Research findings

INTRODUCTION

Teaching skills to students with moderate and severe developmental disabilities linked to their state's grade-level content standards is an innovation that was fostered by recent legislation, including the No Child Left Behind Act (NCLB, 2002) and the Individuals with Disabilities Education Act (IDEA, 2004). For the first time, schools are accountable for all students making adequate yearly progress in language arts, mathematics, and science content standards. For students with significant cognitive disabilities, this progress could be based on alternate achievement of their state's standards in these academic areas. Although reauthorization of these major education acts often creates changes, what is most likely to persist is the educational opportunity to learn academic content that is appropriate to students' chronological age and grade. **Teaching to Standards: Math** and **Teaching to Standards: Science** were created to provide examples of how to make grade-level content for students with moderate and severe developmental disabilities both accessible and achievable. The target is alternate achievement of content that has been streamlined and prioritized. Students learn grade-level content but with alternate achievement.

Teaching to Standards: Math and **Teaching to Standards: Science** were developed based on comprehensive reviews of the research literature and then evaluated in applications by teachers in programs for students with developmental disabilities, including intellectual disabilities and autism. In a comprehensive review of mathematics, Browder, Spooner, Ahlgrim-Delzell, Wakeman, and Harris (2008) found 68 studies of individuals with moderate and severe developmental disabilities. Most studies focused on numbers and operations or money management, but a few focused on the other strands of mathematics (e.g., geometry) identified by the National Council of Teachers of Mathematics (2000). Based on this review, we identified task analytic instruction with systematic prompting as being an evidence-based procedure for teaching specific mathematics skills. In a task analysis, the teacher provides step-by-step instructions on a chain of responses to complete the activity. In the case of math activities, this would be the steps to complete a math problem. By using guidelines from the National Science Education Standards (National Research Council, 1996) to identify science content, Courtade, Spooner, and Browder (2007) found 11 studies that had some intersect with science. Their review also revealed the importance of systematic prompting and feedback, but also the need for new methods that could be used to teach scientific inquiry.

We chose to focus on upper-level mathematics and science content because this can be especially challenging to adapt for students who begin with little background to understand this material. We decided to design examples of content in several areas of science and mathematics to illustrate how adaptations could be made across curricular areas. For each type of learning, we researched current thinking within general education about how to teach these content areas. For mathematics, we used a literacy-based approach in which the math problem was embedded in a simple story. Literature in mathematics education suggests that stories can provide a schema for students to organize facts

(Anderson, Spiro, & Anderson, 1978; Zambo, 2005). We also had experienced some success in using read-alouds of middle school literature as a means to teach grade-linked content in language arts (Browder, Trela, & Jimenez, 2007) and in using task analysis to teach the steps to solve a problem (Jimenez, Browder, & Courtade, 2008). For science, we chose an inquiry-based approach based on recommendations of the National Research Council (NRC, 1996). Because the field of science is ever-changing and expanding, inquiry-based instruction teaches students to be active participants in the world that is changing around them. Courtade, Browder, Spooner, and DiBiase (2008) provided some preliminary evidence that teachers are able to implement inquiry-based lessons, so that students can gain increased independence in participation in these lessons.

In the 2006–07 school year, we implemented the literacy-based approach to mathematics and inquiry-based approach to science with students in the Charlotte-Mecklenburg School System (NC) through funding received from the U.S. Department of Education Office of Special Education Programs (Grant No. H324M03003). The following briefly summarizes the method we used and results obtained. A full report of this research can be obtained from Diane Browder at the University of North Carolina at Charlotte. The opinions expressed here do not necessarily reflect the position or policy of the Department of Education, and no official endorsement should be inferred.

METHOD

Participants and setting

We recruited 10 middle and high school special education teachers for this research. Teachers were randomly assigned to receive either the math or science lesson model plans. Depending on their assignment, special education teachers then invited either a math or science general education teacher as a collaborative partner. While the teachers could implement the model lessons with all of their students, 2–3 students in their class served as participants in this research. We obtained informed consent to observe and assess these target students. There were a total of 42 student participants, including 11 students with autism and 31 with moderate intellectual disabilities. To be eligible, students had to have a full-scale IQ below 55. The model lessons were taught in the students' special education classrooms. During the teacher training days, the general and special education teachers were given time to plan inclusive activities as well as to review the content of the lessons. Only a few students had opportunities to participate in the general education classes, and no research data were taken in these contexts.

Math and science model lessons

The model lessons were those that are now available in **Teaching to the Standards: Math** and **Teaching to the Standards: Science.** Math skills included solving an algebraic equation, graphing (data analysis), identifying points on a plane (geometry), and computing the next dollar amount. Science included Earth's waters, Earth's history, chemistry, and microbiology. These specific skills were chosen in consultation with general education curriculum experts as ones that would be pivotal to the overall content standards. In math, teachers received stories for teaching each math concept, the graphic organizers needed to complete the response (e.g., the "equation prompt" in algebra), and the written lesson plans. In science, the teachers received the materials needed to conduct the experiment, science vocabulary flashcards, the written lesson plans, and student response boards.

Measurement of the dependent variables

The dependent variables for this research were a Math Assessment and a Science Assessment created by the research team. All assessments were implemented by members of the research team. In math, a task analysis was created for each of the skills in the various domains (e.g., geometry, data analysis). These assessments are now available in **Teaching to Standards: Math.** To assess the student, the teacher presented any necessary math manipulatives and the graphic organizer, then asked the student to perform the math problem (e.g., create the graph, find the points on a plane). Each skill was scored as either independently correct or incorrect. No prompts or feedback were given during testing. In science, a task analysis for participation in an inquiry lesson was created. One of the researchers implemented an inquiry-based lesson with the research participants in a small group. The researcher scored the student's participation as independently correct or incorrect. The researcher then tested each student alone on identification of the science vocabulary. This test required making three responses for each vocabulary word: (1) reading the word (no picture), (2) identifying the picture (without the printed word), and (3) matching the word to the picture (to show comprehension). A total of 20 vocabulary words were presented that related to each of the science units.

Research design

The research design was a group quasi-experimental design with students serving as the unit of analysis. Teachers were randomly assigned to receive training in either the mathematics or science intervention. Because the interventions were highly dissimilar and teachers received only one of the two sets of model plans, it was hypothesized that there would be no treatment interference. Teachers continued their ongoing instruction in the content area not chosen for the model plans. For example, in mathematics, most teachers focused on teaching students to identify and count money. In science, teachers used discussions of an online news magazine. While most teachers instructed students on money skills daily, science lessons in the control condition were sporadic.

Teacher training

After being assigned to receive either the model math or model science lessons, the teachers attended workshops with their math or science general education teacher partner, depending on the assigned content. At each workshop, the teachers received some background information on the particular domain of content (e.g., algebra or Earth's history), discussed state standards and general education priorities in this content, viewed videotape demonstrations from a pilot year, and then learned to implement the specific target lessons through role-play practice. Following the training, teachers implemented one domain of content between each workshop. For example, after the first math workshop, the teachers received and implemented the lesson plans for algebra. Two months later, they received and implemented geometry. Similarly, the teachers received the science units one at a time.

RESULTS

Interrater reliability

A second researcher observed and scored 40% of all tests administered. Interrater reliability was computed as agreements over total responses scored and was 99% for these observations.

Mathematics achievement

As shown in Tables 1 and 2, strong effects for mathematics were found for the differences between the treatment and control group across all math units. An analysis of variance revealed significant differences for the interaction effects in geometry, algebra, and measurement and across all units. A significant effect was not found for data analysis. This finding may have been influenced by the small sample size and the treatment group's higher pretest scores.

Table 1: Effect Size for Math Unit Assessments

	Pretest		Posttest		
	M	*SD*	*M*	*SD*	Cohen *d*
Geometry					
Control	3.19	1.99	3.95	2.43	
Treatment	3.88	2.49	7.06	2.27	1.29
Algebra					
Control	3.14	1.35	0.14	0.35	
Treatment	3.29	1.89	4.00	4.37	1.70
Data Analysis					
Control	2.14	3.00	2.81	3.66	
Treatment	4.59	3.79	6.35	3.08	1.01
Measurement					
Control	0.52	0.60	0.14	0.35	
Treatment	0.76	0.66	4.00	4.37	1.29
Total Score					
Control	9.00	5.18	10.48	6.73	
Treatment	12.53	6.80	24.18	10.03	1.60

Table 2: ANOVA for Math Unit Assessments

	Outcome Effect		*F-Ratio*	n^2_p
Geometry	Within Ss	Pre/Post	41.54**	0.54
		Interaction	15.61**	0.30
	Between Ss	Instruction	7.67**	0.17
Algebra	Within Ss	Pre/Post	7.56**	0.17
		Interaction	19.72**	0.35
	Between Ss	Instruction	9.53**	0.21
Data Analysis	Within Ss	Pre/Post	6.99*	0.16
		Interaction	1.43	0.03
	Between Ss	Instruction	8.80**	0.19
Measurement	Within Ss	Pre/Post	9.06**	0.20
		Interaction	14.55**	0.28
	Between Ss	Instruction	16.62**	0.32
All Units	Within Ss	Pre/Post	69.41**	0.66
		Interaction	41.70**	0.54
	Between Ss	Instruction	14.87**	0.30

Note: Degrees of freedom for all tests of significance was 1,37.

*$p < .05$. **$p < .01$.

SCIENCE ACHIEVEMENT

In science, differences between the treatment and control were found for the acquisition of science vocabulary, but not for participation in the inquiry lesson (see Tables 3 and 4). The treatment group had strong effects for acquisition of the science vocabulary. The interaction between treatment and control group showed a significant difference for vocabulary on the analysis of variance. In contrast, the control group, who received the math intervention, also showed an increase on the posttest in scientific inquiry. Differences between groups in inquiry were not significant. While the reason for the control group's growth is unknown, it is hypothesized that the training in mathematical problem solving generalized to lessons in scientific inquiry. An alternative explanation is that the math intervention increased students' active participation in academic learning, which generalized to the science inquiry activity.

Table 3: Effect Size for Vocabulary and Inquiry Assessments

	Pretest		Posttest		
	M	*SD*	*M*	*SD*	Cohen *d*
Vocabulary					
Control	22.89	7.91	23.44	9.34	0.06
Treatment	22.95	7.95	32.62	13.77	0.86
Inquiry					
Control	9.44	2.43	11.39	2.95	0.72
Treatment	8.48	2.29	11.62	3.04	1.17

Table 4: ANOVA for Vocabulary and Inquiry Assessments

	Outcome Effect		*F-Ratio*	n^2_p
Vocabulary	Within Ss	Pre/Post	11.79**	0.24
		Interaction	9.36**	0.20
	Between Ss	Instruction	2.55	0.06
Inquiry	Within Ss	Pre/Post	44.73**	0.55
		Interaction	2.48	0.06
	Between Ss	Instruction	.22	<0.01

Note: Degrees of freedom for all tests of significance was 1,37.
$^{**}p < .01$.

DISCUSSION AND IMPLICATIONS FOR PRACTICE

For a practice to be considered evidence-based, the design of the experiment should minimize threats to internal and external validity and the intervention should be replicated with new groups of students. The model mathematics and science lessons used in **Teaching to Standards: Math** and **Teaching to Standards: Science** should be considered a promising practice because of the initial evidence found for student learning in a quasi-experimental design. Teachers are encouraged to conduct their own student assessments to determine if this intervention is effective for individual learners. In contrast, while this is the first study to evaluate the Teaching to Standards materials, the lesson plans were based on comprehensive reviews of research by

Browder et al. (2008) and Courtade, Spooner, and Browder (2007) and well-established methods for students with moderate and severe developmental disabilities, including task analytic instruction and systematic instruction with feedback.

To achieve positive outcomes with students, it is recommended that the instructional guidelines are followed and then individual modifications are made as needed. For example, the math lesson plans have been developed to follow a most-to-least intrusive prompting system (Collins, 2007). In the early lessons, teachers provide a model so that students can learn the math procedures with minimal errors. Over lessons, the teacher provides progressively less assistance for each step of the task analysis. By the last lesson, the student performs the math procedure while the teacher observes. Although not all students may achieve this level of independence, through systematic instruction and fading of prompts, students are more likely to learn the steps of the task analysis.

In science, the inquiry process requires allowing students to make some guesses. This may be new for teachers who are used to using errorless learning procedures. By following the lesson guidelines, the teacher can provide students the opportunity to make observations and form hypotheses with structure and support so that the target concept is learned. In contrast, when teaching the vocabulary, an errorless learning procedure called *time delay* is recommended (Collins, 2007). Rapid review of the science flashcards with a model gives the student the opportunity to practice naming words that may be new vocabulary. Then through a brief time delay, the teacher waits for the student to anticipate correct answers on known words. All of the guidelines provide help for praising correct responses and correcting any student mistakes. This feedback is also key to student success.

In our research, the opportunities for students to learn the material or practice the skills in inclusive settings occurred only sporadically. When teaching these skills in a general education class, it will be important to select the lessons that match the focus of the class. These lessons may provide additional practice for students who are nondisabled who might serve as peer tutors. In science, teaching students to follow the steps of inquiry and use the KWHL chart may be skills that will transfer across the rapidly changing content of the general education class.

Some students with developmental disabilities do not yet use symbols to communicate independently. We recommend using the symbols in these lessons with all students to give them the opportunity to gain meaning from symbols. In contrast, the goal for student learning may be more concrete for some students. For example, some students in math may be able to create a graph using small objects independently, but need assistance to complete the student worksheet. In science, some students may learn a subset of the inquiry responses. For example, a student may be able to perform the experiment or indicate which of two items is different even if they need assistance to then summarize their findings using the student response pictures.

In conclusion, this early research suggests that Teaching to Standards may be a promising practice for teaching grade-level content with alternate achievement. Multiple studies are needed to confirm an intervention to be evidence-based. This promising practice was derived from comprehensive reviews of the research literature on teaching math and science to students with moderate and severe disabilities. By following the research-based guidelines including the step-by-step (task analyzed) lessons with the systematic prompting and feedback, teachers are more likely to promote student success. Ongoing student assessments are important to determine if this intervention works for individual students.