. On the Batelle, she scored at the 1% rank in the areas of reasoning and academic skills, memory, conceptual development, and perceptual discrimination; all noted as significantly below average.

Materials

Materials (math worksheets) from the Great Leaps Math program (Mercer et al., 2000) were used. In addition, a count-down timer, graph paper, and highlighter were used to monitor student progress.

General Procedure

The Great Leaps Math program (Mercer et al., 2000) was a supplemental intervention used in addition to the daily math curriculum. Prior to beginning the intervention, each student was administered the Great Leaps Math Placement Test. The purpose of the placement test was to determine if the students had the necessary prerequisite skills for the program and where in the program each student would start. The prerequisite included the ability to count to 9 and to demonstrate an understanding of one-to-one object correspondence. Students were assessed using an addition and subtraction basic math fact worksheet with problems arranged vertically. Students were asked to write their responses to each problem on the worksheet within one minute. Based on the student’s age and the number of problems correct per minute, placement within the program was made. Each of the students met both the prerequisite skills and placed in the first lesson of the Great Leaps program.

Each Great Leaps session lasted from 5 to 7 minutes per participant and targeted single-digit addition and subtraction math facts. Sessions were conducted one-on-one at a table in the back of the classroom during flexible instructional time. At the end of each session, the student was administered a one minute fluency probe. A “leap” occurred when a student had at least 25 correct responses with no errors in one minute. As a student “leapt,” the probes increased in difficulty. In addition, all participants began with addition oral fluency, and then when “leaps” were made, moved to the next phase of the program (i.e., addition written fluency, addition written fluency generalization, and subtraction oral fluency probes).

Data Collection and Variables

Data were collected using a multiple-probe across students design (Tawney & Gast, 1984).
Data were collected on the number of correct and incorrect math responses each participant made within one minute probes. Once the student was prompted to begin, the teacher started the count-down timer and at the one-minute time, the teacher prompted the student to stop. A correct response was scored if the student independently answered the math prompt within 3 s. An incorrect response was scored if the student independently answered the math prompt incorrectly or if the student took more than 3 s to answer the prompt. If a student made a self-correction within the 3 s time period and it was correct, the response was coded as correct. Number of oral or written correct problems per minute was then graphed at the end of each session with the student assisting the teacher. If a “leap” was made, the student drew a yellow line on the graph indicating that a new probe would be administered at the next session.

Great Leaps Intervention

Baseline. During baseline, each student was shown 25 single-digit 0-9 addition facts in a random order and asked to say the sum within one minute. As students responded, the teacher put the flashcards the student answered correctly in one pile and those answered incorrectly in another pile.

Intervention. Each Great Leaps session followed the proscribed 5-step “GREAT” strategy. First, the teacher greeted the student and told the student the lesson was about to begin. At this time, the teacher explained what was expected of the student behaviorally (e.g., sit at their desk, to do their best work, and to focus on the task) and academically (e.g., oral versus written responses; addition versus subtraction facts). Second, the teacher reviewed the math facts presented in previous sessions and showed and discussed with the student their previous graphed performance data (i.e., corrects and incorrects). Third, the teacher taught the student by conducting a short-timed practice session, provided error correction, and used objects and/or drawings to clarify commonly missed problems. Fourth, the teacher administered the one-minute fluency probe. Finally, the teacher and student graphed the number of correct and incorrect responses made on the probe. The five phases of the Great Leaps program the students were provided with are described below.

Addition oral fluency. During this phase, the student was shown 25 single-digit 0-9 addition facts in a random order which were presented vertically. The student was asked to orally answer each prompt within a total timeframe of one minute.

Addition written fluency. During this phase, the student was given a worksheet with single-digit 0-9 addition facts in a random order which were presented vertically and a pencil. The student was prompted to respond (in writing) to as many problems as he/she could within one minute.

Addition written fluency generalization. During this phase, the student was given a worksheet with single-digit 0-9 addition facts in a random order which were presented both vertically and horizontally and a pencil. The student was prompted to respond (in writing) to as many problems as he/she could within one minute.

Subtraction oral fluency. During this phase, the student was shown 25 flashcards with single-digit 0-9 subtraction facts in a random order, which were presented vertically. The student was asked to orally answer each prompt within a total timeframe of one minute.

Interobserver Reliability

Interobserver reliability was calculated for 20% of the sessions. Independent variable reliability data were calculated by dividing the number of teacher behaviors exhibited by the number of planned teacher behaviors and multiplying by 100. The independent variable reliability data mean was 93% (range, 85 to 100). Dependent variable reliability were calculated by the point-by-point method in which the number of agreements were divided by the number of agreements plus disagreements and multiplied by 100. The dependent variable reliability data mean was 98% (range, 95 to 100).

Results

Figure 1 illustrates the correct problems per minute for each student as well as each “leap” made by the students. Sam successfully com-
completed the addition oral fluency, written fluency, and written fluency generalization phases of the Great Leaps program and began the subtraction oral fluency phase. Sam’s baseline mean was 22.6 correct problems per minute (CPPM) (range, 21 to 24). For five of
the seven oral fluency sessions, it took only one administration of the probe for Sam to make a “leap.” His mean for oral fluency during this phase was 36 CPPM (range, 20 to 43; a mean difference of 13.4 CPPM). Sam made three “leaps” during the written fluency phase and had a mean of 26 CPPM (range, 19 to 31). In the written generalization phase, he made two “leaps” with a mean of 25 CPPM. During the oral fluency phase for subtraction facts, Sam made two “leaps”; however, it took him an average of seven attempts prior to a “leap” and his mean was 20.3 CPPM (range, 15 to 27). Bridget successfully completed the oral fluency phase and began the written fluency phase of the program. Her baseline mean was 20.3 CPPM (range, 19 to 22). During the oral fluency phase, she made seven “leaps” with an average of two attempts per probe. Her mean was 22.8 CPPM (range, 18 to 31) for this phase. Bridget did not make a “leap” during any of the written fluency probes administered. Her mean was 14.42 CPPM (range, 11 to 18) for this phase. Carrie also successfully completed the oral fluency phase but not the written fluency phase. Her baseline mean was 20.75 CPPM (range, 20 to 22). She made a “leap” after the first or second administration for each probe during the oral fluency phase and had a mean of 30.56 CPPM (range, 25 to 47). During the written fluency phase, she made three leaps; however, each required multiple administrations. Her mean for this phase was 21.87 CPPM (range, 14 to 27).

Discussion

Results of this study suggest that the Great Leaps Math program positively affected mathematical fluency for two students with developmental disabilities and a student with attentional difficulties. All students showed the greatest fluency gains during the oral fluency of addition math facts phase. One student successfully completed the addition fluency portion of the program and began the subtraction portion while the remaining two students ended in the written additional fluency portion. Multiple observations about the student’s performance during the program were made.

One observation was that Bridgette and Carrie both required more administrations of probes prior to “leaps” being made, especially during the written fluency phase. This may be due to several reasons as supported by teacher observation and record reviews. First, both of these students were taught to use the Counting Dots strategy as a means to solve basic math facts. Although this strategy was appropriate for the acquisition of basic math fact computations, it negatively affected the student’s performance on timed tests. Both Bridget and Carrie were observed to use the Counting Dots strategy when new probes were given. Upon observing this behavior, the teacher prompted each student to respond (either orally or in written form) as quickly as they could to the presented math facts. Second, after long weekends or breaks in school Bridget appeared to have difficulty with probes in that she reverted to multiple time consuming strategies (e.g., Counting Dots, making hashmarks, counting with fingers) when presented with her probe. When providing instruction on the probes, the teacher prompted her to solve the problems as fast as she could within the one minute. Even with these teacher prompts, Bridget’s fluency slowed. The use of time-consuming strategies for solving basic math facts directly interferes with the fluency of such facts. It is important that once students acquire basic math facts, that the use of time-consuming strategies be faded. No such fading had occurred with these two students. Bridget, in particular, had the most difficulty with this transition and needed more opportunities prior to a “leap” being made.

A second observation was that Bridget continued to experience difficulties focusing on and maintaining her attention on the math tasks throughout the Great Leaps Math program. As part of her academic adaptations and accommodations outlined in her IEP as well as in addition to the second and third steps of the Great Leaps program, “warm-up” activities were used to assist her in preparing for task engagement. As such, her teacher provided her with several “practice” math facts (ones which were not part of the current probe and ones that she had successfully solved in the past) to orally solve in rapid succession and would praise her for her efforts prior to giving her the Great Leaps probe.
These additional “warm-up” activities appeared to be more effective during the oral fluency phase than in the written fluency phase. During the written fluency stage, Bridget’s teacher reported that task engagement was not consistent and interfered with her performance. Attentional difficulties during any of the sessions would negatively affect student fluency performance. For Bridget, her overall fluency for the written probes were below baseline levels. Future research could target the effects of additional strategies that address attentional difficulties when used with the Great Leaps Math program. Such a combination may be more effective for students like Bridget who present both mathematical fluency and attentional difficulties. In addition, future research could simultaneously measure social behaviors (e.g., on-task) to determine if the Great Leaps Math program also can positively affect such behaviors.

Third, all three students made few to no incorrect responses after the baseline condition. This means, that they may have attempted fewer problems overall but the problems they did answer were correct. As part of the Great Leaps Math program, the students assist in graphing their own progress at the end of each session. Previous research has shown the positive effects of graphing on student performance (e.g., Fuchs, Fuchs, Hamlett, & Whinnery, 1991). For these three students, the lack of errors may be an artifact of the graphing whereby each were visually motivated not to make errors since the focus of “leaping” is on the number of correct responses. Anecdotally, the students commented that each did not want to have to mark any mistakes on their graphs and that they wanted to make “leaps.” Future research may compare the effects on student errors of including versus not including the graphing portion of the Great Leaps Math program.

Several anecdotal observations were made by the teacher concerning student behavior. Prior to the implementation of the Great Leaps Math program, students’ behavior during math instruction was described as inappropriate (i.e., as off-task, distractible, aggressive, and unmotivated). As the students progressed through the Great Leaps Math program, the teacher reported improved behaviors during math instruction. For example, each of these students would enter the resource classroom asking to engage in Great Leaps or other math activities whereas before intervention, instructional time was lost due to teacher attempts to engage the students in math activities. In addition, the student’s academic skills and behaviors during math instruction in the general education classroom were reported to improve too. In fact, the general education teacher approached the special education teacher and wanted to know what “Great Leaps” was and to see if it would be appropriate for other students with math difficulties. Future research may want to measure student social behavior as well as academic behavior when Great Leaps Math is implemented to determine the effects on such behavior. In addition, generalization data on both student academic and social behaviors could be measured within the general education classroom to verify teacher anecdotal reports.

Results of this study should be interpreted with caution, as several limitations are evident. First, this study was conducted with a small number of students. Future research may focus on larger sample sizes and the effects of the Great Leaps Math program. Second, this study focused on elementary-aged students whose discrepancies in math performance as compared to their same aged peers may not be as great as that for older students with basic math fluency issues. Future research may want to extend its focus to older students with developmental disabilities who are performing multiple grade levels below their same aged peers in math fluency. Third, this study used the Great Leaps Math as a supplemental program in addition to the daily math instruction the students received in both the general education classroom and as part of their special education program. Thus, it is not clear if the Great Leaps Math program alone influenced the math fluency gains for these students or if it was a combination of all the math instruction they received. Observations from both the special and general education teachers suggest that the Great Leaps Math program had a positive effect on the student’s performance on math activities and their social behaviors.
(i.e., attention) during math instruction and activities; and such positive effect’s may have strengthened all math related instruction and skills. Future research may want to experimentally assess math fluency comparing the influence of the Great Leaps Math program when used in combination with other mathematical programs and when used as the primary program.

As the National Council of Teachers of Mathematics (2000) indicates, the fundamental goal of mathematics instruction is problem solving. Yet, if students are to progress toward more advanced mathematical levels and solve mathematical problems, it is essential that students be fluent with basic operations (Mercer & Mercer, 1998). Students with developmental disabilities who are not fluent with basic computational skills (i.e., addition, subtraction, multiplication, division) are at risk of never being given the opportunity to acquire more advanced problem-solving skills. This study suggests that students with developmental disabilities can increase both the rate and accuracy at which they use addition and subtraction facts. The use of the Great Leaps Math program provides teachers with another potential method of increasing the mathematical fluency of students with disabilities, enabling them to be better prepared to be successful in school and in life.

References


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