Effects of Self-Graphing and Goal Setting on the Math Fact Fluency of Students with Disabilities

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ABSTRACT

We evaluated the impact of goal setting and students' participation in graphing their own performance data on the rate of math fact calculations. Participants were 3 students with mild disabilities in the first and second grades; 2 of the 3 students were also identified with Attention-Deficit/ Hyperactivity Disorder (ADHD). They were taught to use Microsoft Excel® software to graph their rate of correct calculations when completing timed, independent practice sheets consisting of single-digit mathematics problems. Two students' rates of correct calculations nearly always met or exceeded the aim line established for their correct calculations. Additional interventions were required for the third student. Results are discussed in terms of implications and future directions for increasing the use of evaluation components in classrooms for students at risk for behavior disorders and academic failure.

Descriptors: Goal setting, math fluency, self-graphing

Many students with disabilities lack fluency in solving mathematical calculations using basic math facts (Garnett, 1992). Early difficulties in mathematics are often characterized by deficits in the ability to quickly recall basic math facts as well as delays in applying computation strategies (Jordan & Montani, 1997). These deficits in the automatic recall of basic math facts limit students' future success in higher order problem solving skills. With more emphasis on meaningful problem solving in math classrooms, the speed and accuracy with which computation problems are solved is important (Meltzer et al., 1996). As such, students would benefit if teachers focused on increasing math fact automaticity.

Several strategies have been evaluated to develop more fluent recall of basic math facts, including goal setting and performance feedback. Research suggests that performance feedback has a greater impact on student

achievement when performance data are visually displayed in the form of a graph and shown to students than when the data are simply recorded (Fuchs & Fuchs, 1986). A number of studies have demonstrated the benefits of providing students with graphic displays of their performance data when this type of feedback was implemented alone or as part of an intervention package (e.g., Carr & Punzo, 1993; DiGangi, Maag, & Rutherford, 1991; Gunter, Miller, & Venn, 2003; McDougall & Brady, 1998; Sutherland & Snyder, 2007).

For example, Coddington, Lewandowski, and Eckert (2005) demonstrated that performance feedback and student-selected goal setting were effective in increasing math fluency in students diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD). The participants also graphed their own performance data as part of the performance feedback. Therefore, students received both verbal and visual feedback related to goals that

they set and those set by their teachers. In light of these findings, Gunter and Denny (2004) expressed concern that data graphing is not widespread in classrooms, perhaps due to teachers perceiving the task of graphing as cumbersome. The authors suggested that teachers should involve students as active participants in evaluating their own performance to reduce the time and effort required.

Self-recording academic and social behavior performance data has been found to improve behavior in the absence of other intervention components (e.g., Studswell & Moxley, 1984) and provides the student with immediate feedback (Moxley, 1998). In Gunter et al. (2003), for example, a student with disabilities was taught to use computer software to graph her reading performance data. The authors suggested that further research on this strategy was warranted and that the best use of computerized self-graphing procedures might be to increase fluency of skills students

already have in their repertoire.

As such, the purpose of this study was to evaluate the impact of having students with mild disabilities participate in their own evaluative procedures by graphing their rate of correctly written solutions to basic mathematic calculations and comparing their performance to a goal set by the teacher. Based on the literature reviewed, one might expect students to benefit academically from the graphic display of their performance data. Furthermore, their participation could reduce the burden of daily graphing for teachers and result in more frequent use of this strategy.

Method

Participants

The participants were three female students, all of whom had been identified with a mild disability. Shannon was an 8-year, 6-month old student enrolled in the second grade. Because she had previously been retained in kindergarten and was unable to meet regular promotion criteria at the end of the first grade, she was placed in the second grade for the subsequent academic school year. Shannon had a diagnosis of ADHD and was receiving special education services as a student with mild intellectual disabilities. Her full-scale intelligence quotient (IQ) was 72, as measured by the *Wechsler Intelligence Scale for Children – Fourth Edition* (WISC-IV). Shannon's academic skills were found to be commensurate with her cognitive ability. She participated in a non-standard administration of her state achievement testing at the end of her first-grade academic school year. According to the results of this standardized assessment, Shannon's math skills did not meet the standards set for first-grade students. A weakness was noted in her ability to recall addition facts with sums to 18.

The second participant was a 7-year, 8-month old student who had been retained in the first grade. According to an initial psychoeducational evaluation, Mandy exhibited a significant developmental delay in the area of

communication with a standard score of 69 as measured by the *Test of Early Language Development, Third Edition* (TELD-3). Mandy's cognitive skills were found to be within normal limits as measured by the *Developmental Assessment of Young Children* (DAY-C). However, she was identified as a student with a significant developmental delay/learning disability, and she received specialized support in the areas of reading and math in her special education program. According to the results of a non-standard administration of the state achievement test, Mandy's math skills met the standard set for first-grade students. She demonstrated the ability to recall addition and subtraction problems with sums to 18, but she required more time than was allowed during a standard test administration.

The third participant, Dianna, was a 7-year, 2-month old student, retained in the first grade. She was identified with right hemiparesis, causing weakness on the right side of her body. Although this condition did not impede her ability to write and type, it did seem to affect her endurance with both of these motor activities; that is, she reported often that she was physically tired from writing and typing. This participant had a diagnosis of ADHD but was not receiving medication for the condition. Based on the results of an initial psychological evaluation, Dianna exhibited a significant developmental delay in the areas of communication and motor skills. Her cognitive skills were found to be within normal limits as measured by the *Battelle Developmental Inventory* (BDI). She received special education services for students with learning disabilities at her school; additionally, she received private physical and occupational therapy in the home. Dianna participated in a non-standard administration of the state achievement test. According to the results of this assessment, Dianna's overall performance in math met the standards for first grade; however, she did not meet the standard for number sense and numeration. Dianna was able to recall the sums to addition facts up

to 18 if provided additional time as well as paper and pencil with which to draw pictures to represent those facts.

Setting

Sessions were conducted in a special education resource classroom located in a public K-3 elementary school in the southeastern United States. The classroom was equipped with two student computers (standard Macintosh desktop computers), individual student desks, and a table used for small group instruction. All sessions were conducted during each participant's math instruction period. In addition to the participants, one other student was present; this student worked on academic skills and activities similar to those of the participants. The teacher worked with one participant at a time while the other students in the room (2 participants and 1 non-participant) were working independently.

Materials

During each session, students were administered sheets of 21.6 x 27.9 cm math worksheets consisting of 40 one-digit by one-digit numbers with sums from 0 to 18. Problems were arranged in rows across columns. Only addition facts mastered at an accuracy level of 80% or greater were included on the worksheets used to evaluate fluency of correctly calculated digits. To determine this accuracy level, each participant had the opportunity to answer calculations at least five times prior to the inclusion of any item on the fluency evaluation worksheet, with at least four of those five opportunities resulting in the correct response. Worksheets were constructed each day to ensure a random presentation of the problems by using the *Basic Facts Worksheet Factory* available from Schoolhouse Technologies at <http://www.schoolhousetechnologies.com/>. This program is downloadable at no cost. Problems were added to the problem bank to be included on math worksheets if students demonstrated 80% accuracy in their calculations of new material during separate practice sessions. The number of problems remained the same,

but the problems changed each day.

Response Measurement

After each student completed all problems on her assigned worksheet, the teacher checked each problem and circled any digit(s) that was calculated incorrectly; she then counted the total number of correct digits. All teacher-evaluated worksheets were maintained as permanent product records. Correct digits per minute was the dependent measure and was calculated by dividing the total number of correct digits by the total time required of the student to complete the worksheet. Single-digit numeral reversals were counted as correct responses as long as the intended numeral represented the correct digit.

Baseline

Participants were timed using a digital timer while completing their math facts worksheets. Participants were instructed to begin working only after their teacher provided the direction, "Please begin." The timer was started simultaneously with this direction. Each participant was instructed to raise her hand and put her pencil down as soon as all of the problems on the worksheet were completed. The students were timed until they finished. As soon as a participant completed the assigned worksheet, the teacher recorded the time on the back of that participant's worksheet. The teacher then immediately scored the worksheet, calculated the rate of correct digits per minute for each participant, and entered the performance data for each participant in a Microsoft Excel® spreadsheet. Neither verbal nor graphic feedback was provided to students during these sessions.

Self-Graphing with Goal Setting

An aim line (i.e., goal for each practice session across the entire academic year) was calculated for each participant prior to student participation in development of graphic displays of their performance data. The starting goal was determined by taking each participant's average rate of correct digits during baseline. The

goal for the end of the academic year was then established based upon rates suggested by Binder, Haughton, and Bateman (2002) for single-digit addition problems (70 to 100 correct digits per minute). Given the learning needs of the students, the lower parameter of the expected range was used.

Each student's aim line was superimposed onto her graph. To do this, all possible dates during which instruction would take place throughout the course of the school year were entered in cells on a row of a Microsoft Excel® spreadsheet. Data from the baseline sessions were entered into the cells below each corresponding date. Next, a graph was produced on the spreadsheet that contained the graphed baseline data points and the remainder of an empty graph with spaces for data points for each date of the school year to be graphed. The created aim line was placed on the part of the graph for which data were not entered. It started from a point representing the average of the baseline data points at the beginning of the first intervention phase to the level representing 70 correct digits per minute at the end of the graph area. Additional details about these procedures can be found in Gunter, Miller, Venn, Thomas, and House (2002).

Each participant's graph was saved as a Microsoft Excel® file. Not only can Excel® be used to produce graphs suitable for single-subject designs (Carr & Buckholder, 1998), it also provides the user with several options for customizing the graph. Graphs can be customized by selecting line and marker colors, as well as by selecting background pictures. Background pictures were selected by each participant.

Prior to the first intervention session, each participant received training on how to use the Excel® software program to enter rate data to plot points on her graph. During this training, the teacher explained the purpose of the aim line to each participant. Participants were encouraged to meet or exceed the aim line by increasing their daily correct digits per minute score. Students were

taught to open their Excel® programs, which were saved in individual student folders on the computer's desktop, enter the spreadsheet, find the empty cell corresponding with the date, enter the correct digits per minute score provided by the teacher, and press the "Enter" key to see the data point automatically entered onto the graph. The need to alternate between chart and spreadsheet screens was eliminated by embedding each participant's graph within her spreadsheet.

During the intervention, the procedures employed for the completion of the math worksheets were identical to those of baseline. However, at the completion of the worksheets, students were informed of their performance and allowed to graph their scores using the procedures taught on the training day. The teacher was available to assist each participant if necessary, as well as to ensure that the correct rate scores were entered under the correct days. Verbal praise was provided to participants when the data point was correctly entered and additionally if the data point met or exceeded the aim line. Participants also were allowed to change the background picture on the graph if all data points for the week were entered correctly.

Individualized Modifications

If a participant's progress was below the aim line for three consecutive sessions, instruction was adjusted. With this data-based decision making rule in place, the teacher made modifications in instruction as needed for Dianna. The decision was made to adjust instruction by reducing the number of practice problems from 40 to 20. This was done based on the teacher's observation that Dianna became fatigued before completing the 40-problem worksheet. She completed the remaining 20 problems later in the day but only graphed her performance for the first 20 problems. This resulted in an initial performance increase. However, three consecutive data points were below the aim line by the 29th session. Another instructional decision was made to

continue to present the practice problems in shorter sets as well as to provide an additional verbal reminder not to touch and count every single practice problem, which the teacher observed Dianna doing. The teacher hypothesized that the physical act of touching each problem was actually slowing the addition process. In addition, Dianna was provided 1 min of free time each day her data point for correct calculations met or exceeded the aim line. Although her performance continued to improve, she still did not consistently meet the aim line. Following the 37th session, in addition to all of the instructional changes previously described, Dianna was allowed to work in an individualized setting to reduce distractions. This modification resulted in an immediate increase in rate, but was followed by three additional data points below the aim line. After the 41st session, the number of problems in each practice session was reduced from 20 to 10 in addition to the other interventions. She completed the remaining 10 problems during a timed practice session later in the day but only graphed her correct responses for the first 10 problems. Again, this modification was made based on observations that Dianna became fatigued when completing the worksheets. However, it should be noted that, for the purposes of the evaluation, the results of the two daily practice sessions were combined to calculate the rate of correct digits per minute for all 20 problems. This was done to better compare the data from this phase to those in the previous phases (during which Dianna completed 20 problems).

Return to Baseline

Data entered during the second baseline condition were recorded by the teacher and seen only by the teacher. Each participant's graph was modified so she did not see data from the withdrawal period when intervention was reinstated.

Experimental Design

An ABAB design was simultaneously implemented for 2 of the 3 participants

to evaluate the effect of the intervention. The intention was to use the same design for Dianna; however, an AB design resulted due to the need to continually modify the intervention to improve the outcomes.

Procedural Integrity and Inter-rater Agreement

In order to verify that the researcher was faithfully following the procedures as written, a second observer collected intervention fidelity data. A special education teacher served as the second observer. This observer collected procedural integrity data during 20% of baseline sessions and 20% of the intervention sessions using a procedures checklist. Prior to the first session during which procedural integrity was assessed, the second observer was taught the various steps that were implemented. This observer participated in role-play sessions with the teacher to ensure that there were no questions regarding any of the steps followed. Data were collected on teacher behaviors such as accuracy of time monitoring and calculation of rate, as well as participant behavior such as entering the correct rate score into the computer (the checklist protocol is available from the second author). To compute the percentage of procedural fidelity, the total number of observed teacher behaviors was divided by the total number of behaviors possible. The mean procedural fidelity across observations was 99% (range, 92% to 100%).

Inter-rater agreement was assessed on 25% of each student's worksheets distributed evenly across conditions. Worksheets were independently scored by a second special education teacher trained in scoring procedures by the primary scorer prior to the onset of the study. Duplicated worksheets contained no information regarding the participant's name, date, or condition during which the worksheet was completed. Digit-by-digit agreement was assessed by counting the number of digits agreed upon as correct and incorrect and dividing the number of agreements by the number of agreements plus disagreements and then

multiplying by 100. Mean interobserver agreement across participants and conditions was 99.4% (range, 93% to 100%).

Results

The effects of the intervention on the students' correct digits per minute are shown in Figures 1 and 2. Shannon and Mandy showed a decreasing trend in performance during baseline (Figure 1). During the two phases of self-graphing with goal setting, Shannon and Mandy's performance met or exceeded the aim line on 25 of 30 (83%) and 27 of 30 (90%) occasions respectively.

Dianna's average rate of correct digits during the first baseline phase was 13 (Figure 2). Although there were several data points above the aim line when the intervention was implemented, her performance did not consistently improve until multiple modifications were made to the intervention. During the final phase, Dianna's rate scores increased to an average of 38 digits per minute.

Conclusions and Recommendations for Practitioners and Teachers

In part, the results support and extend earlier findings, indicating that performance feedback (in the form of self-graphing) and goal setting can improve students' fluency (e.g., Carr & Punzo, 1993; DiGangi et al., 1991; Gunter, et al, 2003; McDougall & Brady, 1998; Sutherland & Snyder, 2007). Anecdotally, the participants demonstrated genuine excitement when their data points met or exceeded the aim line and wanted the teacher to observe their progress. The students also expressed disappointment when they were denied the opportunity to graph their daily data during the reversal.

These results suggest that students with and without disabilities may benefit from the use of computerized applications that allow them to participate in their assessment procedures. Once teachers have been trained to use the computer generated graphics, little time is needed to allow student participation. Graphs

Figure 1. Rate of correct digits across conditions for Shannon and Mandy

Figure 2. Dianna's rate of correct digits across conditions (SG* = self-graphing/goal setting plus shorter sets; SG** = self-graphing/goal setting, shorter sets, verbal prompts not to touch and count all numerals, and 1 min of free time for meeting goal; SG*** = all previous modifications plus an individualized setting; SG**** = all previous modifications plus a reduced number of problems)

serve as a powerful visual means to document student progress on an ongoing basis and can be shared with parents and administrators. In addition, teachers can determine instantly if their instruction is working and make changes if needed. The intervention was less successful for Dianna, who required a number of modifications to the intervention. This case highlights the importance of using student performance to guide program development and intervention (Fuchs & Fuchs, 1986).

Although Dianna knew the answers to her math facts fluently when questioned orally, she appeared overly focused on forming her numbers perfectly when required to provide written responses. This delayed the completion of her practice problems. In addition, she appeared to become easily fatigued and often complained that her hand hurt, perhaps due to her right hemiparesis and fine motor delays. She was often distracted to the point that she had difficulty remaining seated and appeared to have difficulty remaining focused on the correct location on the worksheet. For example, she would often forget which problem she was working on and would lose valuable time finding her place. The additional intervention components were intended to improve her progress relative to her aim line; however, the various modifications make it difficult to determine what was responsible for the improvements in her performance. Additional research is needed to identify which students would benefit the most from self-graphing and goal setting.

The teacher's use of verbal praise when students' data met or exceeded the daily aim also may have contributed to the outcomes for all students. This factor should be controlled in future evaluations to better understand the sole impact of students graphing their own performance data. The following specific guidelines are recommended for practitioners and teachers:

- Use technology available in almost every classroom.
- Familiarize yourself with Microsoft

Excel® or other available graphing software.

- Have a paraprofessional, student worker or parent volunteer create an Excel® file for each academic subject for each student prior to beginning the intervention.
- Have students record only data that they will use for self-monitoring.
- Establish a specific time to evaluate graphic displays of performance.

Even if self-graphing alone does not positively impact student performance, it provides teachers with a graphic representation of the data to assist in program modifications.

Given the theoretical relationship between undesirable social behavior and academic responding (c.f., Gunter & Denny, 1998) and the academic achievement deficits of students identified with conditions such as ADHD and emotional and behavioral disorders (Kauffman, 2001), it seems prudent to intervene with unobtrusive methods as early as possible to prevent development of both the aberrant social and academic behaviors.

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Patricia Mills Figarola completed this study in partial fulfillment of the requirements of her Education Specialist degree at Valdosta State University. For further information, contact Patricia Figarola at pfigarola@gocats.org.