Teaching Mathematics and Science Standards to Students With Moderate and Severe Developmental Disabilities

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Abstract:

This study evaluated strategies to teach secondary math and science content to students with moderate and severe developmental disabilities in a quasiexperimental group design with special education teachers randomly assigned to either the math or the science treatment group. Teachers in the math group implemented four math units representing four of the five national math standards. The science teachers implemented four science units representing three of eight national science content standards. A fourth standard, science as inquiry, was embedded within each of the units. Results showed students made gains in respective content areas. Students who received instruction in math scored higher than students who received instruction in science on the posttest of math skills. Likewise, students who received instruction in science scored higher than students who received instruction in math on the posttest of science vocabulary skills. Limitations and suggestions for future research and practice are discussed.

Keywords: science instruction | math instruction | low-incidence disabilities

Article:

Although standards-based reform has been evolving over a period of more than 40 years, it is a relatively new initiative in the field of special education. A little more than a decade ago, special educators were anticipating how standards-based reform would heighten expectations for learning for students with disabilities (McDonnell, McLaughlin, & Morison, 1997; Thurlow, 2002). The Individuals With Disabilities Education Act of 1997 (IDEA) stated that all students with disabilities were required to have access to the general curriculum and be included in state and district large-scale assessments. At the same time, teachers were still learning what teaching to the standards entailed. For example, Maccini and Gagnon (2002) found that teachers of students with learning and behavioral disabilities were not familiar with standards in mathematics and mostly taught basic skills versus algebra and geometry. Teachers of students with severe disabilities were not sure teaching the general curriculum was relevant for this population (Agran, Alper, & Wehmeyer, 2002). The reauthorization of the Elementary and Secondary Education Act, the No Child Left Behind Act of 2001 (NCLB, 2002), reinforced the inclusion of students with disabilities in standards-based reform as these students were identified as a subgroup to be measured for adequate yearly progress in third through eighth grade. Students with significant cognitive disabilities, who had begun participating in alternate assessments after IDEA, now “counted” in school accountability. NCLB (2002) also promoted the use of “evidence-based practices,” which are interventions that have research support.

Unfortunately, educators have had few models for teaching students with moderate and severe developmental disabilities content that links to state standards, especially for mathematics and science. A perusal of the major textbooks on educating students with severe disabilities reveals minimal information on teaching science and mathematics beside health, weather, money, and measurement (Browder, 2000; Cipani & Spooner, 1994; Falvey, 1986; Ryndak & Alper, 2002; Snell & Brown, 2006; Westling & Fox, 2004). Similarly, there is almost no research on interventions in these areas. Although Browder, Spooner, Ahlgrim-Delzell, Wakeman, and Harris (2008) found 68 studies of mathematics in their comprehensive review, most focused on numbers and operations or money management and only a few focused on the other standards of mathematics identified by the National Council of Teachers of Mathematics (NCTM, 2002). Courtade, Spooner, and Browder (2007) found a limited number of studies with science content. A search of the literature using key terms from the National Science Education Standards (NSESs; National Research Council [NRC], 1996) revealed 11 studies in which science content (i.e., weather words, first aid skills, relative position) was taught to this population.

Although the research on teaching mathematics and science to students with moderate and severe developmental disabilities is limited in both quantity and scope, it does offer guidance that effective instruction should occur within a meaningful activity and provide systematic prompting and feedback. In a review of science, Spooner, Knight, Browder, Jimenez, and DiBiase (2010) identified systematic instruction intervention packages (the use of task analysis and time delay in particular) to be evidence-based practices for students with moderate and severe disabilities. In two recent studies, researchers demonstrated that a systematic instruction treatment package including task analysis can be applied to mathematics and science content. In the first, Jimenez, Browder, and Courtade (2008) taught high school students with moderate developmental disabilities to utilize a 9-step algebra task analysis to complete a functional task. Students were able to successfully complete the math equation and solve for *x*. In the second, Courtade, Browder, Spooner, and DiBiase (2010) taught secondary-level special education teachers to implement a 12-step task analysis to instruct students with moderate developmental disabilities to complete guided-inquiry-based science lessons. Both of these single-subject studies provide a foundation for the current research by illustrating how to provide step-by-step task analytic instruction of general curriculum content. What these preliminary studies do not address is whether this task analytic approach can be applied to multiple academic skills in a school year in math and science.

The purpose of the current study was to evaluate mathematics and science interventions that linked to general curriculum content. Because the goal was to demonstrate that a general approach could be used across a wide array of content, one skill set in four standards in mathematics and one skill set in four standards of science were chosen. For experimental control and to phase in teachers beginning a major new curricular endeavor, teachers were randomly assigned to implement either the mathematics or the science intervention.

For math, a literacy-based approach was used that embedded math problems in a story context. Literature in math education suggests that stories can provide a schema for students to organize facts (Anderson, Spiro, & Anderson, 1978; Zambo, 2005). In addition, stories may provide a meaningful context to apply math facts and problems to typical situations in a student's life (Pugalee, 2004). Finally, the process of following a story to solve a math problem can have the added benefit of students practicing literacy skills such as scanning text to identify facts and comprehending the problem to be solved. Research on using read alouds of adapted novels for middle school students provided the framework for how each math story would be presented (Browder, Trela, & Jimenez, 2007). Instead of novels, adapted math stories were developed to be read aloud with the participants.

For science, an inquiry-based approach was used. The NSESs recommend the use of inquiry-based instruction for all students to learn about science in the way it actually works (NRC, 1996). A planning heuristic developed by Magnusson and Palincsar (1995) defined phases of inquiry to include having students (a) engage with materials, (b) investigate, (c) describe relationships, (d) construct explanations, and (e) report findings. The earlier work of Courtade et al. (2010) was used for translating these phases into a 12-step task analysis. Science vocabulary was also taught and tested.

Method

Participants and Setting

The study was conducted in a large urban school system in the southeastern United States. The intervention was conducted by special education teachers in self-contained classrooms where the students received all of their math and science instruction. Participants were identified by recruiting middle and high school special education teachers of the target population and asking them to nominate three to four students who met the following eligibility criteria: (a) full-scale IQ less than 55, (b) adequate vision and hearing to interact with the materials, (c) ability to communicate verbally or with an augmentative communication system, and (d) consistent attendance (absent fewer than two times per month). Ten teachers were recruited, and they then selected up to three to four students each. In the informed consent process, the randomized trials design was explained and teachers agreed to participate in either the mathematics or the science intervention depending on the outcome of a random drawing of their names. Consent was also obtained for students to participate in either an experimental mathematics or science intervention and to be assessed on both. Students continued to receive whatever additional instruction was specified by their individualized education programs.

Teachers. The teachers conducted either the math or the science research intervention. The five teachers for math had a mean of 6 years teaching experience with a range of 2 to 17 years. The five teachers for science had a mean of 7 years teaching experience with a range of 2 to 18 years. Teachers in both groups were considered “highly qualified,” as all had the state’s licensure to teach students with moderate and severe developmental disabilities in Grades K–12. All teachers were female; one science teacher was African American, and the rest were Caucasian. One of the math teachers and none of the science teachers held a master’s degree in special education. None of the teachers were licensed to teach mathematics or science, which was not required at the time of the study for teachers of students who participated in alternate assessment based on alternate achievement standards. Also, none of the teachers had taken any specific coursework in science or mathematics prior to this study. Based on licensure, years of experience, and level of degree, the two groups of teachers were considered comparable.

Students. Most of the participating students were included for lunch and specials but received all of their content instruction in self-contained special education classrooms. There were a total of 16 students in the math group. The students ranged in age from 14 to 20 years with a mean of 16 years. The students’ IQs ranged from 30 to 54, with a mean of 44.85. Of the students, 5 were classified with autism spectrum disorders and 11 with moderate and severe intellectual disabilities. Of the students, 7 were male and 9 were female. In all, 9 of the students were Caucasian, 1 was Hispanic, and 6 were African American. All used English as their primary language.

There were a total of 21 students in the science group. Students ranged in age from 14 to 21 years with a mean of 16 years. Their IQs ranged from 33 to 53, with a mean of 42.90. In the science group, 11 were classified as having autism spectrum disorders and 10 with moderate and severe intellectual disabilities. Of the students, 12 were male and 9 were female. Of the students, 7 were Caucasian, 1 was Hispanic, and 13 were African American. All used English as their primary language. There was no student attrition during the course of this study.

Dependent Variables and Measurement

To choose the content for instruction, the researchers focused on standards that were pivotal to the overall curriculum (e.g., what are sometimes called “power” standards), would be frequently used in the general curriculum content, and could be made meaningful for the participating students. Four NCTM mathematics standards and four NSES science content standards were chosen. For example, in mathematics researchers chose the geometry standard “specify locations and describe spatial relationships using coordinate geometry and other representational systems." The competency goal from the state standard course of study was for students to "represent problem situations with geometric models." Based on the alternate achievement standard (i.e., "identify and describe the intersection of figures in a plane"), students were asked to complete the steps of a task analysis for the math problem (e.g., identify points on a map using facts from the story, draw line segments formed from identified points). In science, researchers used the NSES of "science as inquiry: abilities necessary to do scientific inquiry" across all lessons. One of the competency goals from the state standard course of study aligned to this national standard was to "identify and create questions and hypotheses that can be answered through scientific investigations." To address the alternate achievement standard linked to this standard, students "choose questions, choose procedures with guidance, follow safety procedures, observe, collect data (use measurement tools), analyze data and communicate results in scientific investigation." Teachers were trained to engage students in the inquiry process using a task analysis (e.g., engage, investigate, and describe relationships, construct explanations; see Note 1).

Next, the researchers consulted with university faculty who were experts in middle and secondary math and science education to verify that the standards were priorities within general education. After this verification, the researchers (a) defined the alternate achievement and (b) operationalized this achievement as observable, measurable task analyses (math and science) and as vocabulary to communicate the primary discovery (science). These defined responses were again submitted to the content experts (faculty) for review, and any necessary revisions needed to improve the alignment of the measured responses to standards were made. These task analyses and vocabulary were then developed into data sheets called the math test and the science test. In addition to the content expert's review, a script for test administration and interobserver agreement for scoring (described in the next section) were the methods used to support the technical adequacy of these tests. Both tests were administered by research assistants or a member of the research team. The tests were individually administered to each student once in the fall prior to the professional development and then again at the close of the school year.

The math test. A task analysis was created for the steps for each math standard. For each of the four math tasks, the researcher displayed the needed materials and said, "Show me how to _____ [e.g., find point A]." The student was given 5 s to begin each step of the task analysis. If the student did not complete a step, the researcher completed the step and said, "Keep going." Students received praise for paying attention and working on the tasks. No task-specific prompts or feedback were given. Each step of the task analysis was scored as correct (+) or incorrect (-). This procedure was repeated for the four math tasks. The total correct across all four task analyses formed the math score. There were a total of 39 possible responses.

In the first section of the test there was a 9-step geometry task analysis related to finding points on a plane. The evaluator asked the student to find specific points on a map, draw line segments between the points, and name the figure as a plane. The second section was a 10-step algebra task analysis on solving a simple linear equation. After listening to a story that set up the problem, the student was asked to identify the problem statement, identify key facts from the story, organize facts on a graphic organizer (e.g., algebra prompt), and solve the problem. The data analysis and probability section was a 10-step task analysis. Students interpreted two bar graphs representing information from a story in which votes were tallied to arrive at a choice. The examiner read and pointed to the name of each choice shown on the x axis (e.g., *Lord of the Rings, Harry Potter, Men in Black*). Students were asked to tell how many votes each choice received, then were asked, “Which has the most?” and finally, “Which one is the winning choice?” For the measurement section, the students were asked to solve 10 purchasing problems. The evaluator read a brief story and then stated, “Show how many dollars you give to the cashier.” Although finding the next dollar to make a purchase was taught as a brief task analysis (state the price, count the dollars, add one more), this section of the test was a repeated trial format (10 problems to solve) because of the brevity of the task analysis.

The science test. The first section of the science test was a task analysis of the steps to participate in an inquiry-based lesson. The researcher conducted an inquiry lesson on magnetism (content not taught during intervention) in a group format (inquiry lessons required a group) with the participating students in that class (3-4 students). During the lesson, the researcher gave each student the opportunity to perform the step of the task analysis, waited 5 s, and scored the step as correct (+) or incorrect (-). The researcher alternated which student was asked to respond first. If the student did not complete a step, the researcher completed the step and said, “Keep going.” Students received praise for paying attention and working on the tasks. No task-specific prompts or feedback were given. The total correct across the task analysis steps (12) formed the science inquiry score. This same lesson on magnetism was used in the posttest. Students were also given the Science Vocabulary Test using the vocabulary from all four science standards presented to students with a test binder. The student was asked to identify a vocabulary term (e.g., cell) from an array of four choices by pointing. The vocabulary was tested in three phases: (a) words only, (b) picture symbols only, and (c) matching words to picture symbols. There was a total of 20 terms and a total possible score of 60 (word, picture symbol, and match).

Independent scoring by two observers was performed on 40% of all tests administered. Interobserver agreement was computed as agreements divided by agreements plus disagreements. The percentage agreement was 99% for both mathematics and science. Adherence to the testing protocol was 100% for all sessions observed.

Research Design

A quasiexperimental design was used to examine the effectiveness of the mathematics and science intervention. All students were administered the pretest and posttest for both the mathematics and the science achievement tests. Teachers were randomly assigned to implement either the experimental mathematics or science intervention. Teachers were instructed to continue their typical instructional methods for the other content area. For math, the typical instruction included money or basic computation. Science instruction was more sporadic and typically involved reading science articles that appeared in the weekly *News-2-You* (Clark, 2008) newspaper. Because the interventions were highly dissimilar, each occurred in different classrooms, and students received only one of the two interventions, it was assumed that there would be little if any treatment diffusion. These two interventions are now described.

Mathematics Intervention

All math standards were taught using a story-based problem. Stories were written about a familiar context (e.g., mall, movies), providing students with key facts and a problem statement to be solved. The stories were adapted by pairing key vocabulary with picture symbols for student comprehension. All four standards were taught using a math story (i.e., algebra, data analysis, geometry, and measurement) with an average of eight stories per standard given to teachers. In addition to the stories provided by the researchers, teachers were trained to write additional math stories. Teachers implementing the math received the stories in a binder for each standard along with the task analysis, graphic organizer, and additional manipulatives (i.e., paper money, green and red chips for the algebra prompt, nonpermanent markers; for examples of materials used in this study, see Trela, Jimenez, & Browder, 2008).

The key components of the mathematics intervention included (a) mathematics stories based on familiar activities, (b) a graphic organizer and manipulatives for the mathematics concept (e.g., a template for solving the linear equation), and (c) step-by-step training in a task analysis to identify and organize key facts and solve the problem stated in the written story. Teachers received four professional development workshops.

Three of the four workshops involved training on the mathematics intervention, and the fourth served as a debriefing for the study. In the first two workshops, the teachers received training in the first two units (algebra and geometry); in the third, two units were trained (data analysis and measurement). During each workshop, the research team provided an introduction to the “big idea” of the unit (e.g., geometry addressed spatial organization and vocabulary related to coordinate planes) and a review of current research in teaching mathematics. Following the introduction, each teacher received materials and the task analysis to teach the lessons. Researchers modeled one lesson, and then each special education teacher was given an opportunity to practice. The teachers also invited a general education math teacher to attend the trainings. The math teachers provided help in understanding the math content. Although the math and special education teachers also practiced planning inclusive cotaught math lessons, none were able to implement these in the time frame of the study. Following each of the first three professional development workshops, the special education teachers implemented the lessons in their classrooms with the target students in a small group format. Some teachers adapted the materials for their students’ individual needs (e.g., poster-size version of the number line in algebra). During each lesson, the teacher read the story aloud as students followed using their copy of the story. Then each student was given the opportunity to perform each step of the task analysis while the other students in the group watched. The teachers varied the order of student responding each day. Materials contained a variety of stories so that the problem to be solved and specific numbers to compute varied while keeping the basic math strategy (e.g., use of a bar graph) constant. Teachers continued instruction, adding their own stories if needed, until the next unit was introduced. Although the goal was for students to master the task analysis, to keep pace with the changing curriculum, teachers moved on to the next unit when it was introduced by the research team (after about 6 weeks).

Science Intervention

Similarly, the professional development workshops in science focused on four units, with the last devoted to debriefing. In the first two workshops, the information focused on the microbiology life science standard and the chemistry physical science standard. The science as inquiry standard was embedded across all units. During the third workshop, teachers received information on two earth science units (“earth’s water” and “earth’s history and resources”). Each unit comprised 5 lesson plans. In total, 20 lesson plans were developed and implemented. For each of the four units, teachers received a binder of 5 lesson plans that included student response boards. Response boards displayed an array of six boxes with picture symbol choices in each box. Students were able to use these boards to answer inquiry questions such as “What do you know about it?” (e.g., wet, dry, hot, cold, sticky, loud). Each of the 20 lessons required specific materials for experimentation (e.g., baking soda, bowl, gloves, gravel, microscope slides). At each training session, teachers received science kits that contained most of the materials. To support recognition and comprehension of each vocabulary word, teachers received both printed word cards and a set of accompanying picture symbol cards. Word and picture symbol cards were affixed to 4 in. × 6 in. index cards and laminated (for examples of materials used in this study, see Courtade, Jimenez, & Trela, 2008).

The key components of the science intervention included (a) the use of an inquiry-based lesson, (b) supplemental training in the science vocabulary, and (c) hands-on materials to carry out experiments. During the first of three workshops, the research team gave the teachers a brief background on inquiry-based science instruction and content area standards (e.g., physical science). The team role-played each of the lessons, and then the teachers practiced implementing the science lessons using the materials provided. Finally, the special education teacher planned inclusive cotaught lessons with the science teacher partner whom each invited to the workshop. Two teachers implemented coteaching once each, but no data were taken for this study.

Interventions occurred in a small group setting in the special education classroom. To implement the lessons, the special education teacher first reviewed the vocabulary for the unit using a simple application of time delay. First, the teacher read each word card and had the students repeat the answer. Then, the teacher presented each card, asked one student to read it, and waited 5 s before giving a prompt. If students were correct, they were praised. If incorrect, they were told the correct answer and asked to repeat it. This procedure was repeated for the picture cards and then matching the words to the pictures. As students began to anticipate correct answers, the teacher could eliminate the zero-delay round.

Next, the teacher presented the materials that were used to engage the student in inquiry. For example, in the lesson on precipitation, the teacher presented samples of water, “snow,” or ice in a pan and asked, “What do you think it is?” The students could either initiate a verbal response or use a six-choice response board to select an answer. The research staff provided the teachers with a book of response boards for each step of each lesson. Next, the teacher asked, “What do we know about it?” and “What do we want to know?” After this engagement phase of the inquiry lesson, the teacher helped the students investigate and describe the relationships. First, the teacher asked, “How can we find out?” The answer to this question led to conducting the experiment. As the teacher set up the experiment, she or he would ask the students to make a prediction about what would occur (e.g., “What will happen if I pour a large amount of water in this cloud (sponge)?” The experiments were set up to create a contrast. For example, in the precipitation experiment, one sponge was soaked with a lot of water, which began to pour out (like rain). The other had a small amount of water and became wet but did not drip. After the students participated in the experiment, the teacher would ask them what is the same and different about the two sets of materials. In the third part of the inquiry lesson, the teacher would help the students construct an explanation. First, the teacher explained the concept. For example,

> When the sponge was full from taking in the larger amount of water, the water poured out of the sponge. When clouds are full from taking in water from the air, water pours out and drops to the earth. The water that falls from the clouds is called precipitation. Rain, hail, ice, and snow are precipitation.

Table 1. Pretests, Posttests, and Percentage Gains for Mathematics and Science Achievement Tests Across Intervention Groups

	Mathematics instructional group						Science instructional group					
	Pretest		Posttest		Percentage gain		Pretest		Posttest		Percentage gain	
Tests	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Math total	32.4	18.0	60.3	25.1	27.9	12.3	25.4	16.3	26.4	17.5	1.0	10.6
Science total	42.5	13.2	45.4	15.1	2.9	7.0	41.9	11.5	57.6	22.1	15.7	18.9
Math subscales												
Algebra	31.9	19.1	65.6	24.8	33.8	20.0	31.0	13.4	31.4	16.2	0.5	11.6
Geometry	43.1	28.7	77.8	26.0	34.7	21.8	35.4	22.1	46.6	29.7	11.1	24.1
Data	48.8	37.2	61.9	30.8	13.1	25.0	20.0	30.3	28.1	36.7	8.1	27.5
Measurement	6.9	6.0	37.5	42.7	30.6	43.1	16.2	26.9	1.4	3.6	-14.8	27.5
Science subscales												
Inquiry	62.5	17.0	71.7	17.0	9.2	18.5	56.5	15.3	70.5	21.7	14.0	18.6
Science	37.5	13.9	38.9	16.4	1.4	7.9	38.3	13.2	54.4	23.0	16.1	19.8

The students then reviewed the vocabulary word and accompanying picture for the concept (e.g., precipitation). Then, the teacher implemented the reporting phase of the inquiry lesson. The teacher asked, “What did we learn?” This involved reviewing the predictions the students had made to determine if they were correct. Then the teacher led the student to explain the reason. For example, “Why did the water drip out?” Finally, the students completed a concept statement for the lesson: “Water falls from the clouds because they are _____” (full of water) and “Water that falls from clouds is called _____” (precipitation).

Procedural Fidelity

Procedural fidelity was recorded at both the math and the science workshops by a graduate student who was not a member of the research team. This observer followed the process agenda and indicated the presenter delivered all planned components in all workshops. In addition, a member of the research team observed each special education teacher in the mathematics and science groups eight times (i.e., twice for each unit) to assess fidelity of teaching the task analyses and vocabulary. Procedural fidelity was computed as the percentage of steps taught correctly. On average, teachers implemented lesson plans with 88% fidelity for math (range = 72%-100%) and 92% for science (range = 88%-100%). Two researchers concurrently scored the fidelity of the lessons for 50% (four) of the observations. Agreement between the observers was 100%.

Social Validity

At the final workshop, teachers in both groups were asked to complete an adapted *Intervention Rating Profile* (Snyder, 2002) to indicate the level of satisfaction with the training and instructional materials. Teachers responded to seven items about the intervention using a 6-point Likert-type scale (i.e., 1 = *strongly disagree*, 6 = *strongly agree*).

Results

Mathematics and Science Achievement

There were 16 students in mathematics and 21 students in science intervention conditions. All participants were administered both the mathematics and the science achievement tests. The a priori hypotheses were that the students in the mathematics intervention would have greater mathematics gain scores than students in the science condition; conversely, students in the science intervention would have greater science gain scores than students in the mathematics condition. The mean percentages correct for mathematics and science and all the subscales of the mathematics and science achievement tests are reported in Table 1.

Prior to conducting the major analyses, the data were screened for outliers and statistical assumptions. There were two outliers found for the science gain scores. The major analysis was run with and without outliers to examine possible influential effects of outliers. Mathematics and science gain scores appeared normally distributed, with skewness coefficients less than the absolute value of 1.0. Independent *t* tests were conducted to determine intervention group equivalence before intervention on pretest measures. There were no statistically significant differences between the intervention groups on the mathematics, $t(35) = 1.73$, $p = .10$, or science, $t(35) = 0.15$, $p = .88$, pretest means.

A 2 × 2 ANOVA with one between-subjects effect (intervention groups) and one within-subjects effect (content area) was performed to examine intervention effectiveness. The dependent variables were percentage change from pretests to posttests for both mathematics and science. The ANOVA statistical test of interest for examining differences in the intervention is the interaction effect. There was a significant interaction effect, $F(1, 35) = 42.88$, $p < .001$, which supported the a priori hypotheses. Similar results were found when the two outliers were removed from the analysis; the following analyses include the two outliers. The mathematics instructional group had a higher percentage gain on the mathematics test (30%) and a lower percentage gain on the science test (3%). The science instructional group had the opposite trend; students in the science instructional group tended to have a lower mean percentage gain on the mathematics (1%) and a higher percentage gain on the science test (16%). Simple effects follow-up procedures indicated that there was a statistically significant difference between the intervention groups on mathematics gain scores, $t(35) = 7.15$, $p < .001$, with the mathematics instructional group having a much higher percentage gain than the science instructional group (Cohen's $d = 2.41$). Similarly, there was a statistically significant difference between the groups on the mathematics mean gain score, $t(35) = -2.57$, $p = .01$, where the science instructional group had much higher mean percentage gains on the science tests than did the mathematics instructional group (Cohen's $d = 1.33$).

To provide additional information about how the groups differed, independent *t* tests were conducted to determine differences between the instructional groups on the subscale gain scores. A more conservative alpha level (.01) was set to protect against an increase in Type I errors because of performing multiple statistical tests. For the mathematics subscales, three of the four subscales were significantly different. There were statistically significant differences between the groups for the Algebra, $t(35) = -6.37$, $p < .001$, Cohen's $d = 2.11$, Geometry, $t(35) = 3.08$, $p = .004$, Cohen's $d = 1.03$, and Measurement, $t(35) = 3.90$, $p < .001$, Cohen's $d = 1.29$, subscales, with the mathematics instructional group having higher means than the science instructional group. There was not a statistically significant difference for the Data subscale, $t(35) = -0.57$, $p = .57$, Cohen's $d = 0.19$. For science, the science instructional group had a statistically significant higher gain in the Science Vocabulary subscale, $t(35) = -2.82$, $p = .008$, Cohen's $d = 1.06$, but not for the Inquiry subscale, $t(35) = -0.78$, $p = .44$, Cohen's $d = 0.23$.

Social Validity

Five teachers who received mathematics training and four teachers who received science training completed the *Intervention Rating Profile* to indicate their level of agreement with statements about the intervention. Overall, the nine respondents agreed that the intervention was useful, practical, and beneficial to their students, with mean ratings of 5.75 on a scale of 6 for all items. In addition, teachers commented that they appreciated obtaining materials for lessons, having time to practice lesson plan task analyses with researcher feedback at the workshops, and learning how to adapt instruction to meet the state standards in mathematics and science for their students.

Discussion

The purpose of the current study was to evaluate standards-based instruction for students with moderate and severe developmental disabilities in math and science. The intervention was twofold, including the evaluation of the use of a story-based lesson approach to teach math and inquiry-based lessons to teach science. Overall, results provided support for the impact of the math intervention on learning each of the problem-solving skills and of the science intervention on acquiring the science vocabulary.

Training teachers to use story-based problems, task analytic instruction, and graphic organizers increased students' acquisition of specific math skills. In earlier studies, benefits for using graphic organizers to teach mathematics have been demonstrated for students with mild disabilities (Ives & Hoy, 2003; Maccini & Hughes, 1997). Graphic organizers have also been used with students with moderate and severe disabilities to support learning independent living skills (Gaule, Nietupski, & Certo, 1985). What is new in the current study is the application of a variety of math graphic organizers (not just number lines) for students with moderate and severe developmental disabilities.

A second component of the math intervention was the use of task analytic instruction. The use of a task analysis is also well represented within prior research on mathematics for this population (Browder et al., 2008). What is unique about the current study, compared to earlier research in math for this population, is that the context used to teach math was reading a story about familiar events (e.g., friends voting on which movie to view) and the task analyses were specific to the mathematical problem solving versus to the chain of responses to complete an activity (e.g., use a vending machine). The advantage of the use of stories is that a variety of math problems can be presented.

Results of the inquiry-based science instruction on student vocabulary acquisition indicated that students could learn science vocabulary words and their meanings through word–picture symbol matching as part of an overall science lesson. The teachers used constant time delay when presenting the science words at the beginning of each lesson. This result is consistent with decades of research indicating that time delay is an effective strategy for teaching students with moderate and severe developmental disabilities to recognize vocabulary words (Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006). What is different is that most of the words in the current study were more difficult and abstract than those usually found in the sight word literature (e.g., *precipitation, solvent*) because they were derived from the grade-level science curriculum. A second difference is that students learned comprehension of the science words through word to picture matching and also used them in an inquiry-based lesson to form concept statements. Unfortunately, many studies have not taught or measured comprehension of sight word vocabulary (Browder et al., 2006).

Although the students did show clear differences in learning the science vocabulary, it cannot be concluded that students would have had these same outcomes without the opportunities to learn the meaning of the words in the inquiry lessons. For example, although the student could learn to read *precipitation* and even match it to a picture of rain, this probably would not have created the same degree of understanding as having the opportunity to use a model of a cloud (a sponge) to make rain.

Students with moderate and severe developmental disabilities need opportunities to learn general education content in whatever setting they receive instruction to have a fair chance of demonstrating progress on state standards. The current study demonstrates how grade-level content can be adapted in a self-contained special education class. Even though implemented in a self-contained setting, the teachers collaborated with general educators during their planning sessions to gain deeper understanding of the content. The applicability of these interventions to students who receive instruction in general education classes is a topic for future research. For example, many math skills can be taught using a story, a graphic organizer, and task analysis of the mathematics operation, which may provide a planning template for the rapidly changing content in general education. What will be different in inclusive settings is the need to begin with the general education teacher's identification of priorities or core areas rather than the specific skills targeted for this research. In science classes that use inquiry, providing the student with supplemental instruction to use key vocabulary terms and then response boards to participate in the lesson might prove an effective way to promote learning. For example, Polychronis, McDonnell, and Johnson (2004) embedded time-delay instruction in the context of a general education setting to teach various vocabulary words including some science terms. To build on the work of Polychronis et al., students might be taught to use picture communication boards that permit participation in the inquiry lesson in addition to the vocabulary instruction.

Limitations

Although the results of the current study indicate positive outcomes, several limitations must be noted. First, although the choice of a group design made it possible to evaluate an entire year's math and science interventions across sets of students, it did not provide the evidence on individual student learning that a single-subject design could provide. It also is difficult to recruit sufficient participants to have enough power to use inferential statistics with a low-incidence population. Another disadvantage of group research is that random assignment requires making difficult decisions about withholding treatment. In the current study, professional development was delayed for one school year for one of the two content areas. Teachers continued teaching both content areas but were gaining extensive information on how to teach either math or science.

A second limitation is that the only social validity measure was the teachers' evaluation of the effects of trainings. In an era when many students with moderate and severe developmental disabilities are receiving more emphasis on academic learning than in the past, it is important to include stakeholders in evaluating the outcomes. Future research should include evaluations by parents and students as well about the magnitude and meaningfulness of outcomes. Because this type of academic intervention is new for this population, there are no benchmarks for comparing outcomes. Stakeholder input is especially important for future research to determine if the type and magnitude of gain are of practical significance.

Finally, the study was designed to demonstrate the applicability of two interventions to a variety of content. The goal was to create an intervention "template" that could be applied to many middle and high school math and science standards. Although these templates did emerge (e.g., the inquiry task analysis), the assortment of skills taught in this study would not typically be addressed within one grade level. Instead, teachers should begin planning with general math and science teachers to determine the content that is appropriate for a student's age and grade. For example, students taking algebra should receive instruction on a sequence of algebra skills versus jumping to geometry.

Implications for Research

As one of the first studies measuring the effects of training teachers of students with moderate and severe developmental disabilities to implement standards-based instruction in math and science, the current study raises important questions for future research. One question to consider is the extent to which the students mastered the concepts versus memorizing a method to solve a problem in math. Although the use of a variety of math stories with changing math facts supports the premise that students did indeed develop understanding, more specific assessment of the extent to which the students mastered concepts such as points on a plane and linear equations is needed.

Another focus for future research is the extent to which students are able to generalize the academic concepts to real-life activities. Although general education often assumes this generalization, students with moderate and severe developmental disabilities may need opportunities to apply their skills to daily living. In the current study, these applications were informally provided. For example, students used their algebra graphic organizer when making plans for a party. In future research, generalization could be specifically measured by taking data during such activities. Finally, the extent to which the interventions can be utilized within the general education setting needs further investigation.

Summary

Addressing state standards is a relatively new challenge for teachers of students with moderate and severe developmental disabilities. This is one of the first studies to illustrate how alternate achievement can be targeted and taught. Priority standards were translated into alternate achievement and then used to create specific task analyses (math, inquiry science) and vocabulary terms (science). The intervention approaches used may have wide applicability for teaching grade-level content standards to this population. That is, math may be taught by using a math problem story, a task analysis of the problem-solving steps, and a graphic organizer. Science may be addressed by teaching science vocabulary, the process of inquiry, and a concept statement that gains meaning through a hands-on experiment. Although much more research is needed to evaluate these interventions and build an evidence base, they provide a starting point for planning for students with moderate and severe developmental disabilities who are learning math and science in middle and high school settings.

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Note

1. A table describing all standards and the specific responses measured is available from the first author.

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