Teaching Mathematics to Students With Mild-to-Moderate Mental Retardation: A Review of the Literature

Frances M. Butler, Susan P. Miller, Kit-hung Lee, and Thomas Pierce

Abstract

A systematic search of the literature from 1989 through 1998 was conducted to identify and analyze mathematics interventions for students with mild-to-moderate mental retardation. We found that the focus of instruction has shifted from basic skills instruction to computation and problem-solving instruction. Techniques such as constant-time delay, peer tutoring, time trials, and direct instruction proved beneficial in improving mathematics skills. Further, students with mental retardation learned to employ cognitive strategies successfully when these techniques were included. Although this information is promising, we recommend that further studies be conducted in secondary schools and in inclusive settings.

Developing appropriate instruction for students with mild-to-moderate mental retardation is important when considering the postsecondary transition to adulthood. Patton et al. (1996) identified four primary goals for students with mild mental retardation: successful employment, independent living, competence in basic life skills, and successful integration into schools and community settings. As states increasingly enact legislation requiring students to pass minimal competency examinations as part of their graduation requirements, the probability lessens that students with mild-to-moderate mental retardation will graduate with high school diplomas (MacMillan, 1988). Accordingly, for these students the likelihood of achieving the goals Patton et al. identified is reduced unless the curricular deficits are addressed efficiently and effectively.

Several authorities have challenged the notion that students with mental retardation are incapable of devising cognitive strategies and engaging in mathematical problem solving (Baroody, 1996; Parmar & Cawley, 1991). These researchers noted that students with mild disabilities are capable of more than rote drill and practice lessons. This observation is particularly relevant in light of trends in general education mathematics instruction. The National Council of Teachers of Mathematics (NCTM) developed standards for mathematics curriculum in 1989 and again in 2000 (National Council, 1989, 2000). These standards demonstrate a shift from a behaviorist approach of teaching rote learning of facts and procedures to a constructivist approach, emphasizing the development of conceptual understanding and reasoning. Teachers are encouraged to give students hands-on experiences connected to the real world rather than emphasizing algorithms and abstract routines. Perhaps now more than ever, limiting mathematics instruction to rote computation practice will deprive students with disabilities from competence in important mathematics concepts and, thus, prevent them from succeeding in inclusionary settings and using mathematics effectively in real-world activities.

Recent reviews of literature related to mathematics instruction have focused on teaching students with learning disabilities (Maccini & Hughes, 1997; S. Miller, Butler, & Lee, 1998). Reviews related to teaching mathematics to students with mental retardation have been sparse. One recent review was located (Browder & Grasso, 1999), but the authors limited their search to studies involving instruction on money skills. Only one comprehensive review (Mastropieri, Bakken, & Scruogs, 1991) was located. This review included research conducted from 1973 through 1988. Thus, there is a need to examine validated practices that have...
emerged since 1988, especially given the recent emphasis on increased problem-solving (i.e., word problems, real-world mathematics, application problems) and more rigorous mathematics standards for all students, including those with disabilities. Our intent in this article is to extend and update the work of Mastropieri, Bakken, and Scruggs. Research related to basic-skill, computation, and problem-solving instruction is included.

Overview of the Included Studies

Education Resources Information Center and Psychological Abstracts were searched for articles related to mathematics instruction and mental retardation. Articles published between 1989 and 1998 that described data-based interventions for teaching mathematics to students with mental retardation were included in this review. Studies related to interventions for teaching money skills to students with mental retardation were excluded. Browder and Grass (1999) provided a thorough review of these studies. Articles that dealt with characteristics of mental retardation or compared students with mental retardation to other groups without implementing an intervention were specifically excluded from consideration. Studies in which researchers used a cross-categorical term, such as mildly disabled, were excluded, although studies with students who had other disabilities were included in this review if the data for students with mental retardation were reported separately. A total of 16 articles were found that met these criteria. These studies included 271 students with mental retardation. Group comparison designs were used in 4 studies and single-subject designs in 12 studies. Thirteen studies took place in elementary school settings, 2 in middle/junior high school, and 1 study took place in seven different special education schools. The authors discussed basic or functional mathematics skills in 3 articles, examined methods used in teaching computation skills in 10 studies, and investigated problem-solving methods in 3 articles (See Table 1).

Basic Skills Instruction

Traditionally, basic skills instruction, including functional mathematics and life skills, has been the focus of mathematics curricula developed for persons with mental retardation. Although children without disabilities acquire basic skills with few problems, children with mental retardation often complete their schooling without mastering such skills (Broome & Wambold, 1977; Grise, 1980). Accuracy in counting, recognizing numerals, telling time, and understanding quantity are important if individuals with mental retardation are to achieve employment, independent living, competence in basic skills, and successful integration into school and community settings.

Three studies in this review were focused on improving basic skills. In these three studies the investigators used the traditional behaviorist approach of teaching students with mental retardation rather than the National Council-endorsed constructivist approach used by general educators. However, because these skills are fundamental to the development of higher order mathematics skills, such direct instruction appears necessary before integrating students into inclusive settings.

Use of Discriminant Learning Theory

Young, Baker, and Martin (1990) compared direct instruction, a method based on discriminant learning theory, to teach 5 students with moderate mental retardation basic arithmetic skills, such as counting, recognition of numerals, symbols, equality, and addition. A multiple-baseline across-subjects design was used to measure two dependent variables: mastery of the skills taught and amount of academic engaged time. The baseline phase for all students consisted of group instruction using DISTAR Arithmetic 1. DISTAR is a commercially available direct-instruction method. Baseline was followed by the intervention phase using teacher-made discriminant learning theory lessons covering the material in the first 60 lessons of DISTARArithmetic 1.

For the discriminant learning theory lessons, we used a cognitive individualized approach. Each discriminant learning theory session consisted of instruction followed by a testing phase. Students were presented with cards that included the concepts being taught along with distracter items. They were then required to discriminate between the given concept and distracters. Results for all students revealed flat or decelerating trend lines during the baseline (direct instruction) phase and rapidly accelerating trend lines in the intervention (discriminant learning theory) phase for both dependent variables. The researchers seemed to prefer discriminant learning theory because a simple motor response was required, whereas in direct instruction,
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<td>Basic skills</td>
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<td>Discriminant learning theory</td>
<td>Young, Baker, &amp; Martin, 1990</td>
<td>5</td>
<td>Elementary school</td>
<td>Multiple baseline</td>
<td>DLT© had higher scores than students in DI© (DISTAR). Students benefited from tutoring, but maintenance results were mixed.</td>
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<td>Cross-age tutoring</td>
<td>Vacc &amp; Cannon, 1991</td>
<td>4</td>
<td>Elementary school</td>
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<td>Students benefited from tutoring, but maintenance results were mixed.</td>
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<td>Equality training</td>
<td>Hendler &amp; Weinberg, 1992</td>
<td>32</td>
<td>Elementary school</td>
<td>Group comparison</td>
<td>Equality-training group had higher scores on both post-tests than other groups.</td>
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<td>Computation</td>
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<td>CRA+ sequence</td>
<td>Morin &amp; Miller, 1998</td>
<td>3</td>
<td>Middle school</td>
<td>Multiple baseline</td>
<td>Students improved in learning multiplication facts and problem-solving.</td>
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<td>Constant time delay</td>
<td>Mattingly &amp; Bott, 1990</td>
<td>2</td>
<td>Elementary school</td>
<td>Multiple probe</td>
<td>Intervention was effective in teaching multiplication facts. Both students reached criterion on all 3 math fact sets; error rate was only 1.5%.</td>
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<td></td>
<td>Whalen, Schuster, &amp; Hemmeter, 1996</td>
<td>2</td>
<td>Elementary school</td>
<td>Multiple probe</td>
<td>Students improved in math performance and were able to maintain skills after touch-points were removed from problems.</td>
</tr>
<tr>
<td>Multisensory</td>
<td>Scott, 1993</td>
<td>2</td>
<td>Elementary school</td>
<td>Multiple problem</td>
<td>Students improved in math performance and were able to maintain skills after touch-points were removed from problems.</td>
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<td>Time trials</td>
<td>Miller, Hall, &amp; Heward, 1995</td>
<td>11</td>
<td>Elementary school</td>
<td>ABABC</td>
<td>Rate of problems solved per minute increased with no loss of accuracy. Best results were obtained during the Self-Correction phase.</td>
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<td>Peer tutoring</td>
<td>Harper, Mallette, Maheady, Bentley, &amp; Moore, 1995</td>
<td>3</td>
<td>Elementary school</td>
<td>Alternating treatment</td>
<td>Pre-posttest scores improved for all 3 subjects; retention scores were mixed.</td>
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</tbody>
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Table 1 continued
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<table>
<thead>
<tr>
<th>Intervention</th>
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<th>Setting</th>
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<tr>
<td><strong>Fasko, 1994</strong></td>
<td>2</td>
<td>Elementary school</td>
<td>Multiple baseline</td>
<td>Both students improved in math skills with some evidence of generalization across settings.</td>
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<tr>
<td><strong>Technology</strong></td>
<td>Horton, Lovitt, &amp; White, 1992</td>
<td>7</td>
<td>Junior high school</td>
<td>ABCD with multiple probes</td>
<td>Calculator instruction was more successful than traditional paper-and-pencil and mean grade levels improved.</td>
</tr>
<tr>
<td><strong>Podell, Tournaki-Rein, &amp; Lin, 1992</strong></td>
<td>50</td>
<td>Elementary school</td>
<td>Group comparison</td>
<td>No significant differences between CAI and paper-and-pencil, but response time was better for CAI group.</td>
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<tr>
<td><strong>Lin, Podell, &amp; Tournaki-Reid, 1994</strong></td>
<td>58</td>
<td>Elementary school</td>
<td>Group comparison</td>
<td>No significant differences in accuracy. CAI group had improved subtraction response time.</td>
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<tr>
<td><strong>Problem-solving</strong></td>
<td><strong>Self-regulation</strong></td>
<td>Cassel &amp; Reid, 1996</td>
<td>2</td>
<td>Elementary school</td>
<td>Multiple baseline</td>
</tr>
<tr>
<td><strong>Technology with strategy</strong></td>
<td>Jaspers and Van Lieshout, 1994</td>
<td>84</td>
<td>Elementary through high school</td>
<td>Group comparison</td>
<td>Test analysis students did better on paper-and-pencil tests. Concrete modeling students did better when materials were available but could not eliminate superfluous information.</td>
</tr>
<tr>
<td><strong>Mastropieri, Scruggs, &amp; Shiah, 1997</strong></td>
<td>4</td>
<td>Elementary school</td>
<td>Pre-posttest design</td>
<td>Scores improved from pre- to posttest but students did not always remember strategy steps.</td>
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</table>

*Note.* All dependent measures were criterion-referenced.

`a`Concrete-representational-abstract.  `b`Discriminant learning theory.  `c`Direct instruction.  `d`Computer-assisted instruction.
the oral presentation required students to use both receptive and expressive language skills to process the information. In addition, the discriminant learning theory format allowed teachers to individualize the lessons for each student, whereas the direct instruction lessons were presented in a group format.

Use of Cross-Age Tutoring

Vacc and Cannon (1991) used a cross-age tutoring program to improve basic skills, such as rote counting, counting objects, telling time, and identifying and matching number words and numerals. Four elementary school students with moderate mental retardation participated in the AB design study. Four sixth-grade students without disabilities served as tutors during the 6-week intervention. Sessions were held 4 days a week for 30 minutes each. Before beginning the intervention, tutors spent 30 hours training in sign language (3 students were nonverbal), making folders and instructional materials, learning instructional methods, and learning behavior management techniques. All 4 students increased and maintained the skills they were taught in the 6-week intervention. All 8 students answered questionnaires after the 15th session and at the end of the study. Both tutors and tutees reported that they enjoyed the sessions. Two years later, five follow-up sessions were conducted to assess skill maintenance. Students were inconsistent in their maintenance of various skills, although 3 students maintained or improved their skills in most areas.

Use of Equality Training

Recognizing that children with mental retardation often have difficulty with symbolic representation of quantity, Hendler and Weisberg (1992) compared three interventions to teach the concept of conservation of quantity (i.e., the ability to recognize that the numerosity of a set is unaffected by the position or conformation of the elements in the set). Thirty-two third- and fourth-grade children with mild mental retardation were randomly assigned to one of four groups: control, equality training, discrimination learning-set training, and verbal-rule plus learning set training (verbal rule/learning set). Tasks included number, weight, length, solid quantity, and liquid quantity. For each task, students were asked to determine whether the sets of items were equal or unequal. In the learning set group, three sets were presented with one set being unequal to the other two, and students were required to identify the set that was different. In the verbal rule/learning set group, the same procedure was followed except that a verbal rule was stated reflecting identity (e.g., “They are the same pennies so we must have the same number of pennies”), negation (e.g., “We can put the pennies back and see that their number has not changed”), or compensation (e.g., “Those pennies are closer together, but these have bigger spaces between them”). Students were not required to repeat the rules or demonstrate any understanding of the stated rule. In the equality-training group, students were told which sets were equal or unequal, and they selected numbers to represent the quantities. For example, students selected two identical numbers to represent equal quantities and two different numbers to represent unequal quantities. Thus, if the task consisted of two sticks of different lengths, the student might assign one stick the number three and the other stick the number six. Students were asked whether they started with the same or different numbers, and after the items were manipulated they were asked whether they still had the same or different numbers. The trainer provided rules and feedback, and students were encouraged to repeat the rules and feedback. Control-group students (who also had mild or moderate mental retardation) received no conservation training. Results obtained from two posttests revealed that students in the equality-training group achieved higher scores than did other students, followed by the verbal rule/learning set group and the learning set group, respectively. Students in the control group made no gains.

Computation and Related Instruction

Ten studies focused on improving students’ performance in mathematics computation. Achieving accuracy and fluency in computation is important for several reasons: Students receive higher grades in mathematics, feel better about instruction, and are better able to tackle higher-level problem-solving skills. Competence in computation also facilitates inclusion into general education classrooms. Students are better able to participate in classroom instruction with a minimum of accommodations and modifications. Although in the interventions discussed later, traditional drill-and-practice formats were stressed, in three studies investigators intro-
duced cognitive strategies to encourage active learning and independent thinking.

**Use of Concrete–Representational–Abstract Sequence**

Morin and Miller (1998) investigated the effects of the concrete–representational–abstract sequence on teaching multiplication facts and word problems to three middle-school students with mental retardation. The researchers used a single-subject multiple baseline across-subjects design to evaluate the effectiveness of the intervention. After a pretest/baseline condition, each student was individually taught multiplication facts using lessons from Multiplication Facts 0–81 (Mercer & Miller, 1992). Each daily lesson, with the exception of Lesson 7, consisted of instruction in computation and word problems. Lesson 7 introduced a mnemonic device to facilitate problem-solving of facts not yet committed to memory. The first three lessons were taught at the concrete level. Students used objects (e.g., paper plates and blocks) to represent groups and objects in groups, respectively. Lessons 4 through 6 were taught at the representational level. In these lessons, students were taught to draw groups of objects (e.g., circles or tallies) to represent groups and objects. After the introduction of a mnemonic device in Lesson 7, students were taught three lessons at the abstract level. They were encouraged to use the mnemonic device to aid in recall of multiplication facts. A posttest was administered after Lesson 10, with 90% set as the criterion for mastery. Lessons 11 through 21 consisted of instruction in more advanced word problems using a different mnemonic device. All three students showed significant progress from pretest to posttest, although their scores dropped slightly during the advanced problem-solving phase of the intervention.

**Use of Constant Time Delay**

Mattingly and Bott (1990) examined constant time delay for teaching multiplication facts to two elementary-school students with mental retardation. A multiple probe design was used to assess the effectiveness of the intervention. Following a baseline phase of three sessions, the constant time delay procedure was taught to the students. The first 25 intervention sessions followed a 0-second delay format. That is, the teacher presented a multiplication flash card and immediately provided the correct response. Students were required to repeat the answer correctly, and then the next flash card was presented. The remaining sessions of the intervention followed a 5-second time delay format. During these sessions, the teacher presented the card, asked for a response, and then waited 5 seconds for the student to respond. If the student did not know the answer, the teacher repeated the question and provided the correct response. When the student answered correctly or waited the 5 seconds for the teacher’s prompt, he or she received verbal praise and a token. If the student responded incorrectly or failed to wait, he or she received a verbal reprimand and the teacher dropped her head for 5 seconds as a “time out” from teacher attention. Both students learned their sets of 30 multiplication facts with almost no errors. Students were able to generalize and maintain their learning over time.

Whalen, Schuster, and Hemmeter (1996) also used a constant time delay procedure to teach mathematics facts. Recognizing, however, that in actual classrooms learners are involved in different tasks at the same time, Whalen et al. included unrelated feedback in the form of new sight words in their investigation. Two primary-school students with mild mental disabilities participated in the multiple-probe-across-behaviors study. The teacher used a 3-second time delay procedure to present addition facts printed on flash cards. Following a correct response, the teacher presented an unrelated sight word (e.g., cheese). If the student responded incorrectly to the flash card or failed to wait for the prompt, the teacher restated the fact and gave the answer. The sight word was presented after this error correction process. Both students attained criterion (100% accuracy for two consecutive trials) for each of their nine targeted facts. The researchers noted that the incorporation of unrelated feedback into the procedure did not hinder the learning of the targeted facts. Maintenance probes were conducted after 22 weeks, and both students maintained their 100% accuracy rates. The researchers noted that generalization was demonstrated in other settings and with other persons.

**Use of Multisensory Approach**

In the TOUCH MATH program (Bullock, Pierce, & McClellan, 1989), the visual, auditory, and tactile modes are combined with a counting technique to teach mathematics operations. Students are taught to touch designated spots on a written numeral and to count each spot. Thus, the
numeral 4 has four touch points, while the numeral 9 has nine touch points. For example, in adding 4 plus 9, the student is instructed to start with the 9 and count on using the 4 touch points on the numeral 4 to arrive at the answer of 13. Scott (1993) investigated the effects of teaching mathematics facts using multiple modalities (TOUCH MATH) to two fourth-grade students with mild mental retardation. A multiple probe design was used to determine the effects of the procedure. After providing a short training phase, the investigator individually taught each student separate mathematics skills, such as single- and double-digit addition or subtraction without regrouping. Students were taught to say specific statements as they worked through the practice problems with the teacher. Then, each student was given guided practice using flashcards, write-on boards, or pencil and paper. The touch points were gradually removed from the numerals during the guided practice. Finally, each session ended with a 20-problem worksheet that had the same 20 problems that had been practiced during that session. Maintenance probes were conducted at 3 and 6 weeks after the conclusion of the study. Generalization data were obtained from work samples that contained similar problems to those that had been taught during the sessions. Both students reached mastery (85% accuracy with no touch points) for each of the skills taught in an average of 5 days per skill taught. Both students successfully maintained and generalized the new skills. Accuracy remained at or near 100% for both students.

Use of One-Minute Time Trials
With the decrease of emphasis on drill-and-practice, research has been directed at developing more efficient methods to increase fluency in mathematics facts. A. Miller, Hall, and Heward (1995) used one-minute time trials to build fluency in 11 elementary students classified as developmentally handicapped (mild mental retardation). A multiple-treatment-with-reversal design (ABABC) was used to measure rate and accuracy of responses as well as on-task behavior for three target students. The A condition consisted of 10-minute work sessions with next-day teacher feedback; the B condition, 1-minute time trials with next-day teacher feedback, and the C condition, two 1-minute time trials followed by immediate feedback, choral responding, and self-correction. Results indicated that student accuracy and rate improved with the one-minute time trials and decreased when the 10-minute work sessions were reinstituted. All students achieved the best results during the C condition, when self-correction and immediate feedback were implemented. In addition, the target students exhibited increased time-on-task during the one-minute time trials than during the 10-minute work sessions.

Use of Peer Tutoring
Classwide peer tutoring is another approach used to facilitate fluency in mathematics facts. Some of the benefits attributed to this approach include increased academic engaged time, more opportunities to respond, and the ability to individualize instruction effectively and efficiently. Harper, Mallette, Maheady, Bentley, and Moore (1995) conducted a 10-week investigation to determine the effectiveness of classwide peer tutoring in children with mild disabilities. Three elementary students with mild mental retardation participated in the study along with four students who had learning disabilities and one student with an emotional disturbance. A variation of the alternating-treatment design was used to assess five dependent variables: accuracy, short-term retention, long-term retention, rate of responding, and student satisfaction with peer tutoring. Students were paired according to mathematics skill level and worked on 10 subtraction facts per session. During each 10-minute session, each student spent 5 minutes as the tutor and 5 minutes as the tutee. A reward system using points served as positive reinforcement (i.e., if the tutee answered the problem correctly, the tutor awarded two points. If the tutee answered incorrectly, he or she was required to write the problem and answer three times correctly and was awarded one point). At the end of each session, the teacher totaled the daily points and posted them in front of the class. The intervention proved to be effective on all five dependent measures.

Fasko (1994) also employed a peer-tutoring format to improve multiplication fact retention for two students with mild mental retardation, three students with learning disabilities, and three students without disabilities. A multiple-baseline across subjects design was used to assess the effectiveness of the intervention in increasing recall of basic facts and improving students’ classwork assignments. Students in the study were fully included in an elementary class, but they had failed to master multiplication facts during regular classroom instruction. The tutors were classmates who had dem-
onstrated mastery of multiplication facts. The tutoring sessions consisted of flashcard drill-and-practice and incorporated standard tutoring practices, such as immediate feedback, consistent praise statements, and many opportunities to respond. Both students with mild mental retardation improved in the recall of multiplication facts and in their daily classwork assignments, although one student improved only slightly. Fasko noted that peer tutoring may be an effective intervention for students who need additional practice beyond teacher-directed lessons. In addition, students improved in their classwork assignments, suggesting that generalization across settings occurred.

Use of Technology

Horton, Lovitt, and White (1992) compared the use of calculators to traditional paper-and-pencil methods for solving four-column subtraction problems with regrouping. Seven junior-high students classified as educable mentally handicapped participated in the study. The researchers used an ABCD design with multiple probes to assess the number of correct digits per minute in each of the four phases and two maintenance probes. Each session in all four phases concluded with 2-minute timings that the teacher scored and used for student feedback. Phase A consisted of paper-and-pencil instruction in regrouping. The teacher demonstrated how to cross out digits and borrow at the chalkboard while students practiced at their desks. During a 5-minute feedback period, students corrected their errors and computed additional problems while the teacher and assistant moved around the room helping students as needed. In Phase B, students were given calculators but were not instructed in how to compute problems. Students were simply asked to complete as many problems as possible within a 2-minute time period. During Phase C, they were instructed in using the calculators to solve problems. The teacher taught the students how to key the calculators and demonstrated solving problems at the chalkboard while the students practiced at their desks. A 5-minute feedback session followed teacher demonstration. Phase D introduced a rehearsal strategy using visual clues. On the first day, the teacher demonstrated a specific sequence of steps for students to follow in solving the problems (See-Say, Say-Key). Students were directed to look at the first number and say each numeral, then say each numeral again while pressing the appropriate key. Students were directed to press the “equal” key and write the answer that appeared in the calculator window. On subsequent days in this phase, students completed 5-minute timed drills using the rehearsal strategy. All students showed increased rates of correct digits and decreased rates of incorrect digits during the calculator phases as compared to the paper-and-pencil phase. High rates of accuracy were maintained in both maintenance probes, although students were somewhat variable in their rate of incorrect responses. In addition, mean grade levels as measured by the Stanford Diagnostic Mathematics Test, Green Level, went from 2.6 before the intervention to 5.7 with calculators after the intervention. Podsell, Tournaki-Rein, and Lin (1992) compared computer-assisted instruction practice to paper-and-pencil practice to develop fluency in addition and subtraction facts. Twenty-eight elementary students with mild mental disabilities participated in the addition study, and 22 elementary students with mild mental disabilities participated in the subtraction study. A group comparison design was used to assess accuracy and speed of the students. After a pretest, students were randomly assigned to either the paper-and-pencil group or the computer assisted instruction group. Students in the paper-and-pencil group completed worksheets with two columns of 10 items each. The researchers timed students and gave corrective feedback as they completed the worksheets. If students made an error, they were given the opportunity to recompute the answer. Students in the computer group used Math Blaster software (Davidson & Associates, 1986) on Apple IIc and IIe computers. The software included addition and subtraction fact problems in a drill-and-practice format and had built-in scoring and timing capabilities. Students received a praise statement such as “That’s right” if they answered a problem correctly. If an error was made, the software prompted the student with a “Try again” statement, and the problem was presented again. No statistically significant differences were found between the two instructional groups for addition accuracy or response time or in subtraction accuracy. However, in the subtraction study, students in the computer-assisted instruction condition required fewer trials to mastery than did students in the paper-and-pencil condition.

In a subsequent study, Lin, Podell, and Tournaki-Rein (1994) found similar results. They again compared computer assisted instruction using the Math Blaster software (Davidson & Associates,
1986) to paper-and-pencil practice. Thirty elementary students with mild mental handicaps participated in the addition study, and 28 students with mild mental handicaps participated in the subtraction study. The procedure outlined in the previous investigation was followed, with the exception that a posttest was given after completion of the intervention phase. Results were similar to those of the previous study. There was no significant difference in accuracy between the two groups for either the addition or subtraction studies. However, in the subtraction study students in the computer group showed an improvement in response time.

**Problem-Solving Studies**

Students with disabilities consistently perform poorer on mathematics problem-solving and reasoning tasks (Parmar, Cawley, & Frazita, 1996). Most researchers agree that problem-solving involves analysis and interpretation of information, communication of solutions, and the ability to screen out inconsequential data. Possible reasons for this poor performance might include difficulty with reading, emphasis on basic skills and computation in special education classes, lack of fluency in basic computation, and inability to devise efficient strategies. This is especially problematic because much of the focus in general education mathematics classes has shifted to teaching students how to solve problems and connect mathematics to everyday life (National Council, 1989, 2000). In many ways, problem-solving is viewed as the focus for mathematics instruction, and computation represents the means to that end. Three studies in this review investigated problem-solving for students with mental retardation. The researchers specifically addressed instruction in forming and using efficient strategies.

In one study self-regulation was examined as an aid to students using strategies, whereas in two studies researchers combined strategy instruction with the use of computer software expressly designed to minimize the effects of poor reading skills. Use of Self-Regulation With Strategy Instruction

Cassel and Reid (1996) investigated the effects of including self-regulation with strategy instruction on the problem-solving ability of two students with mild mental retardation. The students in this multiple-baseline study were taught strategies for solving word problems. Each student was given a cue card outlining the nine-step fast draw strategy (Mercer & Miller, 1991–1994) for solving word problems. The student and teacher then discussed the importance of each step of the strategy, and the student developed statements that could be used as reminders for each step. These self-generated statements were transferred to a checklist for use during the problem-solving sessions. The authors noted that although both the strategy cue cards and the self-regulating checklists were available for use during the sessions, the students used the self-regulating checklists exclusively. Both students improved their problem-solving ability over baseline levels and maintained a mastery level of 80% or above at the 6- and 8-week mastery checks.

**Use of Technology With Strategy Instruction**

Jaspers and Van Lieshout (1994) used computer programs to compare two methods of teaching children to solve word problems. The researchers hypothesized that students with mental retardation experience difficulty in solving word problems because they have trouble understanding the text and because they lack skill in concrete modeling of problem situations. Eighty-four children classified as educable mentally retarded participated in the group comparison design study. The children, who attended seven different Dutch schools for special education, ranged in age from 8.6 to 16.8 years. Students were divided into four experimental groups of 21 each: text-analysis; external-modeling; text-analysis/external-modeling; and a control group with neither text-analysis nor external-modeling. Students in the text-analysis group were taught to touch appropriate words on the screen as they followed a four-step sequence consisting of reading the problem, determining the question being asked, locating the relevant sets, and giving the numerical answer. Students in the external-modeling group were presented with word problems accompanied by a set of squares. Using the mouse, students could arrange the squares on the screen to simulate adding and subtracting the objects in the word problems. This group was taught a five-step sequence consisting of reading the problem, representing the first set with squares, locating the second set on the screen, representing the second set with squares, and locating the answer set on the screen. The text-analysis/external modeling group was taught to solve problems using a format that combined elements of the previous two groups, whereas students in the control group practiced the
same number and types of problems without strategy instruction. Results indicated that students who received text-analysis training performed better on paper-and-pencil tests than did students in the other three groups, whereas students in the external-modeling group performed better than did students in the other three groups when they were allowed to use materials to represent the word problems. The authors suggested that students in the text-analysis group learned to construct representations mentally, and, thus, they were more efficient problem-solvers and were not dependent on the availability of materials to solve the problems.

Mastropieri, Scruggs, and Shia (1997) examined the effects of computer-assisted instruction on the problem-solving ability of four students with mild mental retardation. They hypothesized that a computer program that included strategy instruction, animation, and minimal reading would be beneficial to students learning problem-solving skills. These variables were incorporated in a specially designed computer program. All written instruction was accompanied by digitized voice instruction, and a mouse was used to perform all operations except for entering student name and identification numbers. The tutorial component included a seven-step problem-solving strategy that remained on the screen during each problem-solving session. Problems were depicted graphically using animation: Objects were grouped together for addition problems, and objects were removed for subtraction problems. The effectiveness of the intervention was assessed with pre- and posttest comparisons, interviews, and anecdotal information. All four students improved significantly between the pretest and the on-line posttest, and although there was improvement between the pretest and the written posttest, it was minimal. Interviews revealed that all four students enjoyed the computer sessions, and three of the four students were able to accurately recall most of the steps of the strategy.

Discussion

The amount of research devoted to mathematics instruction for students with mental retardation has remained relatively constant over the past 25 years. Mastropieri et al. (1991) reviewed 25 studies spanning a 15-year period; in the present review, we located 16 studies spanning a 10-year period. The emphasis, however, has shifted from basic skills instruction to computation and problem-solving instruction. Based on the current review, students with mental retardation benefited from interventions stressing frequent feedback, explicit instruction, and ample drill-and-practice. These approaches conform to the traditional behaviorist methods of teaching students with disabilities. Techniques such as constant-time delay, peer tutoring, time trials, and direct instruction continue to prove effective for teaching students with mild to moderate mental retardation. However, we have discovered that students with mental retardation learned to employ cognitive strategies effectively when the strategy instruction included these elements. This was especially evident in the problem-solving studies and in the concrete-representational-abstract study. Strategy instruction promoted student independence in addition to increasing mathematics performance. These interventions may be particularly useful when considering the supports necessary for placement of students with mental retardation within inclusive settings. Computer use did not significantly improve mathematics performance when compared to traditional teacher-directed instruction. However, computers were used successfully when students practiced cognitive strategies with specially designed software.

Recommendations for Practice

Teachers can use the existing body of knowledge to plan mathematics instruction incorporating both the behaviorist and the constructivist approaches. As noted by Baroody and Ginsburg (1990), children bring with them to school an informal knowledge of mathematics and the world. For children just learning mathematics, this knowledge includes the ability to count on and to discover patterns. For example, children learn at home that four cookies are more than three cookies. Teachers can link this informal knowledge to new strategies and skills and, by so doing, combine both constructivist and behaviorist approaches in their daily lessons.

After a preassessment to determine individual strengths and weaknesses, the teacher might structure the mathematics period as follows. First, a one-minute daily timing might be used to promote fluency and retention of previously learned facts. Each student in the class could work on an individually tailored worksheet during this time. Next, step-by-step strategy instruction could be given to the whole group. In several of the reviewed studies, a direct instruction method was used to teach strategy...
steps. For example, students might be taught to “count-up” in beginning subtraction. Introduction of a self-regulation routine would be helpful here. Then, students could be divided into small groups for problem-solving practice involving the strategy just practiced. The groups could be based on the individual computation skills students are practicing. Hypothetically, each group could be given a bucket of beads and asked to determine whether there are more blue beads than green beads. Then, the students could apply their newly learned strategy to determine how many more of one color there is than of the other color. Over time, students should be encouraged to use a variety of manipulative devices and schematic drawings to develop possible solutions to the problems and to discuss the process as they work. During this time, the teacher would monitor the groups and ask leading questions based on students’ informal knowledge of mathematics and application of strategies. Finally, individual instruction in basic skills or computation might be appropriate. This could include use of the computer, peer tutors, or teacher-directed instruction using methods such as constant-time delay or a tactile-kinesthetic approach.

As shown by this review, more of the current researchers are beginning to focus on multi-step, higher-level computation and problem-solving for students with mental retardation. Preliminary results from these studies are encouraging, but additional research is needed. Specifically, studies with larger sample sizes are needed to validate the current knowledge base. In addition, there is a need for more research with students at the secondary school level. Finally, because increased numbers of students with mental retardation are receiving mathematics instruction in general education classes, studies need to be conducted in these settings incorporating both behaviorist and constructivist approaches.

References


References in boldface denote studies included in the review.

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