Multisensory Mathematics for Children With Mild Disabilities

Presented by

Kristen S. Scott

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Multisensory Mathematics for Children With Mild Disabilities

Kristin S. Scott
Department of Special Education
University of Georgia

I examined the effects of a multisensory program (the TOUCH MATH™ program; Bullock, Pierce, & McClellan, 1989) on the acquisition of addition and subtraction skills by students with mild disabilities. I taught three elementary students with mild disabilities (learning disabilities and mental handicaps) to use the TOUCH MATH counting technique for addition and subtraction problems within the context of a multiple-probe design across math skills. Target skills included (a) adding two-digit numbers with regrouping, (b) adding columns of two-digit numbers with regrouping, (c) subtracting single-digit numbers from numbers up to 18, (d) subtracting two-digit numbers with regrouping, and (e) subtracting three-digit numbers with regrouping. Results showed significant gains in acquisition of target skills for all three subjects. Maintenance and generalization results also were observed in that the subjects maintained mastery-level performance on all skills and generalized the TOUCH MATH strategies to novel math problems. I discuss these results in relation to the use of a multisensory counting approach with students with mild disabilities.

Researchers have shown that students with mild disabilities (i.e., students with learning disabilities or mild mental handicaps) are often less proficient than their normally functioning peers in computing basic addition, subtraction, and multiplication problems (Fleischner, Garnett, & Shepherd, 1982; Garnett & Fleischner, 1983; Goldman, Pellegrino, & Mertz, 1988). Teachers of secondary-level students with learning disabilities, for example, have reported that their students most often demonstrate deficits in multiplication; division; basic operations involving fractions, decimals, and percentages; fraction terminology; place value; measurement skills; and language of mathematics (McLeod & Armstrong, 1982). Furthermore, these students use less effective and efficient strategies in completing mathematics problems (Goldman et al., 1989).

Requests for reprints should be sent to Kristin S. Scott, Department of Special Education, 570 Adehold Hall, University of Georgia, Athens, GA 30602.

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Garnett and Fleischner (1983) examined the proficiency in mathematic basic fact computation of children with learning disabilities. One hundred-twenty students with learning disabilities and 120 normally functioning students between the ages of 8 and 13 were administered measures on automatization ability and basic fact computation. The students with learning disabilities were found to demonstrate slower automatization and less proficient fact computation. The authors suggested that the poor basic fact computation performance may be due, at least partially, to weak automatization. Similar results were found by Fleischner et al. (1982) and Zentall (1990).

Although the limited available research has shown, and most teachers would agree, that many students with mild disabilities exhibit problems in mathematics, this area often has been neglected by researchers (Beattie & Algozzine, 1982; Frank, Logan, & Martin, 1982). Teachers continue to search for effective math programs, strategies, curricula, and activities to remediate and facilitate the learning of math. Some researchers espouse a multisensory approach to mathematics instruction (Sawada, 1982; Thornton, Jones, & Toohey, 1983), whereas others propose that teachers emphasize improved instruction and enhanced mathematics curricula (Cawley, 1987; Garnett, 1987; Kavale & Forness, 1987; Lloyd & Keller, 1989; Meyers & Burton, 1989; Resnick, Wang, & Kaplan, 1973; Skrtic, Kvan, & Beals, 1983).

Research has supported the use of multiple modalities (i.e., visual, kinesthetic, and auditory) to teach students with mild disabilities (Sawada, 1982; Thornton et al., 1983; Thornton & Toohey, 1985; Zendel & Phil, 1983). For example, Thornton et al. (1983) successfully used a multisensory approach to teach addition facts. Their intervention, the Multisensory Basic Fact Program (MBFP), included a counting-on strategy; mnemonics for doubles, near doubles, and near 10s; and visual, auditory, and kinesthetic instruction. Second through sixth graders who had previously been assigned to remedial math classes participated. Teachers used the MBFP for math instruction during two 20-min sessions per week. The rest of the week, the traditional math program was taught. Results showed that each grade level demonstrated an improvement in mean performance at the end of the 11-week instructional period. Although problems in design (i.e., multtreatment interference) may limit the generalization of the results, the authors did discuss components of the program that are worth noting. The MBFP used multisensory instruction, “starting BIG and counting on” (p. 51) and other strategies that are effective (Thornton & Toohey, 1985).

In an early study, Kokaska (1975) examined the effectiveness of a notation system described by Kramer and Krug (1973) that used dot notation and counting to solve addition and subtraction problems, which is similar to the TOUCH MATH system. Four students with mild mental handicaps were pretested for addition and subtraction skills; two students were unable to complete any problems independently, whereas the other two were able to complete only some addition problems. Then they were taught the notation system for solving addition and subtraction problems. Results showed that two students were able to solve addition problems ranging from single-digit combinations to combinations of two or more digits and to add columns. These results support the use of a multisensory manipulative program.

Although research supports the efficacy of multisensory programs in mathematics, some researchers have suggested that teaching to the preferred modality is not an effective method of instruction (Kampwirth & Bates, 1980; Kavale & Forness, 1987). For example, Kavale and Forness (1987) conducted a meta-analysis of the efficacy research on modality testing and instruction. They included research that assessed modality preferences formally, used instructional materials designed to capitalize on the modality preferences, and assessed results with a standardized outcome measure. Their conclusion from this analysis was that preferred modality instruction is not effective. However, they did acknowledge that all modalities are heavily involved in the learning process. The modality research previously reviewed, as well as the TOUCH MATH program, involved multiple modalities, as opposed to preferred or specific modalities. In addition, some of these studies (i.e., Kokaska, 1975; Thornton et al., 1983; Thornton & Toohey, 1985) utilized a combination of multisensory instruction with other techniques (i.e., the counting-on strategy). Therefore, these studies should not be categorized as the preferred modality instruction included in the Kavale and Forness (1987) article.

Regardless of the approach, students with mild disabilities learn differently, and these differences need to be considered when developing instructional programs. The TOUCH MATH program (Bullock et al., 1989; Bullock & Walentas, 1989) was chosen for this investigation because it is a program that takes into consideration individual student differences by using a multisensory approach to mathematics. Auditory, visual, and tactile modes are all used to reinforce the counting technique implemented to teach the mathematical operations (Bullock et al., 1989; Bullock & Walentas, 1989). In addition, this program targets addition, subtraction, multiplication, and division computation, all of which are areas in which students with mild disabilities have often demonstrated deficits (Fleischner et al., 1982; Garnett & Fleischner, 1983; Goldman et al., 1988). Finally, because students with mild disabilities also demonstrate problems with basic math fact proficiency, the TOUCH MATH program may be beneficial for these students. This program does not require students to have math facts memorized, but rather it seeks to facilitate the acquisition of these facts.

The TOUCH MATH program has been used with large numbers of students (Bullock, 1989). Although research has been conducted with groups of general education students, no research has been published that has explored the use of TOUCH MATH with elementary students with learning disabilities or mental handicaps (J. Bullock, personal communication, October 4, 1990). The purpose of this study was to examine the effectiveness of the TOUCH MATH program with students with mild disabilities. Specifically, I wished to determine whether the TOUCH MATH program is effective in teaching elementary students with learning disabilities or mild mental handicaps how to (a) add two-digit numbers with regrouping, (b) add columns of two-digit numbers with regrouping, (c) subtract single-digit numbers from numbers up to 18, (d) subtract two-digit numbers with regrouping, and (e) subtract three-digit numbers with regrouping.
METHOD

Subjects and Setting

Three 4th-grade students identified as having mild disabilities participated in this investigation. One subject (Subject 3) was identified as having a learning disability, whereas the other two subjects were identified as having mental handicaps. The subjects met the state of Georgia's criterion for identification and placement in the exceptional children's program. Specifically, to be eligible for placement and services in the program for students with mental handicaps (intellectual disabilities), a student must exhibit intellectual functioning below an IQ score of approximately 70 and demonstrate deficits in adaptive behavior. To be eligible for learning disabilities services, a student "must exhibit a deficit in basic learning behavior(s) which is/are manifested in a severe discrepancy between actual achievement and expected performance" (Georgia Department of Education, 1988, p. 56). Even though Subject 1's current IQ score fell within the moderate range of severity, she was receiving services within the mildly mentally handicapped program in a resource room for students with mild disabilities.

The three children received special education services in a resource room for time periods ranging from 2 hr (Subject 3) to 4 hr (Subjects 1 and 2) per day. The subjects' school was located in northeast Georgia. All phases of the investigation took place in the library conference room with a large table (4 ft x 8 ft) and chairs.

In accordance with the TOUCH MATH program, I screened each subject for the following prerequisite skills: knowledge of one-to-one correspondence, number concept, counting forward to 20, and counting backward from 20. All subjects possessed all prerequisite skills, except for counting backward. I taught this skill to criterion before each subject received instruction in subtraction. Additional skills and characteristics of each subject are presented in Table 1.

The TOUCH MATH Program and Materials

The TOUCH MATH program employs visual, auditory, and tactile learning modes. Students point to the touch points (dots or dots with circles on the numbers) with their pencil (tactile) while looking at the number (visual) and counting (auditory). Subjects are taught to count the touch points on each number to assist in their adding, subtracting, multiplying, and dividing. In addition problems, students count forward; in subtraction problems, they count backward. For multiplying and dividing, they sequence count (Bullock et al., 1989; Bullock & Valentes, 1989).

First, students are taught where the touch points are on each number (see Figure 1). Once the students learn the touch points, statements (i.e., addition, subtraction, and regrouping) are taught to instruct them in how to perform an operation. For example, the first statement for adding is "I touch the larger number, say its name, and continue counting." Worksheets include touch points on the numbers until the students can consistently count with them; then the touch points are removed from the worksheet. When the touch points are
removed, the students can still "touch the points" with their pencils from memory. When reading math problems, students are encouraged to read both the problem and the answer to facilitate memorization of facts (Bullock & Walentas, 1989).

I used a variety of materials during the course of the investigation. During probe conditions, a 24-problem worksheet with 8 of each of the 3 types of math problems served as a daily probe worksheet. During the intervention conditions, I used the TOUCH MATH materials for instruction and subject work. These materials include reproducible worksheets of math problems with and without touch points, posters with each numeral and its touch point configuration, and statement posters with the specific rules for addition and subtraction. In addition, I used write-on/wipe-off boards and laminated flashcards with the training math problems so that the touch points could be wiped off when they were no longer needed for solving the problems.

Response Definition and Data-Collection Procedures

I monitored three target skills for each subject during the study. Target skills for Subject 1 included column addition of single- and double-digit numbers with regrouping, double-digit subtraction with regrouping, and three-digit subtraction with regrouping (with 0s and mixed problems). Subject 2's target skills included double-digit addition with regrouping, single-digit subtraction from numbers to 18, and double-digit subtraction with regrouping. Column addition of single-digit and double-digit numbers with regrouping, single-digit subtraction from numbers to 18, and double-digit subtraction with regrouping served as target skills for Subject 3.

I judged written responses as correct (on first attempt) or incorrect. I measured the target skills using permanent products (worksheets) at the end of each session. During probe sessions, the subject completed a daily probe worksheet, and I used this permanent product for collecting data. During intervention sessions, the subjects received direct one-on-one instruction from me using the TOUCH MATH program. At the end of each session, each subject completed a worksheet that was used for data collection. While the subject completed the worksheet, he or she did not receive any assistance. I scored the subject's worksheet at the end of each session, at which time I reinforced the subject for his or her performance. I measured each subject's performance on the worksheet by determining the percentage of attempted problems answered correctly.

Design

I employed a multiple-probe design (Tawney & Gast, 1984) across math skills, replicated across subjects, to assess the effectiveness of the TOUCH MATH program in improving the target math skills of the subjects. Phases in the design included screening, probe conditions, touch point training, and intervention conditions. With this design, I introduced each subject to one type of math problem at a time (intervention condition). The design started with a probe condition in which I monitored all three types of math problems or skills. When a stable baseline was established with the first skill, I began the training phase with the subject. Once the subject reached 100% mastery with touch point training, I initiated TOUCH MATH instruction of the first type of math problem. Once the subject reached criterion (85% or better with no touch points for 2 consecutive days) on the first type of math problem, the probe condition was repeated during which time I monitored all three skills again. After the probe condition, I implemented the intervention with the second math skill. The same sequence continued until I implemented the final probe condition.

Procedures

Each subject received an individual, 15- to 30-min session each day. I trained subjects separately to provide more individualized instruction in the TOUCH MATH program. During the probe and intervention conditions, each subject completed math skill worksheets. After the subject completed the worksheet, I provided feedback and reinforcement.

Screening procedures. The screening test administered prior to data collection consisted of a paper-and-pencil worksheet containing math problems ranging from number identification and single-digit addition and subtraction to three-digit addition and subtraction with and without regrouping. I orally tested the skills of counting forward and backward. The three subjects demonstrated all prerequisite skills, except for counting backward.

Probe condition procedures. During each probe condition, I provided each subject with a daily probe worksheet to complete. This worksheet consisted of the three types of math problems targeted for each subject. Each group of problems included 5 problems from the training set (problems trained during the instructional sessions) and 3 problems from the generalized set (problems not trained) for a total of 24 problems. I allowed each subject as much time as he or she needed to complete the worksheet; on no occasion did any subject require more than 30 min to complete the sheet. I conducted probe sessions until a stable trend was evident. However, the length of these conditions was minimized so that the study could be completed before the end of the school year.

To conduct probe sessions, I took each subject to a conference room in the library where the sessions took place. When eye contact was established with the subject, I explained the directions. I told the subject the following: A worksheet would be received, do the best you can do, and let me know when you are finished. To ascertain that the subject understood the directions, during the first few sessions I asked the subject to tell me what he or she was supposed to do. Then I provided the subject with a worksheet and told him or her to begin. When the subject was finished, I checked the daily probe worksheet and gave positive praise for correct answers and for good work. In addition, if the subject performed at 85% correct or better on the set of problems on which he or she had already received instruction, I allowed him or her to take a reward from the prize box or receive computer time. I decreased this reinforcement throughout the probe conditions by thinning the reinforcement schedule from a 1:1 ratio during
Probe Conditions 1 and 2 to 2:1 ratio during Probe Condition 3 and to a 4:1 ratio for (the final) Probe Condition 4.

Instructional conditions. Before beginning instruction with TOUCH MATH, I implemented a short training phase to teach the subjects the touch point configurations for each number. This phase continued until every subject reached 100% mastery of the touch points. Training ranged from 1 to 3 days. I provided instruction on the touch points and three practice trials per numeral for each subject. Practice trials included at least one of the following: touching and counting the touch points on the numeral, writing the numeral and its touch points, and drawing touch points on the numeral (worksheet). Training lasted for 15 to 30 min per session.

Once the subject reached criterion in the training phase, I implemented the intervention (TOUCH MATH application) with the first target math skill for each subject. Instructional conditions lasted an average of 5 days, with sessions conducted until the subject reached mastery (85% correct or better without touch points for 2 consecutive days). I began instruction with a review of the touch points by asking the subject to touch and count the touch points on each numeral from 0 to 9 in random order. I praised the subject for correct touch point counting. If the subject counted incorrectly, he or she received corrective feedback and practiced the numeral again.

Next, I introduced and explained the addition statement or subtraction statement and the arrow statement (see Table 2). The subject first read the statement with me and then said the statement alone or explained it in his or her own words. I supplied corrective feedback when necessary. Next, I explained and modeled how to use the statements by working through a problem. During the practice trials, I required the subject to complete the problems using the same procedure that I modeled.

The subject then received guided practice on 20 trials of a training set of math problems using the TOUCH MATH statements. These trials were conducted using laminated flashcards, write-on/wipe-off boards, or paper and pencil. During the course of the instructional condition, I gradually removed the touch points from all problems containing touch points, to half containing touch points, and, finally, to no problems containing touch points. If any errors were

| TABLE 2 |
| TOUCH MATH Instructions Statements |
| Statement Type | Statement |
| Addition | I touch the larger number, say its name, and continue counting. |
| Subtraction | I touch the top number, say its name, and count backwards. |
| Arrow (used with multiligit addition and subtraction) | I start on the side with the arrow. The arrow is on the right side. |
| Regrouping | If I cannot continue to count all the touch points, I must borrow or regroup. |

noted in the subject's performance on a trial, I provided the subject with corrective feedback upon completion of the problem. I worked through the incorrect problems with the subject so that he or she could see where the error was made. Training trials included only problems from the training set.

Near the end of each training session, the subject completed a worksheet containing 20 math problems (the same 20 training problems from the session, i.e., the training set). I removed the touch points on the worksheets, just as in the training phase of the instructional sessions. Prior to providing the subject with the worksheet, I gave him or her instructions for completing it. Instructions were similar to those given during the probe conditions, except the subject was working on only one type of problem that he or she should have known how to compute. When the subject was finished, I checked the worksheet, gave feedback, and supplied reinforcement as delineated in the Probe Condition Procedures section. Finally, I decreased the prize/computer time reinforcement using the same reinforcement schedule as described in the Probe Condition Procedures section.

Maintenance and generalization. I obtained two maintenance probes on one subject at 3 and 6 weeks after the study was concluded (during the summer). I conducted the probes in the same manner as the sessions in the probe conditions. However, the subject only received praise for his good work and effort; no prize was awarded. In addition, I obtained generalization information by collecting data on the generalization sets. These sets included any math problems (the same type as the training set) other than those included in the training sets. I included a generalization set to determine if the subjects could generalize this method to novel math problems.

Reliability

An interobserver reliability coder measured subject performance in the same manner as described in the Response Definition and Data-Collection Procedures section. The coder then checked interobserver reliability using the point-by-point method. The formula for this method is percentage of agreement = (number of agreements/number of agreements + number of disagreements) × 100. The coder checked reliability on the scoring of the permanent product measures (workheets). A doctoral student conducted reliability agreement checks on these data for 30% of the sessions (11 times and at least once per condition with each subject). The coder performed this check at the end of the investigation and compared his results to the results that I obtained from the permanent product measures. The coder computed the mean interobserver reliability as 99.5% (range = 95% to 100%), 100% and 99.5% (range = 95% to 100%), for Subject 1, Subject 2, and Subject 3, respectively.

Data Analysis

During each session, I collected performance data from the completed worksheets and utilized these data to monitor progress on the training and generalization sets of problems for each math skill. I recorded these data on data summary sheets
and used this information to construct graphs comparing each subject's behavior under each condition. In addition, I compared the data from each probe condition to the data from each adjacent intervention condition. Data path trends and stability, range of data, changes in data level, and length of conditions were analyzed within and between conditions.

RESULTS

Probe conditions ranged from 3 to 4 days in length ($M = 3.25$), whereas intervention conditions ranged from 4 to 6 days ($M = 5$ days). To reach 100% mastery of the touch points, the touch point training phase lasted 3 days for Subject 1, 2 days for Subject 2, and 1 day for Subject 3. Each subject reached mastery criterion of 85% correct or better on all target skills (all types of math problems).

Figure 2 presents the results for Subject 1. This subject increased her performance on column addition, two-digit subtraction, and three-digit subtraction. Subject 1's performance on column addition increased from the first probe condition to the first intervention condition, with mean scores of 0% correct and 89% correct, respectively. She also improved two-digit subtraction with regrouping from mean scores of 13% correct in Probe Condition 2 to 95% correct in Intervention Condition 2. Finally, performance on the third skill—three-digit subtraction—improved from a mean score of 0% correct in Probe Condition 3 to 96% correct in Intervention Condition 3.

Subject 1 improved scores on all three target skills during probe conditions throughout the study once the behavior had been taught. During the final probe condition, Subject 1 scored 100% on the training sets of all three skills. The mean scores for the generalization sets of each skill were 100%, 89%, and 100% for Skills 1, 2, and 3, respectively. These scores show that the subject improved and maintained her performance at mastery level on both the training sets and generalization sets of all three skills during the probe conditions.

Figure 3 graphically shows that Subject 2 also demonstrated improved performance in his three target skills: two-digit addition with regrouping, single-digit subtraction, and two-digit subtraction with regrouping. This improved performance is shown by his mean scores of 97% correct, 94% correct, and 100% correct for Intervention Conditions 1, 2, and 3, respectively. Subject 2 mastered each skill and maintained his mastery level performance on the training sets of all three skills through the study. During Probe Condition 4, Subject 2 achieved a mean score of 100% correct on each skill. Subject 2 also achieved mastery-level performance ($M = 100%$) on the generalization sets for each skill.

Figure 4 graphically presents the results for Subject 3. This subject mastered each of his target skills—column addition, single-digit subtraction from 18, and double-digit subtraction with regrouping—obtaining mean scores of 94% correct, 99% correct, and 99% correct for Intervention Conditions 1, 2, and 3, respectively. Subject 3's performance in Probe Condition 4 demonstrates that he maintained mastery-level performance on the target skills by obtaining mean scores of 100% on all three skills.

I conducted two additional maintenance probes with Subject 3 both 3 and 6 weeks after the study ended. These probes yielded the following scores: Maintenance Probe 1—100% correct on each target skill for both training and generalization sets and Maintenance Probe 2—100% correct on both training and generalization sets of all target skills, except for the training set of single-digit subtraction (80% correct). On the generalization sets, Subject 3 scores 100% after the target skill had been taught. His performances on column addition, single-digit subtraction, and double-digit subtraction with regrouping all improved significantly and were maintained after instruction on each target skill.

PRACTICAL IMPLICATIONS

Results from all three subjects suggest that the TOUCH MATH program can be effective in teaching column addition, two-digit addition with regrouping,
single-digit subtraction, double-digit subtraction with regrouping, and three-digit subtraction with regrouping. Performance on each set of math problems for each subject improved after TOUCH MATH instruction was implemented. In addition to being successful in improving the performance of the math skills described, the subjects were successful in maintaining criterion performance and in generalizing the TOUCH MATH program to novel math problems.

These results have positive implications for both special educators and mainstream teachers. Because TOUCH MATH is a multisensory counting approach to mathematics instruction, it provides reinforcement of the counting process through the use of multiple modalities. In addition, it does not rely on memorization of facts in order for the student to be successful. This component is important because it allows students with poor memory abilities to continue to develop and learn mathematics skills without being encumbered with fact memorization. At the same time, the TOUCH MATH program facilitates the learning of math facts by requiring the student to read the problem and answer to each math problem. Finally, the TOUCH MATH program, unlike some commercial programs, allows for teacher flexibility and creativity. The teacher has the freedom to add activities or instruction to the existing program so that it may be individualized for each student’s needs.

Students, particularly those in mainstream classes, seem to like using the TOUCH MATH approach (Bullock et al., 1989). This approach is a more inconspicuous method of counting. It is much less obvious that a student is counting to solve a problem when he or she is lightly tapping a pencil on the worksheet than when he or she is counting on fingers.

The success of the TOUCH MATH program with the subjects in this study may be due to several factors. The first factor was the thorough screening administered to assure that each subject possessed the prerequisite skills; those who did not were taught these skills. Further, I determined that the subjects were not already capable of successfully performing the target skills. A second factor
contributing to the success was the requirement of 100% mastery during touch point training. Without 100% mastery, a subject could easily miss problems because of inaccurate touch point counting. In addition, learning the touch points to an automatic level allowed the subjects to concentrate on the TOUCH MATH strategies or statements, rather than counting touch points. Another factor that may have contributed to the positive results was the reinforcement schedule. The study began with a heavy schedule of reinforcement to ensure that the subjects continued to do their best work; however, I decreased the reinforcement to a more natural schedule as the study continued. Because acquisition of the target skills did not occur without instruction (i.e., I had to train each type of problem despite the use of reinforcement), the reinforcement schedule itself was not the major contributor to the positive results.

The positive results with these three subjects regarding acquisition, maintenance, and generalization are encouraging because students with mild disabilities often have difficulties in generalizing and maintaining skills and strategies that they learn. Because only three participants were involved in this investigation, additional studies are needed to determine if these results can be replicated with other subjects. Further investigation in the area of maintenance and generalization resulting from multisensory instructional strategies and approaches, such as the TOUCH MATH program, would be beneficial. Also needed are studies of the long-term effects of the TOUCH MATH program and the use of TOUCH MATH in novel situations (e.g., new math problems) and novel settings.

In addition to further investigation in the areas of maintenance and generalization, studies involving more advanced mathematics operations are needed. It would be interesting to examine the effects of the TOUCH MATH program strategies on teaching multiplication and division. Finally, it would also be beneficial to examine the effects of reinforcement in combination with the program. For example, a study involving a less intensive reinforcement schedule could determine whether reinforcement plays a large role in a subject's performance with the TOUCH MATH program. Perhaps an additional study could examine the effects of reinforcement and the TOUCH MATH program on the rate of acquisition of the skills.

The TOUCH MATH program provides students with a counting method for learning mathematics operations that takes advantage of all learning modalities. This study is similar to previous research (Sawanda, 1982; Thornton et al., 1983; Thornton & Toobey, 1985; Zende & Pihl, 1982) demonstrating positive effects of a multisensory approach with some students with disabilities.

REFERENCES


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