A Comparison of Three Instructional Methods for Teaching Math Skills to Secondary Students With Emotional/Behavioral Disorders

Glenna Billingsley, Brenda Scheuermann, and Jo Webber
Texas State University-San Marcos

ABSTRACT: The purpose of this study was to determine the most effective of three instructional methods for teaching mathematics to secondary students with emotional and behavioral disorders. A single-subject alternating-treatments research design was used to compare three instructional methods: direct teach, computer-assisted instruction, and a combination of both methods. Disability label, age, and IQ were related to learning outcomes. In addition, although the combined method was more effective for some learners, variables such as attendance and motivation, as well as IQ, comorbid conditions, age, and number of years spent in school, affected learning outcomes.

■ The educational prognosis for students receiving special education services for emotional and behavioral disabilities (EBD) is poor. Compared with other populations of students with disabilities, students with EBD have higher rates of academic failure, grade retention, absences, suspension, and dropping out of school (Kauffman, 2005; Wagner, Newman, Cameto, & Levine, 2006; Walker, Ramsey, & Gresham, 2004; Webber & Plotts, 2008). Given the 43% to 56% dropout rate for students with EBD (Landrum, Brubaker, Katsiyannis, & Archwamety, 2004), a high probability for a shortened educational experience, it is critical that these students receive effective educational programs with rigorous, research-based teaching practices as mandated by Public Law 107-110, the No Child Left Behind Act (NCLB). Furthermore, because school failure predicts dropout, careful attention to designing the most effective instructional environments for students with EBD may actually result in students remaining in school longer.

The NCLB and related state mandates to increase participation and accountability in mathematics by students with disabilities have spurred organizations such as the National Council of Teachers of Mathematics to consider ways in which these students can be accommodated in rigorous, higher-level math acquisition (National Council of Teachers of Mathematics, 2003). Yet, as Templeton, Neel, and Blood's (2008) meta-analysis of math intervention for students with EBD indicates, data to help teachers implement comprehensive math instruction for students with EBD are still lacking. These authors found only five studies in the past decade that focused on explicit mathematical instruction for this population.

The research base delineating effective instruction for students with EBD is limited, but generally consistent, indicating that direct, teacher-led, explicit instruction is most likely to produce desired learning and behavioral outcomes for students with EBD (Forness, Kavale, Blum, & Lloyd, 1997). Specifically, instruction for students with EBD should incorporate a direct teach or direct instruction approach that is explicit and clear, presents material in a structured and systematic fashion, provides daily review of previously learned concepts, provides sufficient supports in the early stages of learning, provides high levels of opportunities to respond to ensure maximum student engagement in learning activities, and provides repeated practice opportunities (Gunter, Hummel, & Venn, 1998; Martella, Nelson, & Marchand-Martella, 2003; Scott & Shearer-Lingo, 2002; Sutherland & Wehby, 2001; Yell, 2009). Academic instruction using a direct teach approach has been associated with increased academic gains for students with EBD (Gunter, Coutinho, & Cade, 2002; Pierce, Reid, & Epstein, 2004).

Today's teachers are urged to integrate technology into their lessons to enhance instructional presentation and increase student motivation. The use of computers for instruction, called computer-assisted instruction (CAI), is an appealing concept but has only minimal research support for students with learning and behavioral difficulties. Hughes and Maccini (1997) recommended CAI for improving math performance in students with learning disabilities, based on their review of research in this area, but whether CAI is an effective instructional medium for students with EBD remains to be seen.

Certainly, CAI has intuitive appeal, given the structure inherent in CAI, the fact that CAI software can incorporate effective instructional design principles, and the potential motivational aspects of CAI. In a study by Dawson, Venn, and Gunter (2000), computer-based reading models resulted in improved reading performance compared with a no-reading model condition. However, when the reading model was presented by the teacher, student results were higher than the computer-based approach. Therefore, it is necessary to evaluate the efficacy of computer-based instruction for students with EBD before making blanket recommendations for use with this population.

The present study was undertaken after students in a self-contained high school classroom for students with EBD were provided with a computer curriculum with which to provide instruction. The classroom teacher questioned the efficacy of using CAI with this population but found minimal research recommending its use. Given the significant cost of the computerized instructional system, and given the fact that NCLB and the Individuals with Disabilities Education Improvement Act require evidence-based practices, an evaluation of the efficacy of computer-based instruction was in order.

The purpose of this study was to determine the most effective of these three instructional methods for teaching mathematics to secondary students with EBD: (a) teacher-directed instruction (direct teach) as recommended in the literature, (b) CAI yet to be shown effective for students with EBD, and (c) a combination of these approaches. In addition, variables such as IQ, disability label, grade level, and age were analyzed for their impact on student learning.

Method

Participants and Setting

Participants included 10 special education students in Grades 9 to 11 whose behavioral needs necessitated intensive interventions. All of these students were served in a self-contained setting in an urban, public high school. *Table 1* provides demographic information for all participants. In addition to gender and ethnicity, the table provides age, enrolled grade level, and a measure of grade level equivalency (GLE) in math from the Woodcock-Johnson Psycho-Educational Battery (Woodcock & Johnson, 1977) for each student. The column titled *IDEA* denotes the disability by which the student qualified for special education under the Individuals with Disabilities Education Act (IDEA). Finally, IQ information is included where available; IQ information was unavailable for 2 students (Chad and Tyrene).

The first author served as the teacher of record for these students. This author is a certified special education teacher with more than 20 years of experience teaching students with EBD in self-contained, resource, and inclusion settings. To minimize the risk of internal validity errors, reliability checks were conducted by independent observers to ensure reliability of the dependent measures and fidelity of implementation of the instructional conditions.

Research Design

The study occurred in four phases. The first phase was the identification of 10 target math objectives that students did not master on the math subtests of the WRAT-3 and/or three curriculum-based quizzes covering the 10 objectives. The three curriculum-based quizzes served as a baseline measure. During the second phase, students from three special education classes were taught nine target math skills using three different instructional approaches. Each instructional condition was used for 1 week, to teach one target skill. The instructional condition for each group alternated randomly each week, resulting in students in each of the three groups being exposed to each instructional method three times. During the third phase, the best treatment phase, individual student scores for each condition were averaged, and the best treatment was determined to be the condition in which most participants overall had the highest mean score. The 10th math objective was taught to all classes using the best treatment method. The final phase was a postinstruction probe, which consisted of a curriculum-based quiz to determine mastery of the 10 target objectives.

TABLE 1
Student Demographic Information

Student	Gender	Ethnicity	Age (Years)	Grade	GLE	IDEA	IQ
Clay	M	W	17	11	6.0	TBI, LD	87 (WISC-III; 2/98)
Crane	M	W	17	11	11.8	ED, OHI, LD[a]	111 (WASI; 4/03)
Lupita	F	H	16	11	6.0	ED, LD	83 (WISC-II; 10/02)
Thaddeus	M	W	16	11	5.5	ED	101 (WISC-III; 10/02)
Manny	M	H	16	10	3.8	ED, LD[a]	92 (WISC-III; 5/00)
Bryan	M	H	16	9	6.0	ED, LD[a]	115 (KABC; 4/02)
Chad	M	W	16	10	4.8	ED	[b]
Junior	M	H	16	10	4.8	ED, LD[a]	84 (WISC-III; 12/02)
Tyrene	M	AA	15	10	6.2	ED	[c]
Hank	M	H	14	9	5.4	LD,[a] ED	102 (WISC-III; 3/01)

Note. Pseudonyms have been used in place of students' real names. Ethnicity abbreviations: H = Hispanic, W = White, AA = African American. IDEA abbreviations: ED = emotional disturbance; OHI = other health impairment; LD = learning disability; TBI = traumatic brain injury; WISC II = Wechsler Intelligence Scale for Children, 2nd edition; WISC III = Wechsler Intelligence Scale for Children, 3rd edition; WASI = Wechsler Abbreviated Scale of Intelligence; KABC = Kaufman Assessment Battery for Children.
[a]Students who are LD in areas other than mathematics.
[b]No testing available; examiner relied on teacher report as "very bright."
[c]No testing available; examiner reported "normal intelligence."

Response Measure

The dependent measure of math learning was teacher-constructed, curriculum-based assessments (CBAs) used across research conditions and as the postinstruction probe. First, students completed three different versions of a teacher-constructed, CBA to establish baseline levels of performance. The baseline versions of the quiz evaluated students' proficiency on nine selected math objectives linked to material that was taught during the 9 weeks of intervention, plus one additional objective that was covered during the best treatment phase. Each baseline measure consisted of 20 questions covering 10 math objectives, or two questions per objective. Students were provided one 55-min class period in which to complete each quiz. Calculators were not permitted at any time during the study, and the only assistance provided on quizzes was encouragement for students to put forth their best effort.

The independent variable in this study was the method of instructional delivery: direct teach, CAI, and a combination of those two methods. An alternating-treatments single-subject research design (ATD) was employed to determine which of the three instructional models was most effective for teaching mathematics to secondary students with EBD. According to Barlow and Hersen (1984), an ATD is one in which two or more treatments or conditions rapidly alternate to compare their effectiveness and is ideally suited to multiple-intervention comparisons when a withdrawal design is not appropriate.

Procedures

A behavior management system was in use during the study that reinforced compliance with classroom rules and participation. For appropriate behavior, students earned points with which they could purchase items from a classroom store. Furthermore, students lost privileges for inappropriate behavior.

Baseline

The first phase of the study served to establish a baseline, which included administration of the WRAT-3 and three curriculum-based measurements that covered 10 math objectives that the WRAT-3 assessment indicated most students had not mastered. The WRAT-3 was administered on the first day of the baseline phase of the study followed by three CBAs; students completed one baseline assessment per day.

Students' pretest results from the WRAT-3 were analyzed to identify specific skill areas that would become targets for instruction. This analysis was accomplished by first ordering the objectives reflected in skills assessed on the Written Arithmetic subtest. The ordering was done in terms of item difficulty and necessary prerequisite skills. The skill areas that the majority of students answered incorrectly were then targeted for instruction.

Ninety percent of the students incorrectly answered problems dealing with one- and two-digit division. Fifty percent were unable to simplify fractions, 90% were unable to add or subtract fractions without regrouping, and 100% were unable to subtract fractions requiring regrouping. No students were able to correctly solve problems requiring multiplication and division of fractions. Ninety percent were unable to correctly multiply decimals. Finally, no students were able to convert fractions, decimal, and percentages or determine the percent of a number. Hank did not get any of these questions correct; Crane got the most answers correct, but he missed 47% of them.

Based on this analysis, 10 math objectives were targeted for instruction. Those 10 objectives in the order they were taught were as follows: division with a one-digit divisor; division with a two-digit divisor; simplifying fractions to lowest terms; multiplication of fractions; division of fractions; addition and subtraction without borrowing of fractions; subtraction of fractions involving regrouping; multiplication of decimals; conversion of fractions, decimals, and percents; and finding percent of numbers.

Crane was the only student who correctly answered any problems involving fractions, but he missed some of the more basic, untargeted items including column addition and subtraction without borrowing. These were perhaps careless errors, typical of students with learning disabilities (LD) and attention deficit hyperactivity disorder, both conditions with which Crane had been diagnosed.

Training

The second phase, the intervention, provided each student exposure to each instructional modality three times over a period of 9 weeks. Interventions were randomly assigned across weeks for each of three math classes; all classes covered a common objective. For example, although students in all classes were learning to add fractions, students in the first- and sixth-period math classes were exposed to the direct teach approach, and students in the fourth-period math class were exposed to the OdysseyWare® CAI to facilitate their learning to add fractions. Each respective unit of instruction was designed to be covered within a period of 3 to 4 class days.

The following procedures used during the intervention phase were specific to the instructional condition and were rigidly followed.

Direct teach. The following direct teach components, as described by Scheuermann and Hall (2008), were used during the teacher-mediated instruction conditions. First, the designated math objective was written on the board each day. Second, the teacher introduced the lesson by connecting new material to prior learning, showing a correctly finished problem, and describing how the skill could be used in real-world applications. Third, the teacher presented the lesson in a variety of formats including lecture, modeling, and interaction with math manipulatives. Fourth, students practiced the skill by performing problems on the board or individual dry-erase response boards and were asked to verbally demonstrate the process or strategy for performing the work. Fifth, students completed additional problems on individual dry-erase response boards while the teacher checked for understanding and provided high levels of response opportunities. Finally, the teacher provided another example of the type of problem being studied and left that problem on the board before closing with a summary of the lesson, its relevance, and the importance for building a base for future learning. Following the direct teach portion of the lesson, students engaged in independent practice of the skill taught. The number of independent problems assigned matched the number of questions that were presented to students during CAI conditions for the sake of consistency. Further assistance in the form of additional explanation or a different strategy such as a flowchart was provided as needed.

Computer-assisted instruction. The following procedures were followed during times the class was using CAI. For this study, the software curriculum OdysseyWare® was used. OdysseyWare® is a multimedia-enhanced CAI curriculum published by Pathway Publishers® that includes diagnostic features; individualized, self-paced instruction; and teacher management utilities. After beginning-of-class procedures, students were dismissed to their assigned computers. Headphones were available, but students were reminded to use them only for listening to the instruction-related material. All activities and assignments for the week were listed on a chart posted in the room. Students went to the Odyssey menu, located their name, selected "Math," and participated in the assigned lessons. Although the OdysseyWare® curriculum offers prepared courses appropriate to a particular grade level, the lessons assigned for this study were customized based on specific objectives to be taught. The program's scope and sequence were used to create customized lessons and activities on a particular math objective at grade levels appropriate for each student. The module created for each objective was a broad sampling across grade levels and ranges of difficulty. Each module included an introductory lesson in which the skill was presented and four to six additional lessons for practice were provided. Students worked through the lessons and activities at their own pace, although a recommended schedule suggested the completion of 20 to 30 problems during a 50-min class period. Students were encouraged to work on OdysseyWare® independently. Those who became too frustrated were allowed to leave the computer for a brief break. Students were allowed to get tutoring from the teacher on problems similar to the ones on which they were working but not the exact problem. The teacher utilities on OdysseyWare® allow the teacher to set the level of feedback the student received. For students participating in CAI, immediate feedback as to the accuracy of the answer was provided. Incorrect problems recycled themselves until a mastery level of 100% was achieved. If students did not finish the assigned lessons by the end of the period, a completion grade was assigned. Omitted problems were counted as incorrect, just as they would on paper-pencil tasks.

Combination strategy. In the combination direct teach and CAI condition, students received direct instruction from the teacher on the assigned material. The direct teach components, as described previously, were used until time for independent practice. At this point, students were dismissed to their computers, where they were instructed as to which section of the OdysseyWare® program was to be used for the day. In this approach, students used the OdysseyWare® program as a textbook, with further explanations being offered by the teacher. For example, the teacher reviewed sample problems on the board or used interactive videos infused into OdysseyWare®. When needed, students were assisted at their computer, just as a teacher would assist students with a problem from a textbook. The utilities of the program were adjusted so that once a student entered the answer, it was immediately assessed, and missed problems did not cycle through again, as was the case during the CAI condition. Grades were taken just as grades would be taken from textbook problems or worksheets.

On Friday of each week, all treatment groups completed a teacher-made, criterion-referenced test relating to the specific objective covered during the week. If students were absent or refused to participate, they were allowed to retake intervention-phase quizzes until instruction began on the next objective. Regardless of instructional method, all students took the same pencil-paper quiz. Students' percentages of correct responses on this weekly quiz (dependent variable) were graphically displayed for each individual. Participating students' data from each class produced a unique data graph, resulting in 10 single-subject studies.

The instructional condition (or treatment) for each class alternated in a random sequence for each math objective. Each objective was presented for 1 week using a different instructional method for each class; then a new objective and new methodology were introduced. This means that students were exposed to each instructional method three times. Instruction continued in this manner for 9 weeks, with each group exposed to each methodology three times on various objectives. Week 10, during which students were taught the skill of finding the percent of a number, was part of the third phase, the best treatment phase.

The first-period class was taught simplifying fractions, division of fractions, and conversion of fractions, decimals, and percents using direct teach. This class was taught division with a two-digit divisor, multiplication of fractions, and subtraction of fractions involving regrouping with the CAI method. Finally, they were instructed in division with a one-digit divisor, addition and subtraction of fractions without regrouping, and multiplication of decimals using the combined method.

The fourth-period class was taught division with a one-digit divisor, multiplication of fractions, and addition and subtraction of fractions without regrouping using direct teach. They were taught division with a one-digit divisor, division of fractions, and subtraction of fractions involving regrouping using CAI. They were taught simplifying fractions, multiplication of decimals, and conversion of fractions, decimals, and percents using the combined method.

The sixth-period class was taught simplifying fractions, division of fractions, and subtraction of fractions involving regrouping using direct teach. They were taught division with a two-digit divisor, multiplication of fractions, and multiplication of decimals using CAI. Lastly, they were instructed in division with a one-digit divisor, addition and subtraction of fractions without regrouping, and conversion of fractions, decimals, and percents using the combined method.

Follow-up. The third phase provided instruction in one additional math objective using the modality data shown to be the most effective overall across students. The purpose for this best treatment phase, which followed the 9th week of the intervention, was to demonstrate the superior effectiveness of one condition over any other. This was determined by averaging scores for each condition. The best treatment was determined to be the condition in which most students overall had the highest mean score.

Following the baseline, intervention, and best treatment phases, a postinstruction probe was given to assess each student's progress compared with baseline. The postinstruction probe consisted of a teacher-made, curriculum-based 20-item assessment, similar to the ones used in the baseline phase.

Procedural Integrity and Observer Reliability

This study was implemented by the teacher who was also the researcher. To minimize the risk of internal validity errors, checks were conducted by independent observers to ensure scoring reliability on the dependent measures and fidelity of implementation of the instructional conditions.

The two special education department chairs at the campus served as the two observers. One was a former teacher with 5 years of experience teaching students with EBD; the other had 3 years of experience teaching math in resource settings. Observers' training was held prior to the beginning of the study where they were told about the nature of the study, their role in checking the fidelity of quiz grades, and assessing the presence of the critical components of each method.

The critical components of each instructional method were thoroughly explained and modeled. For evaluating fidelity of implementation of each of the instructional methods, observers were provided with a checklist of the critical components of the three types of instruction (see the appendix). As critical components were modeled, observers identified those components on these checklists. Finally, the two observers were provided a schedule of times during which study-related instruction would be occurring. The observers selected five occasions to conduct reliability checks; these observation times were not communicated to the researcher.

Scoring reliability on dependent measures was assessed by having one of the two observers score a random sampling of CBAs. The observer inspected 20% of the baseline quizzes and 25% of all intervention, best treatment, and posttest quizzes. Interobserver reliability for baseline measures was 100%, and checks of weekly quizzes during the intervention and follow-up phases yielded an agreement level of 95%.

During fidelity observations, each observer used his or her checklist to record those essential components that they observed during the period. There were 15 components for the direct teach method, 6 components for CAI, and 16 components for the combined method. The observers attended two sessions in which the combined method was in use, two sessions of direct teach, and one occasion when CAI was used. Thus, there were a total of 68 opportunities for agreement. The percentage of agreement for critical components of each method was calculated by dividing the total number of agreements by the total number of items on the checklist. The observers agreed on 64 of the 68 critical components, resulting in interobserver agreement of 94.1%. Agreement of 90% or higher is considered a reliable measure (Alberto & Troutman, 2006; Bailey & Burch, 2002). Next, the observers were instructed to determine which of the three methods was being used for instruction during the observation period by attending to activities occurring during the observation. They were able to correctly identify the instructional method being used in five out of five occasions, or 100%.

Data Analysis

The most common form of analysis for single-subject design is visual inspection to examine data paths for lack of overlap. The degree of differential effect produced by two or more different independent variables is determined by the amount of vertical difference between data paths (Cooper, Heron, & Heward, 2007). Furthermore, according to Parker, Vannest, and Brown (2009), determining effect size is a useful supplement to visual analysis. Thus, the effect size for each condition was computed using standard mean difference (SMD_{ALL}), the recommended method to complement visual analysis for single-subject research designs (Olive & Smith, 2005). To calculate (SMD_{ALL}), the baseline mean is subtracted from the mean of the intervention phase. This number is then divided by the standard deviation of the baseline scores. Because the intervention phase was composed of three instructional conditions, this resulted in three distinct calculations to attain an effect size for each condition. Lastly, the mean effect size for each condition overall was found by calculating the mean of all students' baseline scores, subtracting that from the mean for each condition across all students, and dividing by the standard deviation of all baseline scores.

Analysis of the CBAs followed the conventions of single-subject research designs. Quantitative analysis consisted of visual inspection of data to determine which method was most effective (i.e., high scores on quizzes) for mastery of math objectives. Students' individual quiz grades during baseline or intervention phases were calculated as a percentage of correct responses and graphed with each instructional condition plotted as a separate data path. The greater the separation of data points between data paths, the stronger the indication of differentiation of treatment. Descriptive statistics, including mean, mode, and variance, were calculated for individuals, groups, and overall to determine which method was associated with the highest scores, as well as to determine whether students exposed to a particular methodology for a particular objective received similar scores.

Results

Baseline

Results were calculated as the percentage of correct responses for each of the three CBAs used as baseline measures, as well as the mean of these assessments; scores ranged from 0% on all assessments to a passing score of 70% or higher. Clay's percentage scores for the baseline CBAs were 25%, 30%, and 15%, with a mean of 23%. Crane scored 70%, 80%, and 60%, with a mean of 70%. Lupita scored 5%, 0%, and 10%, with a mean of 5%. Thaddeus scored 0%, 5%, and 0%, with a mean of 2%. Manny scored 0% on all assessments; thus, his mean score was also 0%. Bryan scored 10% on the first assessment and 5% on the third assessment. He was absent and did not make up the second assessment, yielding an 8% mean. Chad scored 5% on the first assessment and 10% on the third assessment, yielding an 8% mean. Chad was absent and did not make up the second assessment. Hank scored 0%, 5%, and 5%, with a mean of 3%. Junior scored 5%, 0%, and 5%, with a mean of 3%. Finally, Tyrene scored 20%, 5%, and 0%, with a mean of 8%.

Each participant's individualized education plan (IEP) specified 70% as the mastery criteria for math skills. Only two students reached mastery on any of the skills assessed during the WRAT-3 pretest. Clay displayed mastery in multiplication of decimals and in conversion of fractions, decimals, and percents. However, he was unable to answer any questions involving fractions and only 25% of questions involving division on the CBA used for baseline. Crane demonstrated mastery in 6 of the 10 objectives: division of one- and two-digit divisors, addition and subtraction of fractions including those requiring regrouping, division of fractions, and conversion of fractions, decimals, and percents.

Intervention

Results of each student's performance on the CBAs for each treatment condition are presented in *Figures 1 and 2*. The graphs are presented in order by class period and descending order of age. Clay, Crane, Lupita, and Thaddeus were in first period. Manny was in fourth period, and Bryan, Chad, Junior, Tyrene, and Hank were in sixth period.

Absences and refusal to work resulted in a number of missing data points for most of the participants. Students were encouraged to make up missing quizzes, but they often lacked the motivation to do so. This was the case with Manny, Bryan, and Crane; each missed one intervention phase quiz and did not choose to make up the quiz despite

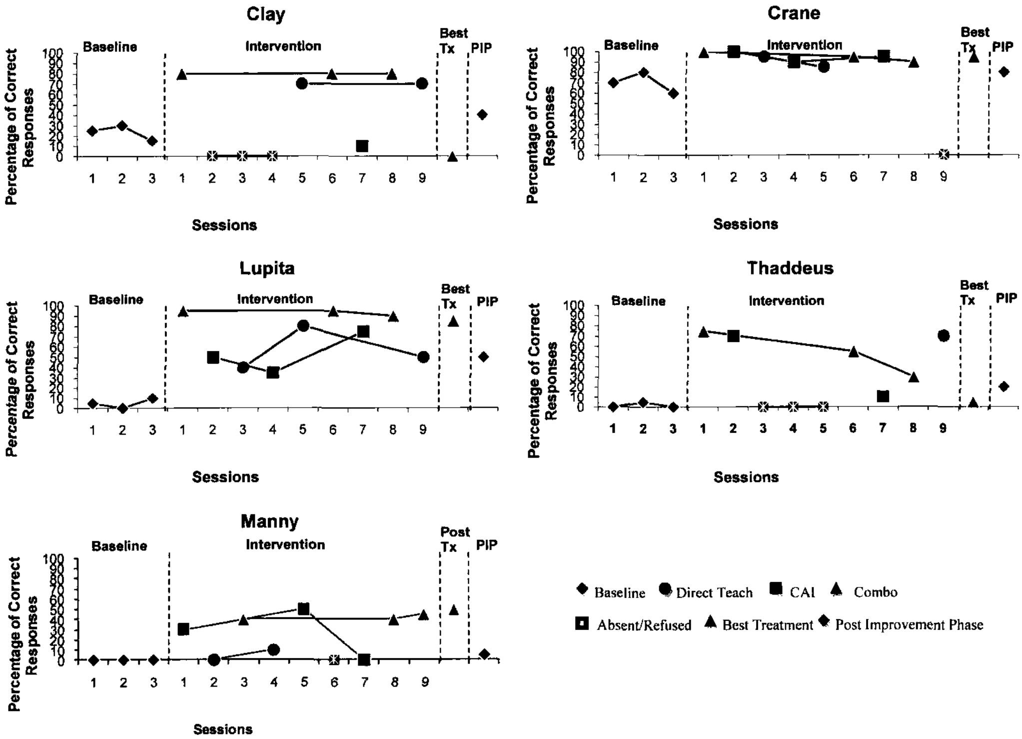

Figure 1.* *Percentage of correct responses for Clay, Crane, Lupita, Thaddeus, and Manny.

having the opportunity and incentive to do so. Clay missed 3 consecutive weeks of instruction and quizzes during this phase because he was expelled to a disciplinary alternative education placement. Furthermore, some students refused to work even though they were aware of behavioral consequences (e.g., loss of privileges) and academic consequences (e.g., lowered grades) that accompanied that choice. Tyrene had one episode of refusing to take an intervention phase quiz, whereas Thaddeus refused to take CBAs for 3 consecutive weeks.

Mean Scores for Conditions

Standard mean difference (SMD_{ALL}) was calculated by subtracting the mean of the baseline from the mean of each treatment condition and dividing by the standard deviation of the baseline values, as suggested by Olive and Smith (2005). Again, no one condition was clearly superior for all students. *Table 2* shows the mean score for each condition, as well as the effect size for all students across conditions. The effect size ranged from .83 to 1.00, except for Clay during the CAI method, where the mean of this intervention score was less than his baseline score, and Manny, whose baseline mean was 0, making calculation of (SMD_{ALL}) impossible. Thus, the various interventions did have a positive effect over baseline, but variables other than instructional conditions appeared to affect individual student performance.

None of the instructional conditions were clearly superior for all students, as evidenced by the fact that data paths for most students showed some degree of overlap across conditions. Likewise, effect size, which provided data identical to visual analysis, showed only that the intervention had a very high effect on student performance. One condition was not significantly superior to another.

When mean scores for each condition are considered, scores for the combined method were higher for five students (Clay, Lupita, Manny, Chad, and Hank). Two additional students (Crane and Bryan) had a mean that was highest for the combined method and one other method, CAI and direct teach, respectively. Thaddeus and Tyrene had a higher mean score during the direct teach method, and Junior had a higher mean score during the CAI method.

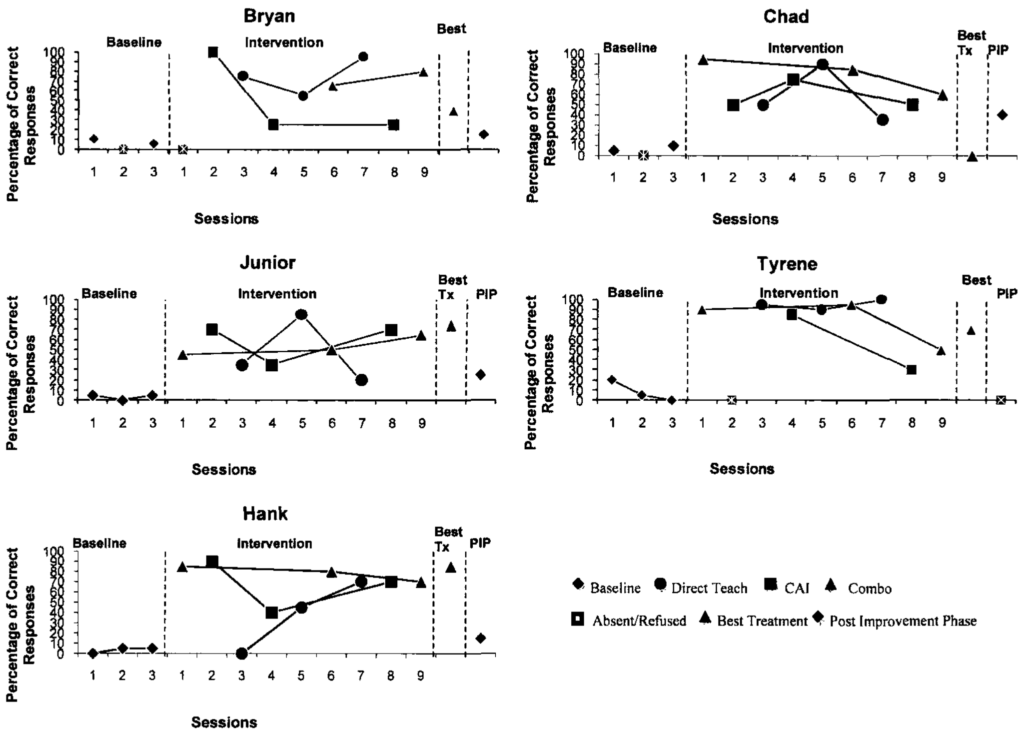

Figure 2. Percentage of Correct Responses for Bryan, Chad, Junior, Tyrene, and Hank.

A passing rate of at least 70%, the minimum standard required on each student's IEP, can also be considered a measure of practical significance. The mean score was passing during the direct teach method for 5 students (Clay, Crane, Thaddeus, Bryan, and Tyrene). Only Crane received passing scores during the CAI method; Junior scored highest during CAI but did not receive any passing scores. Clay, Crane, Lupita, Bryan, Chad, Hank, and Tyrene had an average score in the passing range when the combined method was used. Manny did not receive any passing grades on quizzes during any condition.

Direct teach. Direct teach appeared to be more effective for students with above-average IQ than for participants with lower cognitive levels. Although an IQ score was not available

TABLE 2
Mean Scores, Standard Deviation, and Effect Size (ES) for Each Instructional Condition

Student	Mean Direct Teach	Mean CAI	Mean Combination	Baseline Mean	SD	Direct Teach ES	CAI ES	Combination ES
Clay	70	10	80	23	6.24	.97	−.72	.98
Crane	90	95	95	70	8.16	.77	.83	.83
Lupita	60	53	93	5	4.08	.99	.99	1.00
Thaddeus	70	40	53	2	2.36	1.00	.99	1.00
Manny	5	27	42	0	0			
Bryan	73	50	73	8	2.5	1.00	.99	1.00
Chad	58	58	80	8	2.5	1.00	1.00	1.00
Junior	47	58	53	3	2.36	.99	1.00	1.00
Tyrene	95	58	78	8	8.5	.98	.95	.97
Hank	38	67	78	3	2.36	.99	1.00	1.00

for Tyrene, the examiner did state that he had average intelligence. Bryan had the highest IQ of all participants (115), and Thaddeus was in the average range with a score of 101. Bryan's quiz average for direct teach was the same as his mean average during the combined method, which exceeded his mean during the CAI method.

Furthermore, direct teach appeared to be more effective for students who were identified only as emotional disturbance. Thaddeus and Tyrene were the only students who qualified with the singular diagnosis of emotional disturbance. Both had a higher mean score and effect size for direct teach.

Computer-assisted instruction. Junior had a higher mean score on quizzes while using the CAI method. Although his average was not in the passing range, he did pass two of the quizzes during the CAI method. Crane scored the same for CAI and the combined method. Crane had a strong preference for the CAI method but received passing scores during all conditions.

Combined method. The combined method was clearly superior for 2 students (Clay and Lupita), the only students labeled emotional disturbance and LD in math calculation. With the exception of Junior, all students with a comorbid learning disability showed the combination method to be superior either by mean score for each condition or higher number of quizzes passed. Crane and Bryan scored equally well during the combined method as when another condition was being used. Chad's and Hank's averages for conditions were higher during the combined method, and they passed more quizzes during the combination method. Although Manny received no passing score during any condition, his quiz average was higher during the combined method.

The combined method seemed to be more suitable for younger learners as well. Students who had both higher mean scores and higher passing rates during only one condition (Lupita, Hank, and Chad) were younger than 16 years old and tended to have lower GLEs.

Effect size for all conditions. The following are the mean scores on quizzes following instruction in direct teach, CAI, and the combination method, respectively: Clay (70, 10, 80), Crane (90, 95, 95), Lupita (60, 53, 93), Thaddeus (70, 40, 53), Manny (5, 27, 42), Bryan (73, 50, 73), Chad (58, 58, 80), Junior (47, 58, 53), Tyrene (95, 58, 78), and Hank (38, 67, 78).

The total baseline mean was 13.0, and the standard deviation of the baseline scores was 19.94. The mean for each condition across all students was 60.6, 51.6, and 72.5 for direct teach, CAI, and the combined method, respectively. The resulting effect size was found to be .696 for CAI, .767 for direct teach, and .83 for the combined method. An effect size of .2 is generally considered a small effect size, .5 is considered to be a medium effect size, and .8 is considered to be a large effect size.

Best Treatment Phase

The best treatment phase is instituted in an alternating-treatments design to make a stronger case for the existence of a functional relationship (Alberto & Troutman, 2006). In the present study, the 10th math objective, concepts of percents, was taught using the combined method. The combined method was identified for the best treatment phase based on mean scores on CBAs, which were highest for the combined method for 7 of the 10 participants (Clay, Crane, Lupita, Manny, Bryan, Chad, and Hank). Because students within class periods could not logistically be taught using differing methods, the 10th objective was taught to all classes using the combined method.

Student scores on the CBA at the end of the best treatment phase were as follows: Clay, 0%; Crane, 95%; Lupita, 85%; Thaddeus, 5%; Manny, 50%; Bryan, 40%; Chad, 0%; Junior, 75%; Tyrene, 70%; and Hank, 85%.

Of those 7 students for whom the combination method produced the highest mean scores, 4 (Crane, Lupita, Manny, and Hank) scored within 10 points of that mean score on the 10th objective. For these students, performance was consistent with previous scores for this instructional method.

Clay and Chad, for whom the combined method had appeared more effective during the intervention phase, as evidenced by a higher mean score and as many or more passing scores during the combined method, did not correctly answer any questions on the quiz during the best treatment phase. Furthermore, Junior and Tyrene had a higher mean score during a condition other than the combined method, yet both received passing scores during this phase. In fact, Junior did not pass any quizzes during the intervention phase when the combined method was used.

The postinstruction probe, a teacher-made quiz similar to the baseline measures, was administered 2 weeks following the best treatment phase. *Table 3* provides a comparison of mean baseline scores for each student with scores on the postinstruction probe. All scores are reported as a percentage of correct responses.

All students who took the postinstruction probe demonstrated improvement over their baseline mean; however, only Crane achieved mastery level of at least 70%, as set forth in his IEP. In this study, methodological conditions were adhered to closely, and students were encouraged only to try their best. In routine classroom operations, a variety of strategies and alternative activities are used until a student demonstrates mastery over a concept.

TABLE 3
Comparison of Baseline Scores to Postinstruction Probe

Student	Baseline Mean	Postinstruction Probe	Percentage Increase
Clay	23	40	+73.9
Crane	70	80	+14.2
Lupita	5	50	+900
Thaddeus	1.7	20	+1,076.4
Manny	0	5	[a]
Bryan	7.5	15	+100
Chad	7.5	40	+433.3
Junior	3.3	25	+657.5
Tyrene	8.3	NA	NA
Hank	3.3	15	+354.5

Note. NA = not available due to absence.
[a]Percentage increase cannot be calculated because the baseline mean was zero.

Limitations and Implications for Future Research

Certain limitations of this study should be considered. Single-subject design results, particularly alternating-treatments design, can be affected by how rapidly the dependent variable responds to the intervention (in this case, performance on math quizzes) as well as how many times the intervention (each instructional method) is applied. In alternating treatments, the number of intervention occasions for each intervention is, by virtue of the design, reduced compared with other research designs. In addition, the time constraints of typical classrooms pose a challenge for researchers. For example, in this study, 1 week was lost to state testing, another week to spring vacation, and a few days to school holidays. Finally, the looming end to the school year prevented optimal application of the alternating-treatments design. Generally, in alternating-treatments design, conditions are alternated at least five times after clear differences have emerged. However, given the reality of the end-of-year schedule of this public school, it was not possible to do so. Ideally, future studies will allow for more exposure to each instructional condition.

In addition, this study involved measurement of acquisition of new learning in mathematics, which is most likely dependent on a cumulative effect of exposure to the intervention. Such an intervention may produce weak results after one application but stronger results after multiple, consecutive applications. Typically, acquisition of new skills, particularly in math, is the result of repeated exposure to instruction. The nature of the alternative treatments design, although useful for evaluating multiple interventions, may not be well suited for evaluating cumulative intervention effects.

Effect size data may also have been affected by the time constraints of the study. Barlow and Hersen (1984) recommend a minimum number of three data occasions per intervention to determine effect size. For this study, precisely three data points were prescribed for baseline and for exposure to each instructional method. These applications were calculated to fully encompass the entire semester of instructional days. However, only 3 of the study participants completed all prescribed data points for both baseline and intervention. Absences, suspensions, and refusals, all common characteristics of this population, reduced the number of data points to less than the recommended minimum, possibly compromising effect size calculations; thus, results should be cautiously considered. Although single-subject designs accommodate small sample sizes (Cooper et al., 2007), a study in an applied setting with this population may well present various real-life limitations, especially with regard to time and frequency of intervention occasions. Intervention schedules that allow for more frequent instructional applications might produce more robust effects. Planning for increased applications of each intervention may also address the problem of student data missing for behavioral, health, or other reasons.

Intervention randomization posed another limitation. Because of the small number of intervention occasions, it would have been better to randomize sequences of interventions and assign them to classes rather than randomizing the instructional method for each class. Subsequently, an identical sequence of interventions occurred for the first 6 weeks of the study, possibly resulting in a weaker research design. Future studies should address this limitation.

Experimenter bias may be considered a limitation because the teacher conducted her own interventions. However, the motivation for this study was this teacher's curiosity about which method would provide the best learning outcomes for her students, and the researcher had extensive experience and regard for all three instructional methodologies. To reduce this limitation, fidelity checks were conducted to monitor the teacher's adherence to correct practices for each method.

Finally, this study further illustrated the complex interaction of the presenting characteristics of students with EBD and learning. Comorbid conditions, IQ, age, and motivational factors seemed to affect results regardless of instructional method. The math performance results must also be considered in the context of multiple absences, suspensions, refusal to complete quizzes, and lack of motivation to perform. Future studies may want to address the interactions among instructional methods, student characteristics, and preferences for a particular method.

Conclusions and Implications for Best Practice

Despite limitations, the results of this study seem to support all of these interventions for teaching math to secondary students with EBD. However, no single treatment achieved best results for all the students. Therefore, we might assume that application of any one of these strategies across students with EBD will probably not achieve universal positive learning outcomes. Instead, as is the premise of special education, strategies should be chosen based on individual learning factors.

In this study, the combined CAI and direct teach model resulted in higher math quiz scores for 7 of the 10 students; the direct teach model resulted in better scores for 2 students, and 1 student learned better through the CAI-alone strategy. These results were also evident in mean quiz passing (70%) scores across all students (combined, 72.5; direct teach, 60.5; CAI, 51.6). Importantly, all students improved their math quiz scores with the alternating treatments; however, only 1 student achieved his targeted 70% mastery level. This failure to obtain mastery levels may not be a function of each treatment's potential effectiveness so much as the research design limitations, time constraints, and individual student variables.

Nevertheless, the combined method (large effect size = .83) for teaching math to secondary students with EBD seemed to result more often in better test performance than did the other two methods, although direct instruction (medium effect size = .767) and CAI (medium effect size = .696) also showed positive results. CAI is often popular with teachers because it reduces teacher preparation time and works well in self-contained settings where students work at multiple academic levels in a variety of coursework. CAI can also assist special education teachers to coordinate their instruction with general education content. However, teachers may do well to reconsider CAI as the sole source of instruction; instead, additional instruction and practice is recommended. Furthermore, students will have little opportunity to master critical social skills if they spend large amounts of time solely interacting with computers.

In sum, secondary teachers of students with EBD may find, as was found in this study, that any of these three instructional approaches will likely result in math content acquisition for their students given enough instruction over a period of time. However, we would caution teachers to resist generalized applications of any of the strategies. In this era of widespread placement of students with EBD into general education classes as a result of NCLB and IDEA 2004 mandates for grade-level testing and for highly qualified content teachers (Webber & Plotts, 2008), it is likely that these students may very well be exposed to singular instructional approaches. This study supports the notion that individualized determination for instructional interventions may serve students best. Finally, although the results of this study did not clearly identify a best method of instruction for teaching math to secondary students with EBD, it does illustrate that quality research can be conducted by practicing teachers by using a single-subject design. Results of such research can augment instructional outcomes as well as contribute to the sparse body of literature pertaining to effective academic instruction for this population.

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AUTHORS' NOTE

Address correspondence to Glenna Billingsley, Texas State University-San Marcos, Curriculum and Instruction, 601 University Dr., San Marcos, TX 78666. Phone: (512) 293-3402; Fax: (512) 245-3158; E-mail: gb28@txstate.edu.

MANUSCRIPT

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Appendix

Fidelity of Instructional Methods Checklist

Directions: Put a check mark by each element you observe. At the end, circle the instructional method you thought was in use during your observation.

Direct Teach

__ Students are verbally reminded and visually prompted with a chart stating the week's objective. (A chart that cannot be seen by observers will indicate which method a particular class will be using. This chart will list the activities and exercises for the day.)

__ Teacher reviews prior learning and ties this prior learning to today's lesson.

__ Teacher establishes relevancy by discussing real-world application.

__ Teacher introduces lesson by illustrating what a correctly finished problem will look like.

__ Teacher presents the lesson in a variety of formats including lecture, demonstrations, or manipulatives.

__ Teacher provides multiple opportunities for all students to respond to the learning.

__ Teacher verbally explains the process or strategy while simultaneously working the problem, then has students do the same.

__ Students practice the skill by performing problems on the board, individual dry-erase response boards, as the teacher solves problems on the board in a parallel manner.

__ Feedback is provided as students work through problems.

__ Students perform problems on individual dry-erase response boards while the teacher checks for accuracy and understanding.

__ The teacher closes the lesson with another example of the type of problem being studied that will be left on the board.

__ A summarization of the lesson and its importance provide closure.

__ Students practice the skill taught by completing a worksheet of approximately 20 problems.

__ Individual assistance is provided when a student asks for help. The teacher re-teaches where needed and has the student solve a question similar to the problematic one.

__ Completed work is turned into an assigned basket corresponding to the period number. Teacher grades work and records the grade in their individual folder.

Computer-Assisted Instruction

__ Students are verbally reminded and visually prompted with a chart stating the week's objective. (A chart that cannot be seen by observers will indicate which method a particular class will be using. This chart will list the computer activities and exercises relative to the week's objective that must be completed by the end of the week.)

__ Students are sent to their assigned computer stations.

__ Students log in, click on "Math," and participate in the assigned lessons and activities at their own pace.

__ When students have questions, they are encouraged to go back and study the information and videos that taught the skill. The teacher may assist the student in locating the answers to their problems, but they cannot reteach the information. Students are encouraged to participate in the Odyssey work independently.

__ Missed questions recycle at the end of the lesson until all questions are answered with 100% accuracy. Once they accomplish this, they announce that they are through, and the teacher comes and records their score in their individual folder.

__ Students continue to the next lesson until all lessons for the week are complete. (Students will have completed approximately 80 problems after a completed learning unit.)

Combination

__ Students are verbally reminded and visually prompted with a chart stating the week's objective. (A chart that cannot be seen by observers will indicate which method a particular class will be using. This chart will list the computer activities and exercises for the day.)

__ Teacher reviews prior learning and ties this prior learning to today's lesson.

__ Teacher establishes relevancy by discussing real-world application.

__ Teacher introduces lesson by illustrating what a correctly finished problem will look like.

__ Teacher presents the lesson using videos and explanations offered by the OdysseyWare® projected onto a screen. Teacher may also present lecture, manipulatives, or additional examples.

__ Teacher provides multiple opportunities for all students to respond to the learning.

__ Teacher verbally explains the process or strategy while simultaneously working the problem, then has the students do the same.

__ Students practice the skill by performing problems on the board, individual dry-erase response boards, as the teacher solves problems on the board in a parallel manner.

__ Feedback is provided as students work through problems.

__ Students perform problems on individual dry-erase response boards while the teacher checks for accuracy and understanding.

__ The teacher closes the lesson with another example of the type of problem being studied that will be left on the board.

__ A summarization of the lesson and its importance provide closure.

__ Students are sent to their assigned computer stations.

__ When students log in and click on "Math," the program takes them to a lesson where they begin completing approximately 20 problems.

__ Individual assistance is provided when a student asks for help. The teacher re-teaches where needed and has the student solve a question similar to the problematic one.

__ After students complete a problem, they submit their answer for grading. They announce that they are through, and the teacher comes and records their score in their individual folder.

Date:______________________________

Period:_____________________________

Circle the method you think was in place during your observation:

Direct Teach
Computer-Assisted Instruction
Combination