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Teaching Mathematical Problem Solving to Middle School Students in Math, Technology Education, and Special Education Classrooms

Brian A. Bottge
Mary Heinrichs
Zara Dee Mehta
Enrique Rueda
Ya-Hui Hung
Jeanne Danneker
University of Wisconsin-Madison

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Abstract

This study compared two approaches for teaching sixth-grade middle school students to solve math problems in math, technology education, and special education classrooms. A total of 17 students with disabilities and 76 students without disabilities were taught using either enhanced anchored instruction (EAI) or text-based instruction coupled with applied problems (TBI). Results showed that both EAI and TBI students benefited from instruction in their math class, but EAI students were able to maintain and transfer what they learned in the technology education classroom several weeks later. The performance level of students with disabilities was low in both groups, but additional small-group instruction in special education settings helped several students with disabilities achieve at levels commensurate with their peers without disabilities.

In its recent report, the National Middle School Association (NMSA) emphasized the importance of integrating curriculum formats to help middle school students master basic skills and develop more complex levels of thinking *(NMSA Position Statement on Curriculum Integration,* NMSA, 2002). The authors suggest that teams of teachers should identify common concepts in their curricula that are grounded in real-world contexts and then teach them across subject areas. Accomplishing this goal would help to ensure that every student is prepared for life beyond school, a theme emphasized in the *Carnegie Corporation Report, Turning Points 2000: Educating Adolescents in the 21st Century* (Carnegie Corporation, 2000).

The NMSA and Carnegie recommendations are closely aligned with workforce expectations. For example, government reports (e.g., *What Work Requires of Schools: A SCANS Report for America 2000*, U.S. Department of Labor, 1991) state that success in the workplace depends on the ability of workers to use their academic skills in social contexts to solve important problems. In addition to these content-oriented skills, employees are expected to communicate orally and in writing with individuals of diverse backgrounds, form and test hypotheses, and perform simple tasks on personal computers (Gray & Herr, 1998; Murnane & Levy, 1996).

Helping students identify and understand the contextual elements of problem situations is not a new idea. Early in the last century, several writers recognized the importance of context in transferring skills from one situation to another (Thorndike, 1922; Thorndike & Woodworth, 1901; Whitehead, 1929; Woodworth, 1921). Contemporary theorists have also emphasized the importance of incorporating contextual factors in learning, naming this pedagogical approach *situated cognition* (Brown, Collins, & Duguid, 1989; Greeno & the Middle School Mathematics Through Applications Project Group, 1998; Lave, Smith, & Butler,1988) or *contextualized* or *anchored instruction* (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Cognition and Technology Group at Vanderbilt, 1997).

Despite the progress in mathematics reform (e.g., National Council of Teachers of Mathematics, 1989, 2000), large differences still exist in the ways students use mathematics in school and workers apply mathematics in job settings (Boaler, 1998; Masingila, 1993; Smith, 1999). School-based problems are typically embedded in text-laden descriptions, which some students with low math *and* reading skills cannot understand and do not find motivating (Cawley, Parmar, Foley, Salmon, & Roy, 2001; Ellis, 1998; Miller & Mercer, 1997; Mtetwa & Garofalo, 1989). The inability to comprehend text severely limits these students' ability to construct the mental models, or pictures, of problem contexts that are necessary for solving authentic problems (Norman, 1983; Shepard & Cooper, 1982).

In mathematics, essential work skills include the ability to compute fractions and decimals, interpret tables and graphs, manipulate algebraic formulas, and solve problems with fellow workers. Ethnographic studies have provided insight into the kinds of mathematics problems that workers solve on the job. For example, carpet layers know that carpet comes in standard widths, the nap must all run the same way, and seams should be placed out of heavy traffic areas (Masingila, 1993). Tile installers need to be able to lay tile symmetrically from the center of a room and then shift tiles as needed to eliminate or reduce waste at the outer edges. Automobile assembly workers measure tolerances in English or metric systems according to machine and part specifications (Murnane & Levy, 1996; Smith, 1999). In each profession, the problems and procedures (i.e., number and nature of math operations) are constrained by the context.

For several years, we have investigated ways to help students with and without learning disabilities gain deeper understandings of mathematics in contextualized learning environments based on a theoretical model of teaching and learning mathematics we call the Key Model (Bottge, 2001) (see Figure 1).

At the center of the model is *Enhanced Anchored Instruction* (EAI), a pedagogical approach that contrasts sharply with traditional *text-based instruction* (TBI). EAI is a form of anchored instruction (Cognition and Technology Group at Vanderbilt, 1997) that situates, or "anchors," problems in authentic contexts (Newmann, Secada, & Wehlage, 1995) that students find meaningful. Video-based problems on CDs, called *anchors*, are especially motivating for students with low reading skills because they can immediately access the problems embedded in the anchor without having to decode and comprehend word-based problems. EAI also extends students' learning by affording them opportunities to apply their skills in building hands-on projects (e.g., skateboard ramps, compost bins, hovercrafts). EAI brings together teams of mathematics, special education, and technology education teachers with diverse but complementary skills to plan, develop, and deliver the unique curriculum.

Previous studies have shown that average- and low-achieving students who were taught with EAI solved sophisticated problems in mainstream and remedial math classrooms and were more successful in applying what they learned in technology education classrooms than students who were taught with TBI (Bottge, 1999; Bottge & Hasselbring, 1993; Bottge, Heinrichs, Chan, & Serlin, 2001). In a recent study conducted in inclusive classrooms, the same positive results were found for students without disabilities (Bottge, Heinrichs, Mehta, & Hung, 2002). However, the findings were equivocal for students with disabilities. Close observations of students with learning disabilities showed that some either copied the work of more capable students or did not participate at all.

The overall purpose of this study was to compare students' math performance after they learned with EAI or TBI in their math classroom and to assess their problem-solving skills in the technology education classroom several weeks later. The second objective was to investigate how much additional instruction was necessary to help students with disabilities perform at the level of their average-achieving classmates.

Method

Participants

A total of 93 sixth-grade students in four math classes in a middle school located in the upper Midwest participated in the study, which spanned seven months from November through May. Descriptive information is provided in Table 1. Seventeen students were receiving special education services and 13 of these students had been diagnosed with LD. According to the Wisconsin Department of Public Instruction (2002), students may have a learning disability when they do not achieve commensurate with their age and ability levels and have functional achievement at or below 50% of expected achievement (derived by the formula: IQ x Years in School x .5 = Grade Score).

Two math teachers (Ann and Marj) each taught one EAI class and one TBI class during the first phase of the study. Ann had a master's degree in learning disabilities and reading and an additional 24 credits in curriculum. She was in her 26th year of teaching and was licensed to teach general education in Grades 1–8, reading in Grades K–12, and all students with disabilities except those with sight and hearing impairments. The other math teacher, Marj, had taught general education for nine years in Grades 1–6 and was also licensed to teach students with learning disabilities (LD) in Grades K–8. Connie, a special education teacher, had a master's degree in emotional disabilities (ED), certification to teach LD, and was in her sixth year of teaching. She assisted students with LD/ED in the general education classrooms and also helped students who needed additional academic assistance in her resource room. Russ was in his second year of teaching and taught the technology education classes.

Classes of students were randomly assigned to EAI or TBI because the school schedule could not be changed to assign individual students to instructional groups. Non-White students constituted a higher percentage of Marj's classes (18/47 or 38%) than Ann's classes (13/46 or 28%), although the overall percentage of non-White EAI and TBI students was equal (33%). Marj's classes also included a larger percentage of students with disabilities (28%) than Ann's classes (9%), but the percentage of students with disabilities in EAI and TBI was almost the same (18% and 19%, respectively), as was the total number of minutes per week students received special education services.

On pretests administered prior to instruction, the means and standard deviations of all EAI and TBI students were 26.1 (SD = 11.0) and 25.3 (SD = 11.8) on fractions computation, $t(89) = .33$, $p = .74$, 24.0 (SD = 10.1) and 23.7 (SD = 9.7) on the word problem test, $t(88) = .16$, $p = .88$, and 6.1 (SD = 3.2) and 5.4 (SD = 3.7) on the video problem test, $t(78) = .89$, $p = .38$. An attitude questionnaire was also administered to gauge the students' general impressions about math. In both groups, just over a third of the students indicated they like math.

Research Design and Instrumentation

We employed a nonequivalent pretest-posttest design coupled with a finer-grained analysis of teacher and student performance to answer the research questions. Several authors (e.g., Gersten, Baker, & Lloyd, 2000; Mastropieri, Scruggs, & Shiah, 1991; Woodward & Baxter, 1997) have urged researchers who study special populations to use experimental methods to test the effects of interventions on student achievement and in-depth descriptions to uncover the contextual factors that may have contributed to these performances.

The study was conducted in two phases. During Phase 1, Ann's and Marj's mathematics classes were randomly assigned to either EAI or TBI, yielding two EAI and two TBI groups. Immediately before and after instruction, students in the four classrooms took a test emphasizing computation with fractions and two problem-solving tests. A week after students finished the posttests, three students with LD and one student with the disability label, Other Health Impaired (OHI), (2 from EAI and 2 from TBI) worked in pairs in the special education resource room to learn the concepts that they had not learned, as documented by their scores on the problem-solving posttests. Connie, who helped the students with disabilities in the mathematics classrooms, supervised the work of the students and answered questions to clarify obvious misconceptions they had about the problems. Immediately after they had solved the EAI video-based problem, they took the video problem-solving test again.

Phase 2 took place in technology education classes that included cohorts of students (including students with disabilities) who learned with EAI or TBI in their math classes 6, 13, and 22 weeks before. The main objective of the class was to engage students in applying the skills they had learned in the math class to plan and build a hovercraft frame in the technology education classroom. Students were assessed before and after they worked on the project.

The content validity of the tests was supported by their use in previous studies (e.g., Bottge, 1999; Bottge & Hasselbring, 1993; Bottge et al., 2002) and by previous research showing that the test items reliably estimated mathematics achievement (Cohen, Bottge, & Wells, 2001). We calculated the interrater reliability of each measure on 20% of the test protocols from a randomly selected sample of pretests and posttests by dividing the number of agreements by the total number of agreements and disagreements and multiplying by 100 (Sulzer-Azaroff & Mayer, 1977).

Fractions computation test. An 18-item, 36-point computation test assessed students' ability to compute fractions. Twelve items asked students to add and subtract simple fractions with like denominators, mixed numbers without renaming, and mixed numbers with renaming. We awarded students one point if they correctly renamed fractions before computing them and one point if they expressed the correct answer in simplest terms. Cronbach's coefficient alpha was .98, and interrater reliability was 99% (range = 94%–100%).

Word problem test. We developed an 18-item, 36-point test with a reading level at or lower than fourth grade to measure students' ability to solve single-step and multistep word problems. Students could earn one point per item for showing how to solve the problem (i.e., correct operations) and one point per item for arriving at the correct answer. The content of the items paralleled the instruction in EAI and TBI, which included using information from charts and figures to compute linear measurements and calculating construction costs. Cronbach's coefficient alpha was .97, and interrater reliability was 99% (range = 92%–100%).

Video problem test. Based on work from previous studies (Bottge et al., 2002), we developed a 36-point assessment to measure students' ability to solve the problem presented in the video Fraction of the Cost. The test was finalized only after undergoing five revisions based on the recommendations of two raters who scored protocols of students not involved in the study. Partial or full credit was awarded on 15 procedures in five major categories: computing money; indicating the lengths of two-by-fours (2 x 4 dimensional lumber) the students measured in the garage; converting lengths of wood from feet to inches; showing combinations of lengths of lumber; and calculating the total cost.

The test was administered in math class in the following way: First, the teacher asked students to watch the video once without interruption and to pay close attention to the questions at the end. After checking the students' understanding of the problems they were to solve, the teacher showed the video a second time. Then the teacher gave each student a five-page packet that contained relevant and irrelevant information for solving the problems in the video, such as a savings statement from a bank, building plans for a skateboard ramp, and a newspaper flier showing a sale on building supplies. The teacher asked the students to show how to solve the problems in a 6 x 6 in. work area on the problem response form. Cronbach's coefficient alpha was .80, and interrater agreement was 94% (range = 64%–100%).

Hovercraft problem test. A 22-point performance-based assessment in the technology education class asked students to show how they would use lengths of polyvinyl chloride (PVC) pipe in the most economical way to build a "rollover cage" for a hovercraft, based on a drawing, a materials list, and a specified amount of money. The content of the problem closely aligned with the problems students had solved in EAI and TBI in their math class. Students had to calculate and compare sums of money, add and subtract fractions, and figure out combinations of PVC pipe that would enable them to build the hovercraft cage with the money available. Unlike the problems they solved in math class, the hovercraft problem required students to make their calculations based on real-life constraints. For example, PVC pipe is sold only in 10 ft. lengths, unlike two-by-fours, which are available in 6 ft., 8 ft., and 10 ft. lengths. Students also had to figure out how many 45- and 90-degree connectors they needed to hold the cage together, calculate the cost of the connectors, and add this amount to the total cost.

Like the problems in TBI, the hovercraft problem included diagrams and text-based descriptions of the problem on paper (not video). Like the problems in EAI, the text-based descriptions were brief and easy to read. Students described their solutions in an open work area on a single page of paper as they had on the problem-solving tests. The scoring protocols included eight criteria we had identified from field tests and previous studies. Raters were trained on scoring papers with the protocols from tests administered to students who were not involved in this study. Cronbach's coefficient alpha was .94, and interrater agreement was 91% (range = 60%–100%).

Instructional Materials and Teaching Procedures

Phase 1: Instruction in the Math Classroom

EAI. The video anchor *Fraction of the Cost* depicts three students who decide to construct a skateboard ramp rather than buy one. They find some two-by-fours in the garage that they can use for the project, but they must calculate how much additional wood and other materials they need to build the ramp. To determine how much money each student can contribute to the project, the students must add and subtract whole numbers and calculate percentages.

To solve the problem, students accessed relevant information on the CD, which included the dimensions of the skateboard ramp, the cost of materials, and the money available for buying the materials. Using this information, the students attempted to determine (a) the amount of money they had to spend if they pooled it, (b) the most efficient use of the wood they already had, (c) the materials they needed to build the ramp (lengths and quantity of screws, lengths of two-by-fours, thickness of decking material), and (d) the most efficient use of the wood they still needed to buy. Students received full credit for showing one of the two possible solutions to the problem. Students could also receive partial credit if they provided a close but not totally accurate solution. Within six 45-minute class sessions, most groups of students had arrived at one of the five full or partial solutions.

The teachers facilitated class discussions by asking students questions such as, "What are some of the things you need to know when solving the problem?" These classroom discussions helped keep the students on track and reinforced their newly acquired understandings. Students could test their ideas by measuring two-by-fours in the classroom that had been cut to the same lengths as the wood shown in the video. Students could also inspect a small-scale model of the ramp to determine how the ramp frame was put together. The teachers instructed the students to work in pairs. On the last day of Phase 1, the groups presented their solutions to the rest of the class.

TBI. Students in TBI worked on solving word problems and constructed response problems that were not posed in a video format. The teacher taught students an eight-step strategy for solving word problems: read, paraphrase, visualize, (re)state, hypothesize, estimate, compute, and self-check (Montague, 1997). The teachers encouraged the students to create a mnemonic device to help them remember the eight-step process. Students created mnemonics such as "Robert picked very red hot eggplants cause he's crazy" or "Remember parents very realistically hope that every child can." As the teacher displayed each word problem using an overhead projector, students discussed how to solve the problem and then wrote their answers in their folders. The following are examples of the word problems:

- *Word problem 1*. During the first week in January, Mary earned $43.00 at her job at Pizza Hut. She spent $24.75 on clothes and $10.75 on entertainment. Her friend, Ann, bought her lunch at Burger King for $3.25. How much money did Mary have left out of her first week's paycheck?

- *Word problem 2*. Roy wanted to build a model glider. The main wing needed to be 25 1/2 in. long. The back wing had to be 6 3/4 in. long. How much wood was needed for both wings?

After students finished solving the word problems, they worked on the worksheets in their packets while they waited for their classmates to finish the word problems. This format allowed the students to work at their own pace. On average, the class managed to solve two to three problems a day.

Each day after students solved the word problems, the teacher gave them hands-on problems that complemented the concepts taught in the word problems. Each problem engaged students for two or more class sessions. The following are examples of the hands-on problems:

- *Applied problem 1*. The purpose of this project was for students to work in pairs and build a picnic table out of straws. Each student pair was given six straws that were to be assumed to measure 8 ft. length. The students' finished table had to have a top and be strong enough to support an egg. Once a pair of students had created their table, they had to measure the table's dimensions, create blueprints, calculate the cost of their final product, and check its weight capacity.

- *Applied problem 2*. The goal of this project was for students to build the cheapest, strongest, and tallest structure measuring a minimum of 20 in. in length and 18 1/2 in. in height. Upon completion, this structure had to support a brick for 20 seconds. The students were given an imaginary budget of $100 with which they could purchase paperclips, cards, and a fold in the card for $1 each.

The students in TBI worked on these applied problems and other word problems in their academic classroom for six days.

Posttest scores and classroom observations showed that several EAI and TBI students with disabilities did not understand the concepts that they were supposed to have learned in the math classroom. We decided to test whether four of these students would profit from more individualized instruction on solving the video-based problem. Two students from the EAI group and two students from the TBI group worked in pairs with the special education teacher in the resource room for 50-minute sessions over five days. The intervention group also served as a pilot group to test revisions and additions to the *Fraction of the Cost* video, including a color-coded, rotating ramp; an interactive, click-and-drag help module; and a talking calculator to help students compute whole numbers. Each pair of students shared one laptop computer, which they used to search relevant parts of the video. They also used the click-and-drag modules of the CD to help them visualize the best way to use the wood.

Phase 2: Related Instruction in the Technology Education Classroom

In the technology education classroom, EAI and TBI students worked on building a hovercraft rollover cage as economically as possible out of four 10 ft. lengths of PVC pipe and connectors. The central concepts in the hovercraft project paralleled those taught in the math classrooms 6, 13, or 22 weeks before. Before they built the cage, students worked on designing and building scale models of a house and a hovercraft frame out of drinking straws. The students voted on the four best designs, which they then used to construct the full-size hovercraft cage. Once the cages were complete, the students lifted them onto a 4 x 4 ft. plywood platform (i.e., the hovercraft) and inserted a leaf blower into a hole in the plywood. The leaf blower elevated the hovercraft slightly above the floor. Students took turns riding the hovercraft and competed in relays, racing from one end of the technology education classroom to the other.

Fidelity of Treatment Implementation

Several methods helped ensure that teachers followed the instructional plans. During Phase 1, one researcher observed the EAI and TBI classrooms 100% of the time. On 10% of those occasions, a second observer was present. Independently, the observers took notes on the classroom activities and later compared their notes, identifying similarities and differences. Although no substantive discrepancies in instruction were noted, minor inconsistencies in the amount of detail provided to students and in the pacing of lessons were brought to the teachers' attention. One researcher attended all of the classes in the special education classroom. During Phase 2, a researcher attended 81% of the class periods, with a second observer also on hand 10% of the time. Several class periods were also videotaped, which provided a readily available look at what transpired during all three phases of the study.

Results

We describe the results in two ways to provide the most complete picture of the findings. In the first section below, we present statistical analyses of the test performance of all students (with and without disabilities) who participated in the learning activities in the mathematics and technology education classrooms. In the second section, we provide a more detailed description of how students with disabilities fared on the math problems in the mathematics, special education, and technology education settings.

Performance of Students with and without Disabilities

Math classroom. Table 2 reports the obtained and adjusted means and standard deviations of the participating students. We conducted 2 x 2 analyses of covariance (ANCOVA) on the fractions computation, word problem, and video problem posttests, with each pretest serving as the covariate. One factor was the class (Ann's or Marj's), and the other was the type of instruction (EAI or TBI). (The probability of Type 1 error was maintained at .05 for all subsequent analyses.)

Results were mixed across the three posttests. On the *fractions computation test*, there was a significant interaction between class and type of instruction, $F(1, 77) = 4.14$, $p = .04$, $\eta^2 = .05$, but there was no main effect for class, $F\ (1, 77) = .55$, $p = .46$, $\eta^2 = .01$, or for instruction, $F(1, 77) = 1.34$, $p = .25$, $\eta^2 = .02$. Taking into account differences in pretest scores, the adjusted posttest mean of Marj's TBI class was 2 to 3 points higher than those of the other three classes. On the word problem test, there was a main effect for type of instruction in favor of TBI, $F(1, 83) = 9.30$, $p = .003$, $\eta^2 = .10$, but not for class, $\mathrm{F}(1, 83) = 1.43$, $p = .23$, $\eta^2 = .02$, or for class by type of instruction, $F(1, 83) = .31$, $p = .58$, $\eta^2 = .00$. On the video problem test, there was a main effect for type of instruction in favor of EAI, $F(1, 67) = 17.32$, $p = .000$, $\eta^2 = .21$, but not for class, $F(1, 67) = .05$, $p = .83$, $\eta^2 = .00$, or for class by type of instruction, $F(1, 67) = .96$, $p = .33$, $\eta^2 = .01$.

Technology education classroom. Table 3 shows the scores of students on the hovercraft problem-solving test before and after instruction in the technology education classroom. To determine how much EAI and TBI students remembered from instruction in the mathematics classroom, we conducted a 2 x 3 ANCOVA on the hovercraft pretests, with the fractions computation, word problem, and video posttests serving as covariates. One factor was type of instruction (EAI or TBI), and the other was technology education session (6, 13, or 22 weeks). The analysis showed a main effect for type of instruction in favor of the EAI group, $F(1, 33) = 6.98$, $p = .01$, $\eta^2 = .17$, and for session, $F(2, 33) = 10.32$, $p = .00$, $\eta^2 = .385$, but not for type of instruction by session, $F(2, 33) = .289$, $p = .75$, $\eta^2 = .02$.

We used a 2 x 3 ANCOVA to analyze the performance of students in each group (EAI or TBI) in each technology education session (6, 13, or 22 weeks). The tests showed differences in students' performance depending on the technology education session they attended, $F(2, 36) = 3.75$, $p = .03$, $\eta^2 = .17$. Students in the last technology education cohort scored almost 3 points higher than students in either of the other two cohorts. There were no differences for group, $F(1, 36) = .31$, $p = .58$, $\eta^2 = .01$, or for group by session, $F(2, 36) = .37$, $p = .70$, $\eta^2 = .02$.

Performance of Students with Disabilities

Because of the small sample size of students with disabilities in each group, statistical tests could not be conducted. The combined posttest scores of students with disabilities in the EAI and TBI groups were about half those of students without disabilities: 15.1 with disabilities, 29.7 without disabilities on computation test; 15.2 with disabilities, 27.6 without disabilities on word problem test; 7.9 with disabilities, 12.2 without disabilities on video test. However, all four students who worked on the EAI problem in the special education setting improved their posttest scores considerably over what they had earned the first time they took the video posttest (2 pretest, 30 posttest, +28 points; 0 pretest, 21 posttest +21 points; 11 pretest, 34 posttest, +23 points; 9 pretest, 28 posttest, +19 points). In the following paragraphs, we describe in detail the work of two students with disabilities (Will, Serena) whose performance is representative of the other two students with disabilities who received small-group instruction on the video-based problem.

Will. Will had a pleasant disposition and was motivated to learn math. His individualized education program (IEP) stated that he was a "slow learner" with learning disabilities who needed special education services in speech and language and in math. Each week, he received five hours of math instruction and one hour of speech instruction in the regular or special education classroom.

Will watched the video-based problem in the math classroom with interest. The video shows three friends—Cindy, Ryan, and Michael—deciding that they should each contribute the same amount money to the skateboard ramp project. Cindy has $19 left over from her birthday money and is allowed to spend all of it. Ryan has $210 in his savings account and is allowed to withdraw 10% at a time. Michael has $73 in his savings account and must keep a minimum balance of $50. Together, the friends have a total of $63. This amount divided by 3 is $21, $2 more than Cindy can afford. Because Cindy has only $19, the total amount the friends can spend on the ramp is $57.

Will understood that Cindy could spend $19 and that Michael could spend $23 ($73 - $50), but he did not know how to calculate 10% of Ryan's savings account balance. He wandered to a neighboring group to find out how much Ryan could spend. When he obtained this information, he went back to his own group and tried to convince his partners that the three friends could spend $57. On subsequent days, Will searched portions of the video for more relevant information but also continued to ask students in other groups for answers to the other subproblems.

During two days in the math classroom, the special education teacher remarked that Will was "extremely engaged." She added that "he likes the video, measuring, and the ramp. It is the tactile stuff that he really likes." Although Will worked diligently on parts of the problem, he did not contribute much to whole-class discussions. Notes from classroom observations revealed that he became frustrated when he was unable to add mixed numbers (lengths of wood available for building the ramp). Will improved his computation scores from 4 on the pretest to 15 on the posttest, but he showed little or no new understanding of the video problem (pretest = 0, posttest = 2).

In the resource room, Will worked with another student with disabilities, Serena, to solve the video problem. Will was excited about getting the chance to work on the computer. He remembered from the math classroom that each person in the video had contributed $19 to the project. He seemed proud of himself after computing 10% of $210 with a calculator and adding each person's contribution ($19 + $19 + $19 = $57) without help. However, Will was confused as he tried to find the dimensions of each part of the ramp shown in the video that corresponded to the dimensions of lumber in the schematic drawing. On the next day, he used the color-coded click-and-drag module to figure out which lengths of wood on the CD corresponded to the dimensions in the plan.

On the final day of the intervention in the resource room, Will and his partner calculated the total cost of building the skateboard ramp. Unfortunately, Will did not get the chance to construct the hovercraft cage in the technology education classroom because his family moved out of the school district.

Serena. Serena was labeled “other health impaired” (OHI), did not like school, and seemed unhappy much of the time. One day, her math teacher asked why she had not come to school the day before. Serena answered “... because I did not feel like or want to come to school, so I didn’t.” When the other students were engaged in solving the TBI problems in the math classroom, Serena said very little and did not interact with the teacher or the other students. In fact, whenever students came too close to her, Serena reacted violently, trying to poke them with her pencil. When she was not staring blankly into space, she drew pictures of devils covered in blood.

In the resource room, Serena at first complained about having to solve the video problem. However, she and her partner, Will, gradually grew more interested in the problem when they realized that they had the computer all to themselves. Serena took charge of the mouse and told Will that “we should write something down so we can buy something.” She paused at several points in the video where she thought important information was located, such as the store ad that listed the cost of lumber, screws, and other materials. At one point, she told Will that the students in the video needed to use treated lumber to build the ramp or else the ramp would warp (one of the students in the video provided this fact). Serena used a calculator to compute costs and then checked her findings with Will’s.

One day, Serena and Will got into a debate about how many two-by-fours the students in the video needed for the ramp. Serena counted seven (the correct answer), but Will insisted they needed more. So Serena explained to Will how she arrived at seven. When she could not convince him that they needed seven boards, she hit her head with her hand in frustration. Together, Serena and Will eventually figured out that Will had mistakenly added the two-by-fours in the garage to the two-by-fours they needed to buy.

In the resource room, Serena’s behavior changed drastically. She seemed happy and took charge of solving the problem. For example, she teased Will about not copying prices of materials into their problem-solving booklet as fast as she did. She told him that he was “as slow as heck.” As Serena became more engrossed in the problem, she did not mind that Will’s arm almost touched hers. On only a few occasions did she point her pencil at Will as if she were going to stab him.

In the technology education classroom, Serena returned to the behaviors she had exhibited in the math classroom. At times, she seemed interested in the classroom activities, but she became withdrawn at other times. When the technology education teacher asked students to build the largest house possible using plastic straws, Serena was interested and engaged. In fact, she built the second-largest house in the class. She was surprised by her accomplishment and visibly excited. However, this excitement faded as the students began to design the hovercraft cage. Once again, she lost interest and did not communicate with her classmates or participate in the planning.

Discussion

The purpose of this study was to compare the math achievement of students with and without disabilities in several learning contexts and instructional conditions. Our results show that, overall, students in the mathematics classroom learned with EAI or TBI. That is, EAI students scored higher on the video problem test than TBI students and, conversely, TBI students scored higher on the word problem test than EAI students. These results are not surprising because we would expect students to score better on well-designed, curriculum-aligned measures. Despite the practice students gained in computing fractions while working on both kinds of problems, no differences were found in computation scores of either group.

Several weeks later (6, 13, 22), students were tested in the technology education classroom on a transfer test that was similar in concept but different in format than the ones they had worked on in their math classroom (EAI or TBI). This transfer task was actually the pretest for an applied problem that the math, technology education, and special education helped the researchers design. Results of the transfer test showed that EAI students remembered the central concepts they had learned in the math classroom better than TBI students did.

Posttests administered after instruction on the hovercraft construction showed that instruction in the technology education classroom closed the achievement gap between EAI and TBI students.

Four students with disabilities who received extra help on the video-based problem in the special education classroom improved their scores on the video test by almost 23 points. This was a remarkable improvement considering they only spent four additional days working on it with the special education teacher in her resource room. Their scores on the hovercraft tests indicated little or no transfer of concepts from the math to the technology education classroom.

Limitations

Several limitations temper our findings. First, the school schedule forced us to use intact classes and did not permit us to assign students randomly to instructional groups. Second, we were unable to analyze with statistics the scores of students with disabilities because of the relatively small number of students in each comparison group. Third, absences from school and transfers to other schools reduced the number of students who participated in all phases of study. We had anticipated and planned for this problem, but the attrition rate was higher than we expected.

Practical Significance

In this study, mathematics, special education, and technology education teachers with diverse but complementary skills joined together to plan, develop, and deliver the central concepts embedded in the math and technology education curriculum. The impact of each teacher was clearly evident throughout the study. The math teachers assisted students in interpreting and illuminating the math concepts embedded in the EAI and TBI problems. When the special education teacher realized that some of the students with disabilities did not understand how to solve the problems in the math classroom, she used her specialized skills to help them in the resource room.

The technology education teacher translated the math concepts into a motivating project that asked students to apply and practice what they had previously learned. In this study, the hovercraft project motivated students to do academic work, in keeping with recommendations by the President's Committee of Advisors on Science and Technology (PCAST, 1997) and the International Society for Technology in Education (ISTE) National Educational Technology Standards Project (ISTE, 1999) that recommended technology education focus on learning, emphasizing content and pedagogy, not just hardware. In this study, students benefited from the opportunity to learn using the video-based anchors in the math classroom and the hovercraft projects in the technology education classrooms.

As for accommodating the needs of students with disabilities, this study showed that instruction in general education classrooms without additional, individualized help was not sufficient to raise their academic performance. However, the four students who received additional instruction from a skilled special education teacher scored well above the average of their peers without disabilities on the video posttest. For a variety of philosophical, legal, social, budgetary, and educational reasons, special educators are advocating for students with disabilities to be educated alongside their peers without disabilities in general education classrooms. Although some authors have found that the performance of students with disabilities in inclusive classrooms equals or surpasses their performance in pullout settings (e.g., Rea, McLaughlin, & Walther-Thomas, 2002), the results of this study support other authors who warn that even in general education classes with small groups of students, some students with disabilities do not get the individualized attention they need to understand the academic content (Baxter, Woodward, Voorhies, & Wong, 2002, Bottge et al., 2002; Kauffman, 1999).

The goal of designing and implementing instructional materials and plans across subject areas was, for the most part, achieved in this study. Students without disabilities profited from the contextualized instruction in their math classroom as demonstrated by their ability to transfer their skills across content areas. However, the results also showed that students with disabilities required more attention than both the general education and special education teacher could give in the whole-class setting. When the instruction was individualized to the needs of students with disabilities, they were able to profit from the integrated curriculum.

Brian A. Bottge is an assistant professor in the Department of Rehabilitation Psychology and Special Education, University of Wisconsin–Madison; Mary Heinrichs is an associate researcher at the Wisconsin Center for Education Research; Enrique Rueda is a multimedia artist and design specialist at the Wisconsin Center for Education Research; Zara Dee Mehta, Ya-Hui Hung, and Jeanne Danneker are doctoral students in the Department of Rehabilitation Psychology and Special Education. Correspondence may be addressed to: Brian A. Bottge, 432 North Murray Street, Room 431, Madison, Wisconsin 53706. E-mail may be sent to: bbottge@education.wisc.edu.

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Figures and Tables

FIGURE 1. Enhanced Anchored Instruction Based on Key Model of Learning Mathematics

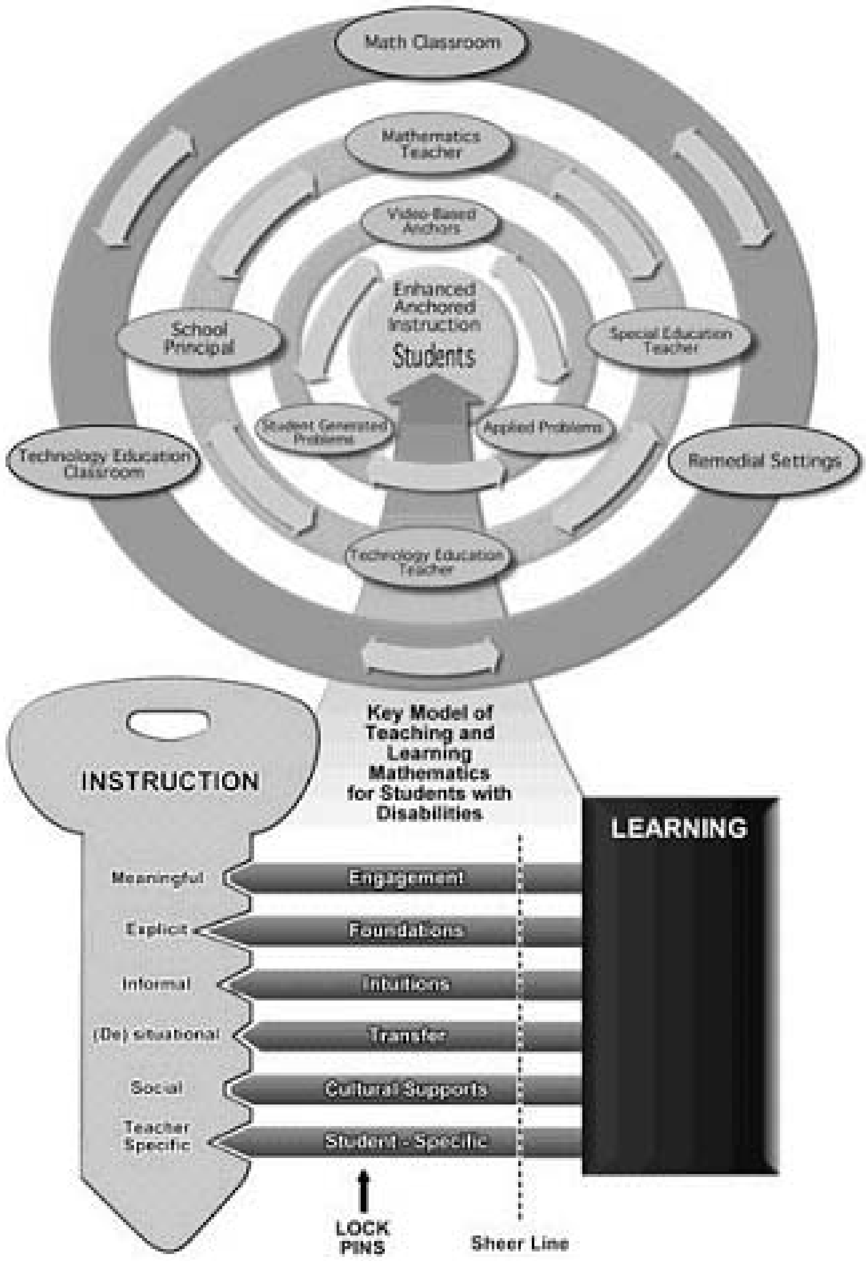

TABLE 1. Description of EAI and TBI Students in Ann's and Marj's Math Classes

	Ann's Classes		Marj's Classes	
	EAI	TBI	EAI	TBI
N	22	24	23	24
Gender				
Boys	10	12	12	15
Girls	12	13	11	9
Ethnicity				
Caucasian	15	18	15	14
African American	1	3	5	7
Asian	3		2	2
Hispanic	2	2		1
Middle Eastern	1	1	1	
Special Education (SPED)				
LD [a]	2	1	4	2
SL [b]				1
LD & SL			1	3
OHI [c]		1	1	1
Total students in SPED	2	2	6	7
Minutes/week SPED	300	390	3042	3290
Attitude Questionnaire				
Like math				
Yes	6	7	11	10
Sometimes	13	11	10	9
No	2	0	1	0
Need to know math				
Yes	15	16	19	17
Sometimes	4	0	2	1
No	2	2	1	1

[a] Learning Disabilities [b] Speech and Language [c] Other Health Impaired

TABLE 2. Obtained and Adjusted Means of Students in EAI and TBI on Three Measures

	Ann's Classes		Marj's Classes	
	EAI	TBI	EAI	TBI
Fractions Computation Test				
N =	19	21	21	21
Pretest				
M	29.05	27.19	24.52	23.95
SD	7.8	11.0	12.8	11.6
Posttest				
Obtained M	29.37	26.95	24.24	26.52
SD	7.1	11.5	11.9	10.8
Adjusted M	26.76	26.00	25.64	28.43
Word Problem Test				
N =	21	24	22	21
Pretest				
M	24.62	25.58	23.68	22.52
SD	8.2	7.9	12.0	10.4
Posttest				
Obtained M	25.52	28.17	23.45	25.29
SD	6.8	6.1	11.0	9.0
Adjusted M	25.15	27.04	23.82	26.56
Video Problem Test [a]				
N =	18	22	15	17
Pretest				
M	7.67	5.14	4.13	6.12
SD	2.1	3.6	2.5	4.0
Posttest				
Obtained M	16.89	7.64	12.73	9.47
SD	6.9	2.3	11.0	3.6
Adjusted M	15.66	8.10	13.82	9.26

[a] Some students missed the video problem pretest and posttest because they attended an accelerated math class.

TABLE 3. Obtained and Adjusted Means of EAI and TBI Cohorts on the Applied Problem Test 6, 13, and 22 Weeks After Instruction in Math Classroom

	EAI Instruction	TBI Instruction
6 Weeks		
N =	8	7
Pretest		
M	10.50	5.86
SD	8.6	4.0
Posttest		
Obtained M	12.87	11.86
SD	7.4	9.1
Adjusted M	14.97	17.93
13 Weeks		
N =	11	6
Pretest		
M	16.27	14.00
SD	7.7	8.7
Posttest		
Obtained M	13.27	11.83
SD	8.2	8.5
Adjusted M	10.43	10.94
22 Weeks		
N =	4	7
Pretest		
M	18.75	13.43
SD	5.85	5.9
Posttest		
Obtained M	18.50	13.43
SD	7.0	7.4
Adjusted M	15.54	13.02
Total		
N =	23	20
Pretest		
M	14.70	10.95
SD	8.1	7.1
Posttest		
Obtained M	14.04	12.40
SD	7.7	8.0
Adjusted M	12.98	13.96