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Using an Early Science Curriculum to Teach Science Vocabulary and Concepts to Students with Severe Developmental Disabilities

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Abstract

Teaching academic content to students with severe developmental disabilities is a topic that has recently been debated, even though science content is one of the academic areas that comprise a standards-based curriculum. Science content like other academic skills can be taught to this population using forms of systematic instruction, a validated evidence-based practice. In this study, three elementary aged students between 6 and 8 years old were taught units from an *Early Science* curriculum via inquiry-based lessons and effects were measured by a multiple probe design across behaviors (units). Visual analysis shows a functional relationship between the introduction of the intervention and a change in each participant's responding. These successful outcomes are discussed in light of other comparable work, the practicality of classroom teachers implementing similar lessons, social validity, and extending the knowledge-base of teaching science content to students with severe developmental disabilities.

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In the current era of standards-based education, teachers need guidelines for providing effective instruction to all students, including those with severe developmental disabilities. Science content is one of the academic areas that comprise a standards-based curriculum. One approach to providing effective instruction is to use interventions that have a foundation of research support. When the research on this intervention has met some criteria for design quality, it is called an "evidence-based practice" (Cook & Cook, in press; R. H. Horner et al., 2005; Odom et al., 2005; Tankersley, Harjusola-Webb, & Landrum, 2008). When the focus of teaching academic content (literacy, mathematics, and science) via evidence-based practices was first being promoted (Individuals with Disabilities Education Act, 2004; No Child Left Behind [NCLB], 2002), comprehensive reviews of the literature in these academic areas for students with severe disabilities were conducted to identify practices both supported by the literature and that met the quality indicators and quantity dispersion requirements to be evidence-based (e.g., literacy [Browder, Ahlgrim-Delzell, Spooner, Mims, & Baker, 2009; Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006]; mathematics [Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008]; science [Spooner, Knight, Browder, Jimenez, & DiBiase, 2011]. Although multiple models exist for determining evidence-based practice, here reviewers applied the R. H. Horner et al. (2005) quality indicator guidelines (e.g., 20 variables across seven major areas, participants, setting, dependent variable, independent variable) to each content area because a significant proportion of research in the area of severe developmental disabilities has employed single-case designs (McDonnell & O'Neill, 2003; Spooner & Browder, 2003; Spooner, Knight, Browder, Jimenez, et al., 2011). From these comprehensive reviews, it is clear that more information is available about teaching literacy (128 experiments) than teaching mathematics (68 experiments), and more about teaching mathematics than teaching science (17 experiments) to this population. These reviews focused on content areas to derive effective practices and found behavior analytic principles reflected in systematic instruction to be an evidence-based practice for teaching academic skills. More specifically, Spooner, Knight, Browder, and Smith (2011) found task analytic instruction to teach chained tasks and time delay to teach discrete tasks to have a strong evidence base for teaching academic content to students with severe developmental disabilities.

Systematic instruction has been used as an overarching teach strategy to train persons with severe developmental disabilities beginning with the first applied investigation (Fuller, 1949), to teach a multitude of functional skills (e.g., dressing [Azrin, Schaeffer, & Wesolowski, 1976], feeding [Azrin & Armstrong, 1973], toileting [Azrin & Foxx, 1971], safety [Bannerman, Sheldon, & Sherman, 1991]), as well as academic content (literacy, mathematics, & science Spooner, Knight, Browder, & Smith, 2011). In general, it is a set of procedures used to teach socially meaningful skills by (a) defining target skills which are observable and measurable, (b) using data to demonstrate that skills were acquired as a result of the intervention, (c) using behavioral principles to promote transfer of stimulus control including differential reinforcement, systematic prompting and fading, and error correction, and (d) producing behavior change that can be generalized to other contexts, skills, people, and/or materials (Collins, 2007; Drascow, Wolery, Halle, & Hajiaghamohseni, 2011; Snell, 1983; Spooner, Knight, Browder, Jimenez, et al., 2011; Stokes & Baer, 1977; Wolery, Bailey, & Sugai, 1988).

Spooner, Knight, Browder, Jimenez, et al. (2011) found educators have been teaching science-related content dating as far back as the 1980s (e.g., Spooner, Stem, & Test, 1989) with daily living skills, like first aid, that are a component of Content Standard F: Science in Personal and Social Perspectives of the National Science Education Standards (National Research Council, 1996). Recent work in the area of science, for the most part, has augmented interventions for science-related daily living skills (e.g., first aid and safety skills, Collins & Stinson, 1995; Gast, Winterling, Wolery, & Farmer, 1992; Winterling, Gast, Wolery, & Farmer, 1992) by demonstrating ways to teach more identifiable science content like the science vocabulary found in general education (e.g., Jameson, McDonnell, Johnson, Riesen, & Polychronis, 2008; Jameson, McDonnell, Polychronis, & Riesen, 2007; McDonnell et al., 2006).

Spooner, Knight, Browder, Jimenez, et al. (2011) have described both a rationale and focus for this stronger focus on science content. Some reasons for teaching more science content to students with severe developmental disabilities are: (a) to promote a full educational opportunity, (b) to prepare students for the assessments in science schools are required to administer under No Child Left Behind, (c) to help students gain knowledge of the natural world in which they live, and (d) to teach students to explore and pose questions about this world. Spooner, Knight, Browder, Jimenez, et al. (2011) also advocate for teaching content from the state's science standards. For example, students will need to acquire science vocabulary and to master the major concepts in a science unit. The NSES place a priority on inquiry-based science learning. Students with severe developmental disabilities also need the opportunity to learn the skills of inquiry. For example, students should learn the skills necessary to interpret the world around them by asking questions such as "Why does it rain?" and then using inquiry skills to develop steps to make a prediction, experiment, and find answers their questions.

Several researchers have demonstrated how to teach both core content and the skills for inquiry. Courtade, Browder, Spooner, and DiBiase (2010) trained teachers to follow a specific task analysis to engage students in science experiments. To teach core content, Knight, Spooner, Browder, Smith, and Wood (2011) used graphic organizers with middle school students with autism and Knight, Smith, Spooner, and Browder (2011) used explicit instruction of science descriptors with similar students. Jimenez, Browder, and Courtade (2009) demonstrated student acquisition of the steps of an inquiry lesson and generalization of science concepts to new materials for students with moderate intellectual disability.

While each of these studies added to the knowledge base about how to apply interventions like task analysis, systematic prompting, and explicit instruction to teach science to students with moderate and severe developmental disabilities, each were applied to a small sample of learning compared with the vast array of topics teachers encounter in general science content. The need exists for methods that can be applied across many topic areas (e.g., animal and human life cycle, land formations and erosion) in the course of a school year. Browder et al. (2012) evaluated mathematics and science interventions that crossed multiple content areas for secondary students with moderate and severe developmental disabilities through a quasi-experimental design where special education teachers were randomly assigned to either a mathematics group or a science group. Teachers in the science group implemented four science units representing three of the eight national science content standards with a fourth standard, science as inquiry, embedded across units. Specifically, time delay was used as the major instructional intervention by teachers to show gains for students on the acquisition of science vocabulary. Although this study demonstrated how teachers could apply a method across multiple units of science content, it focused primarily on vocabulary rather than concept learning. For inquiry-based science lessons (e.g., ones that involve experiments), it may be especially important to teach not only science vocabulary (e.g., energy), but also concepts to describe phenomena in the natural world related to that concept (e.g., dark, light, hot, cold). While Browder et al. (2012) focused on middle and high school students, beginning concept instruction in the elementary grades can provide a foundation for future science learning.

The current study extends prior work in the content area of science by teaching grade-level science concepts and vocabulary via an inquiry-based lesson delivered with systematic instruction to elementary students with severe developmental disabilities. The intervention was designed to be used across different units of elementary science content. The research questions were (a) what is the effectiveness of an adapted early science curriculum on acquisition of science content for students with severe disabilities, (b) will students maintain acquired knowledge over time, and (c) can teachers implement the task analyzed inquiry lessons with procedural fidelity? Another purpose was to extend the prior research to students with more severe disabilities. Nearly all prior studies on science learning focused on students with moderate levels of intellectual disability or autism. The current study targeted students with severe developmental disabilities.

Method

Participants

Students. Three elementary age students (i.e., one male, two females) with severe disabilities participated in this study. Participants were nominated by their special education teacher based on the following inclusionary criteria (a) meeting alternate assessment based on alternate achievement standards state eligibility, (b) vision and hearing adequate to see the target materials or perceive the verbal instructions, (c) ability to imitate a verbal model or motor ability to indicate selection response, (d) use of a consistent response mode (e.g., grasp, point, verbal) to indicate a selection using pictures. Possible participants also were excluded from the study if they demonstrated knowledge of targeted science content (i.e., if a student independently and correctly answered six out of the 12 questions on any of the four Unit Assessments). All three participants received special education services in a self-contained classroom for children with severe disabilities within their neighborhood school in a southeastern state. In addition to those services, all three participants also received speech language and occupational therapy services during the school day. The following are brief descriptions of the three participants. Due to the unique characteristics of this population, additional participant demographic information and the most current evaluation data are available in Table 1. Note that none of the students were able to participate in standardized tests of intelligence so their psychological assessments relied on developmental profiles (see Table 1).

Amy was a 6 years, 4 months old female student with Down Syndrome. According to Amy's last evaluation, she scored well below that of her same age peers across all adaptive behavior domains

Table 1
Demographic Information for Participants

Participant	Disability Classification	Ethnicity	Most Recent Evaluation Scores	Assessment	Mode of Communication
Amy	Intellectual Disability	Caucasian	Physical—15 months Adaptive Behavior—29 months Social Emotional—25 months Cognitive—24 months Communication—22 months	Developmental Profile—3	Verbal, use of picture symbols
Nancy	Multiple Disabilities	African American	Motor—18 months Perceptual—34 months Daily Living—24 months Cognition, Communication—30 months Social—22 months	Callier-Azusa Scales	Verbal, use of picture symbols
Brent	Multiple Disabilities	Caucasian	Physical—12 months Adaptive Behavior—18 months Social Emotional—23 months Cognitive—20 months Communication—16 months	Developmental Profile—3	Facial expressions, vocalizations, use of picture symbols

(e.g., social-emotional, communication). Amy primarily communicated verbally; however, at times was difficult to understand and required additional communicative efforts such as gestures to be fully understood. Although Amy was typically highly motivated to please her teachers and often complied with directives, at times, Amy refused to work. During trials of refusal to work, Amy also would answer questions that she historically answered correctly, incorrectly to gain attention or escape a task. Amy was highly motivated by social attention and access to tangible items (e.g., dolls, crackers) to accomplish tasks, particularly tasks that were unfamiliar or difficult to complete.

Nancy was a 7 years, 10 months old female student who in addition to having a severe developmental disability, also had a medical diagnosis of Cri du Chat Syndrome. Cri du Chat Syndrome is a rare chromosomal disorder in which the child's voice may mimic the tone of a cat meowing. Additional characteristics include delayed motor development, low muscle tone, and other physical appearances such as downward slanting eyes, small head, and partial webbing or fusing of fingers. Nancy received physical therapy services once a week to address gross motor goals. Although education professionals were unable to give a formal psychological evaluation, Nancy's adaptive behavior scores were well below that of her same-aged peers without disabilities across all adaptive behavior domains (e.g., daily living skills, communication, social/emotional). When the study began, Nancy primarily communicated using facial expressions and gestures to objects and pictures. She spoke few words (e.g., Hola, no) and did not use them functionally during the school day. Nancy had a history of refusing to complete academic tasks across a variety of settings and people. High preference reinforcers, identified by the classroom teacher, were used during the school day including social praise, access to tangibles (i.e., toys), and edibles (e.g., crackers).

Brent was a 7 years, 10 months old male student. Brent received special education services under the category of multiple disabilities. In addition to a developmental disability, Brent had a seizure disorder, agenesis of the Corpus Callosum, and a physical impairment. Although Brent was able to bear weight, he used a wheelchair for mobility. This wheelchair was fully manipulated by the educator, not Brent himself. Brent also received physical therapy services once a week to address additional gross motor goals. Brent was taking medication to regulate his seizure activity; however, Brent typically had one to two seizures during the school during the school week. Similar to his classmates, Brent's last evaluation showed adaptive behavior scores considerably lower than his same-aged peers without disabilities (e.g., independent living skills, communication). Brent was nonverbal and predominately communicated using facial expressions, reaching and grasping for items, and vocalizations (e.g., loud, high pitch scream). Brent also had a history of refusing to complete tasks during the school day. The teacher identified high preference reinforcers used throughout his school day which included access to affection (e.g., hugs, light massage) and edibles (e.g., crackers).

Experimenter, teacher, and second observer. The first author served as the experimenter for unit assessments and data collector during teacher implemented lessons for this study. At the time of implementation, she was a second year doctoral student at a local university conducting research on general curriculum access for students with a severe developmental disability. The classroom teacher implemented the majority of classroom lessons during regularly scheduled science time. The teacher had worked with students with disabilities for seven years. During probe sessions, a second observer, the third author, collected reliability and fidelity data.

Settings and Materials

All probe sessions occurred in a 10′ X 10′ tutor room located next door to the participants' classroom. The tutor room housed physical therapy equipment as well as two small tables, chairs, and a student desk. During probe sessions, only the experimenter, the participant, and occasionally a second observer were present. The primary experimenter sat beside the participant during implementation of the probe session. Materials used during probe sessions included assessment questions from the appropriate Unit Assessment, response options, a response board with Velcro, and data sheets. All science lessons were taught via whole group (seven students) instruction by the classroom teacher in the students' classroom within the public elementary school. These additional students were not included within the study because they did not meet inclusionary criteria (i.e., no independent and consistent response mode).

The materials used for this intervention were from the *Early Science Curriculum* developed by Jimenez, Knight, and Browder (2012) that includes four units comprised of seven lessons per unit. This curriculum was created based on prior research on teaching science to students with severe disabilities (Spooner, Knight, Browder, Jimenez, et al., 2011) and included scripted lessons and task analyses that introduced vocabulary, provided explicit instruction of concepts, and created opportunities for students to use inquiry skills like prediction and experimentation. The materials from the curriculum included a script to explain key science content, a task analysis for each lesson as shown in Table 2, a KWHL chart (What you Know, What you Want to know, How are you going to find out, and What did you Learn), Science Rules Chart, wonder stories for each lesson, a student report, and any materials needed to complete the experiment. For example, during lessons about erosion, the teacher made land models using soil in a small plastic container. Student reports included four to five questions specific to lesson (e.g., Did the land change?) and was completed as a group. Some additional materials were provided that were needed for these specific students including Yes/No switches and SMART™ board projections of materials. The teacher also provided some materials designated in the lessons such as a water and a fan to simulate the forces of wind and water to change the landforms. The script included statements for the teacher to read aloud such as "The water is like rain. It makes the land look different, or change. Wind and water change the land (see Table 2)."

Response Definitions and Measurement

The primary dependent variable was a unit assessment based on concepts trained during the science lessons. For example, one concept assessed within the "Objects in the Sky" Unit included "Where do we live?" Independent, correct responses required the participant to touch the correct response option (i.e., picture symbols paired with the science vocabulary word) within 5 s of the verbal discriminative stimulus (i.e., assessment question/statement). The three choice array of response options included the correct answer (e.g., "earth") and two distractors (e.g., "sun," "moon") in random order. Assessment items included questions as well as statements for the student to complete (e.g., We live on the ______). The Early Science curriculum had four units on Life Processes, Objects in the Sky, Rock Cycle, and the Five Senses based on typical elementary science curriculum. For each unit, there was an assessment that consisted of 12 total items, two from each lesson within a unit. These questions were taken from the "Science Report" for each lesson. These reports were completed at the end of every lesson and are provided within the Early Science curriculum. The experimenter, the first author, collected all probe data across baseline, intervention, and maintenance sessions on participants' correct and independent responses on unit assessments.

Data Collection

In this study, the experimenter measured the effect of the independent variable (i.e., task analyzed science inquiry lessons) on the dependent variable (i.e., number of independent, correct responses to assessment items during probe sessions). The experimenter used

Table 2
Example Task Analysis for One Lesson

Teaching Step	Student Response	Specific to This Lesson
Read Wonder Story Place question on KWHL	Find the Question	Circle of Life
Teach new vocabulary with time delay	Point to picture at 0 delay; at 5 s delay (out of an array of at least 3 choices)	Dead, decay
Review prior concept statements for the unit and fill in K on KWHL	Point to picture for each review concept statement (out of an array of at least 3 choices)	Plants, Plants and Animals, Life Cycle, Change, Grow, Living, Need
Activity	Engage with materials	None
Teach discrimination of concept (e.g., example/nonexample)	Point to object for concept	Living/Dead (use pictures and real plants if you have them)
INVESTIGATE Ask for a prediction	Yes/No for prediction	I think plants and animals are/are not always living
Fill in H of KWHL chart	Student pick appropriate sense	Eyes to see
Review safety rule		#5

Table 2 (continued)

Teaching Step	Student Response	Specific to This Lesson
Conduct experiment See explanation	Engage with materials	Living/Dead
Present two concept statements—0 delay	Point to picture to complete each statement	(0 delay) ___ is a dead plant; Dead plants and animals ____
DESCRIBE What happened and give second trial on concept statements—0 delay	Point to picture to complete each concept statement	(0 delay) ___ is a dead plant; Dead plants and animals ____
Give third trial with concept statement—5 s delay	Point to picture to complete each concept statement	(5 s delay) ___ is a dead plant; Dead plants and animals ____
EXPLAIN Review prediction See Script	Yes/no for prediction correct	Yes/no
REPORT Point to materials and give fourth trial of concept statements—5 s delay	Point to picture to complete each concept statement Put on KWHL chart under L	(5 s delay) ___ is a dead plant; Dead plants and animals ____
Learn statement	Put on KWHL chart under L	I know this because.…
Complete student report	Point to picture to be pasted into report	Dead, decay

a discrete trial data collection method. Only correct responses made during probe sessions across all conditions were graphed and counted toward criterion based performance. All probe sessions were implemented in a 1:1 format.

Procedures

The experimenter collected baseline data for a minimum of five sessions or until data were stable across all units. During baseline procedures, the experimenter did not reinforce participant responses, but did reinforce their participation intermittently during all probe sessions using high preference reinforcers identified by the teacher. Following baseline sessions, intervention sessions on Unit 1, "The Five Senses," began. During intervention, data collection continued on the target unit only via unit assessment probes. Probe sessions occurred once after the teacher repeated the same science lesson three consecutive days. Therefore, one unit assessment probe was implemented approximately once a week. Before instruction on a new unit began, the experimenter assessed participant responses across all units (see Experimental Design).

Although the Early Science Curriculum contained fully scripted lessons and task analyses for each lesson, the participating teacher had extensive experience using systematic instruction and requested teaching from the task analysis that was the foundation for these scripts. This task analysis is shown in Table 2. As the task analysis indicates, the components of the lesson included reading a personally relevant "wonder story," identifying a question, making a prediction, conducting an experiment, confirming or re-evaluating a prediction, implementing systematic instruction on key vocabulary and assessment items, and completing a student report. The "wonder story" was a vignette that set up the concept to be trained (e.g., a story about seeing the full moon at night). One of the reasons the teacher was able to work from the task analysis was that she was skilled in using systematic prompting with feedback and did not need the word-for-word instructions the curriculum provides for teachers who may not have this background. Within each lesson, the teacher gave each participant the opportunity to respond to four trials to identify the key vocabulary term and two trials to complete the concept statement dispersed throughout the lesson (e.g., at the start of the experiment). These were the same vocabulary and statements used on the unit assessments. The teacher applied a constant time delay procedure (Cooper, Heron, & Heward, 2007; Gast, 2010; Snell & Gast, 1981; Touchette, 1971). During the key vocabulary trials, the teacher gave the first trials at zero second time delay by pointing to the correct response and waiting for the student to imitate this model. If the student was correct, she praised the participant's response. If the student did not respond to the model, she corrected the student by physically guiding the response and gave no praise. She then gave the second two trials at 5 s delay in which she waited for the student to find the correct response. If the student waited 5 s, she provided the model prompt and praised the student's imitation. If the student did not imitate the prompt, she physically guided the response and gave no praise. If the student anticipated the correct answer, she gave enthusiastic praise. If the student made an error (touched wrong card), she physically guided the correct response and reminded the student to wait if unsure. She used this same time delay procedure on the concept statements with one trial at zero delay and one at 5 s. During the lessons, the teacher also reinforced engaging with materials or conducting the experiment with praise and intermittent small edibles (crackers). Each lesson was repeated in full, including all experiments or activities, a minimum of three times over three instructional days before the experimenter implemented probe sessions.

Once a lesson had been repeated three times, the experimenter tested student responses using the corresponding unit assessment. Based on the student's performance the experimenter then determined if the lesson needed to be repeated (participant did not answer at least one of the two assessment items targeted in the lesson correctly) or if the teacher could continue to the following lesson. If at least one participant did not answer one of the two assessment items for that lesson correctly, the teacher repeated the lesson for the entire class and the participant was assessed the following day. Once all seven lessons within the unit had been taught, the experimenter assessed participant responses using the same unit assessment. Following criterion-based performance on the unit (i.e., at least six out of 12 correct responses), the teacher began instruction on the following unit. This procedure was repeated across all units for all participants.

Probe procedures. All probe sessions began with a brief attention cue to engage students. For example, the experimenter often would rub Brent's arms prior to providing the first assessment item to ensure he was alert and ready to work. Following the attention cue, the experimenter presented three response options and provided the verbal discriminative stimulus for each assessment item (e.g., "Show me the moon"). All response options contained both word and picture stimuli. Next, the experimenter waited a 5 s interval for student to initiate a response. If the participant touched the correct response option, the experimenter recorded a correct response (i.e., "+"). If the student touched an incorrect response option or did not initiate a response (e.g., reaching toward array) within 5 s, the experimenter recorded an incorrect response (i.e.,"-"). It is important to note that while students were required to initiate a response within 5 s, once that response was initiated the experimenter did not limit the amount of time to complete the response. Participants completed their response regardless of how long it took to make their choice in an effort to account for the extensive response time needed for Nancy and Brent. This procedure was repeated for all probe sessions across all units and conditions.

Science inquiry lessons. A similar task analysis was implemented for all lessons across units. The only variation in task analysis across units was the inclusion of skills in Units 3 and 4 that were taught in Units 1 and 2. For example, in Units 3 and 4 students choose which sense they are going to use to investigate (taught in Unit 1) as well as identifying how they answered the question (e.g., "we did an experiment" or "because we put people on the model of the Earth"). Table 2 includes a sample task analysis from one lesson in Unit 4. The task analysis not only included teacher steps, but also included how the student would respond. For example, during vocabulary instruction the task analysis describes using a three-response option array as well as what type of delay interval is required for each trial for the teachers. The task analysis also included the expected student response (e.g., touch the correct option). The teacher always began with 0 s time delay trials before continuing to 5 s constant time delay trials to teach key vocabulary and concept statements.

Another component of these science inquiry lessons including engagement with the classroom's SMART™ board. During each lesson, students used the SMART™ board to engage in the wonder story, prediction, and student reports. For example, students took turns coming to the SMART™ board and answered questions from the student report by touching response options on the SMART™ board. Although the teacher utilized this technological component, it is important to note that during the time delay procedure to train the vocabulary and concepts included on the probe assessments, the teacher used the identical laminated response options as those used during probe procedures so that during these probes we were assessing student knowledge and not the participants' ability to generalize across materials.

Maintenance. The experimenter implemented maintenance probe sessions to assess participants' ability to maintain acquired vocabulary and concepts over time. Maintenance probe procedures were identical to the unit assessments described previously. All maintenance sessions occurred approximately five weeks following criterion-based performance for Units 1–3. The maintenance probe for Unit 4 was conducted two weeks following criterion-based performance on that Unit due to the end of the school year.

Experimental Design

This study used a single-case multiple probe across behaviors (i.e., units) with concurrent replication across participants design (R. D. Horner & Baer, 1978; Tawney & Gast, 1984). The use of a multiple probe experimental design has successfully been used in published research examining academic instruction for students with severe developmental disabilities (e.g., Flores & Ganz, 2007; Jameson et al., 2008). In accordance with the multiple probe design, this study included three components: (a) an initial probe to determine the level of performance on the behavior or skill, (b) a series of intermittent baseline measurements on level of performance on behaviors being trained as well as prior to the intervention for each behavior or skill, and (c) following criterion based performance, a probe to determine what change the intervention had on the level or trend of the data (Cooper et al., 2007).

Reliability and Fidelity

A second observer collected interobserver and procedural fidelity data across at least 30% of all probe sessions across all conditions. The experimenter collected teacher procedural fidelity data across a minimum of 30% of all intervention sessions using a procedural fidelity checklist similar to the task analyzed lesson plan used for implemented lessons.

Results

Effectiveness Data

Results of the effectiveness of the task analyzed science inquiry lessons on the number of assessment items participants answered correctly and independently during probe sessions are reported in Figures 1–3. Visual inspections of the graphs show a functional relationship between the introduction of the intervention and a change in level and trend across all four tiers and replicated for each participant (see Figures 1–3).

Amy. During baseline probe sessions Amy correctly responded to a mean of 2 out of 12 assessment items for Unit 1, a mean of 1.6 for Unit 2, a mean of 4.2 for Unit 3, and a mean of 1.8 for Unit 4. During and following intervention Amy correctly responded to a mean of 6.5 (range 4–8) assessment items in Unit 1, a mean of 5.3 (range 2–8) in

Unit 2, a mean of 6.2 (range 3–10) in Unit 3, and a mean of 5.6 (range 2–8) in Unit 4. In addition to acquiring the vocabulary and concepts taught in the science inquiry lessons, data also indicated her ability to maintain that knowledge over time. Specifically Amy maintained the same number of correct responses for Unit 1 and only decreased the number of correct responses by two in Units 2, 3, and 4.

Nancy. During baseline probe sessions Nancy correctly responded to a mean of 2 out of 12 assessment items for Unit 1, a mean of 2.5 for Unit 2, a mean of 2.6 for Unit 3, and a mean of 2.4 for Unit 4. During and following intervention Nancy correctly responded to a mean of 4.8 (range 3–7) assessment items in Unit 1, a mean of 6 (range 3–8) in Unit 2, a mean of 7.4 (range 5–9) in Unit 3, and a mean of 6.9 (range 3–10) in Unit 4. During maintenance probes, Nancy demonstrated the same number of correct responses as that of the last intervention session for Units 1 and 2. The number of correct responses made during maintenance sessions for Units 3 and 4 actually increased by one.

Brent. During baseline probe sessions Brent correctly responded to a mean of 3 out of 12 assessment items for Unit 1, a mean of 0.8 for Unit 2, a mean of 1 for Unit 3, and a mean of 1.6 for Unit 4. During and following intervention Brent correctly responded to a mean of 6.5 (range 4–9) assessment items in Unit 1, a mean of 5.5 (range 3–8) in Unit 2, a mean of 6.5 (range 4–9) in Unit 3, and a mean of 5.8 (range 3–9) in Unit 4. Similar to the other participants, Brent's data also indicated his ability to maintain that knowledge over time. The number of correct responses made during maintenance sessions for Units 1 and 3 actually increased. When comparing the number of correct responses made during the maintenance probe for Units 2 and 4 to the last probe following intervention on that unit, the total decreased by two despite an increase of seizure activity as the school year progressed.

Reliability and Procedural Fidelity

Interobserver agreement. The third author collected interobserver agreement data during probe sessions across all conditions. The second observer collected interobserver agreement across 33% of baseline probe session and 30% of intervention probe sessions for Amy, 33% of baseline probe sessions and 36% of intervention probe sessions for Nancy, and 30% of baseline probe sessions and 45% of intervention probe sessions for Brent. Interobserver agreement was determined by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100 (Cooper et al., 2007). The interobserver agreement mean for all participants during baseline probe session was 99.6% (range 92–100) baseline probe sessions and intervention sessions was 100%.

Procedural fidelity. The same second observer collected procedural fidelity data during probe sessions across all conditions. The observer used a copy of the unit assessment and scored each item administered as correct or incorrect. To be correctly administered, the examiner had to give the target materials and directive to respond, wait 5 s, and provide no praise or correction. The observer collected procedural fidelity data across 33% of baseline probe session and 30% of intervention probe sessions for Amy, 33% of baseline probe sessions and 36% of intervention probe sessions for Nancy, and 30% of baseline probe sessions and 45% of intervention probe sessions for Brent. Procedural fidelity agreement was calculated by dividing the number of observed behaviors by the number of planned behaviors and multiplying by 100% (Billingsley, White, & Munson, 1980). Mean procedural fidelity across all participants for both baseline and intervention probe sessions was 100%.

The experimenter collected procedural fidelity data on the classroom teacher implementation of the task analyzed inquiry based lessons. To collect procedural fidelity, the observer used a copy of the task analysis for the lesson and scored each step as taught correctly or not. To be a correctly taught step, the teacher needed to perform the designated teacher action including providing opportunities for student responses, prompting, and feedback as planned. Fidelity was computed as the number of steps taught correctly. The experimenter collected procedural fidelity data across 29.7% of lessons across all units. Procedural fidelity was calculated dividing the number of steps taught correctly divided by total number of steps and multiplying by 100. The mean procedural fidelity across all units was 97.5% (range 93–100).

Social Validity

Via questionnaire, the experimenter collected social validity data from the classroom teacher implementing the science inquiry lessons and from each participant. The teacher's questionnaire included a 5-point Likert Scale ranging from strongly agree to strongly disagree. The classroom teacher strongly agreed that (a) the time spent implementing the lessons was a good use of students' time during the school day and (b) she would like to participate in future research opportunities in providing general curriculum access for students with severe disabilities. She also agreed that the targeted skills were important for students in her classroom and that she would consider incorporating aspects of the lesson (e.g., making a prediction) into other instructional routines during the school day. She did not agree that the skills acquired during the instructional lessons generalized to other curricular areas across the school day.

The student questionnaire included three yes/no questions. The teacher verbally read to each question and the response options to the participants. The response options were paired with a face smiling and thumbs up for "yes," and a face frowning with thumbs down for "no." These smiley faces were the same smiley faces used in the classroom in a variety of contexts during the school day. The teacher read all questions to the students and allowed students to responds by pointing independently to their response and based on their response, students marked their answer using a pencil independently or using hand over hand prompting from the teacher. Participants of the study all responded affirmatively to the social validity questions "Did you like playing the science game" and "Would you play another game, like a math or reading game if I asked?" Two of the participants responded negatively to the question "Did the science game help you do other work in school?"

Discussion

This study demonstrates that elementary students with severe developmental disabilities can learn science vocabulary and concepts linked to grade-level standards via a task analysis with systematic instruction that is applied across changing content. Similar to the findings of Jimenez, Browder, Spooner, and DiBiase (2012) and Jimenez et al. (2009), students not only learned new vocabulary terms via time delay instruction, they also were able to gain concept knowledge within the context of a science lesson. In contrast, while prior researchers focused on students with moderate disabilities, this study was conducted with elementary aged students with severe developmental disabilities who had communication and motivation factors that typically make general curriculum access increasingly difficult due to the extensive support needed for these students to make academic gains (e.g., adapted materials, concrete representation of vocabulary).

All three students began this study with limited knowledge of the science content; however, all three students were able to meet the criteria for progressing through science lessons for all four units of instruction with time delay trials embedded during an inquiry-based science lesson. Often in teaching vocabulary like sight words to students with severe disabilities, researchers have used massed discrete trials with time delay (Browder et al., 2006). Similarly, the science words in the current study could have been taught in isolation and produced word recognition. In contrast, the current study assessed whether students comprehended the word through its use in a concept statement or by answering a question. Browder et al. (2006) note that for students with severe disabilities, vocabulary has often focused on word identification without a measure of word comprehension. Isolated word recognition may not produce comprehension. One reason for embedding the time delay in the science lessons was that students were given hands-on experiences with the meaning of the concept word. For example, the students did an experiment to see how a rainbow is formed by a prism of light. Embedded time delay trials also may be used in general education contexts (e.g., Jameson et al., 2008; Jimenez, Browder, et al., 2012). What is unknown in the current study is whether participation in the inquiry lesson including responses like making a prediction and conducting an experiment contributed to the comprehension of the vocabulary. Future research might compare massed trial training of the concept statements with this embedded instruction. It also would be helpful to know the scope of the concept learning in these varying conditions, for example, by assessing generalization to untrained materials like Jimenez et al. (2009) included in their research.

Besides the focus on concept learning that occurred through the embedded time delay trials, a second variable to consider in this research is the use of a generic teaching task analysis that provided a format for teaching across varying content. Science instruction can be complex for several reasons. A special education teacher may not understand the concept well enough to know how to present it simply without presenting misinformation. The open-ended inquiry processes sometimes used in general education typically lack the systematic instruction students with severe developmental disabilities often need to learn new information. In contrast, how to apply procedures like task analysis and prompting may not be readily apparent when working from a typical science text or general education lesson plan. Teaching procedures that can be used across changing content may promote teacher ability to manage this content. Courtade et al. (2010) demonstrated how teachers could master a generic task analysis for teaching inquiry. The current study built on this approach, but added more trials for the student to master the concept. Future research is needed to see the extent to which teachers can generalize teaching from a task analysis or other template for modifying general curricular materials. For example, would teachers be able to create new versions of the task analysis for science concepts not provided by the researcher?

Limitations

While all three students demonstrated an increase in science behaviors across all four units of instruction, it is possible that some students came into the study with prior knowledge before the intervention. During Unit 1 and 3 baseline probes, students' background knowledge may have contributed to their responses (e.g., parts of the body, identification of the sun/moon). Despite this knowledge, all participants still showed a change in level and trend across all units following introduction of the intervention. While prior knowledge of specific learning objectives is not optimal in research, it is to be noted that typically developing students often begin instructional units with varying entry knowledge; the overall objective for all learners is an increase in the breadth and depth of that knowledge.

Second, although for the majority of units participant's scores reflect a change in level immediately following introduction of the intervention, for some units, participants' correct responses to assessment items appear delayed (e.g., Amy's performance in Unit 4). As part of each task analyzed lesson, the third step is to review all the vocabulary and concept statements taught in previous lessons. It is possible that this delay is due to the repeated practice often required for students with severe developmental disabilities to acquire new skills. This is most readily apparent in the performance data associated with Unit 4. Because the curriculum used is progressive, it is possible the participants needed more opportunities to respond and experiences in the lesson to answer questions for these more complex concepts (e.g., life cycle, change, growth).

A third limitation of this study was the experimenter's inability to collect data following the final lesson of the first unit due to student absences prior to winter break. Since all three students had demonstrated criterion-based performance on data collected through the first five lessons of the Unit, the research team chose to continue with the intervention, moving on to Unit 2 after the winter break. Additionally, this decision was made because maintenance data would be taken on Unit 1 following the completion of Unit 2 (see Figures 1–3).

A possible fourth limitation of this study was the number of response options the students had to indicate comprehension of the science content. Only three response options were given to the students with a 33% chance of students guessing the correct answer. Increasing the number of response options for the students would increase the likelihood that students would not be able to guess the correct answer during probe sessions. On the other hand, with this group of students' lack of motivation to respond and communication challenges, all three students were seldom given more than two to three options with the remaining portion of the school day during academic instruction. For consistency in implementation and concerns with lack of participation, three response options were used during lesson plan implantation and probe sessions. While students did have a 33% chance of a correct answer, data indicated a significant enough increase in correct responses to suggest that students were not guessing, rather knew the

Figure 1. Amy's number of assessment items correct

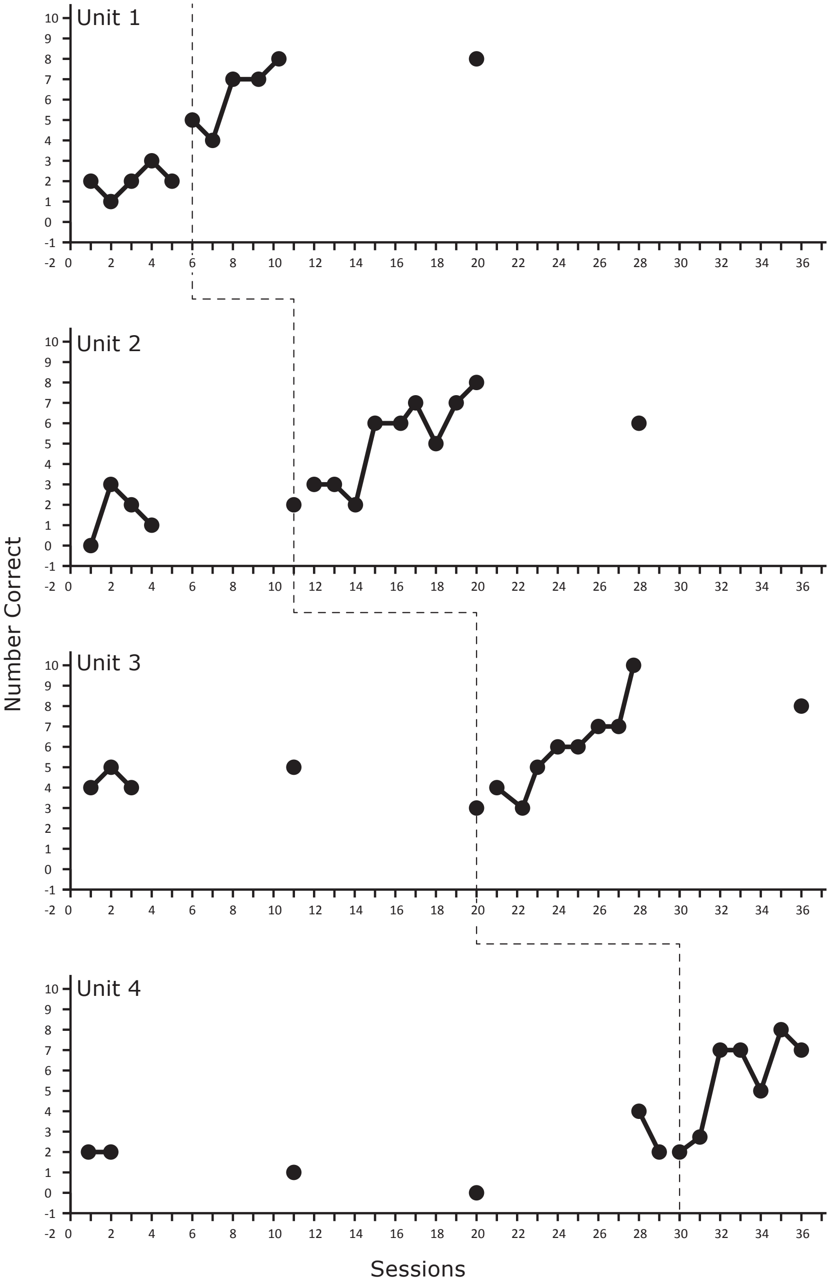


Figure 2. Nancy's number of assessment items correct

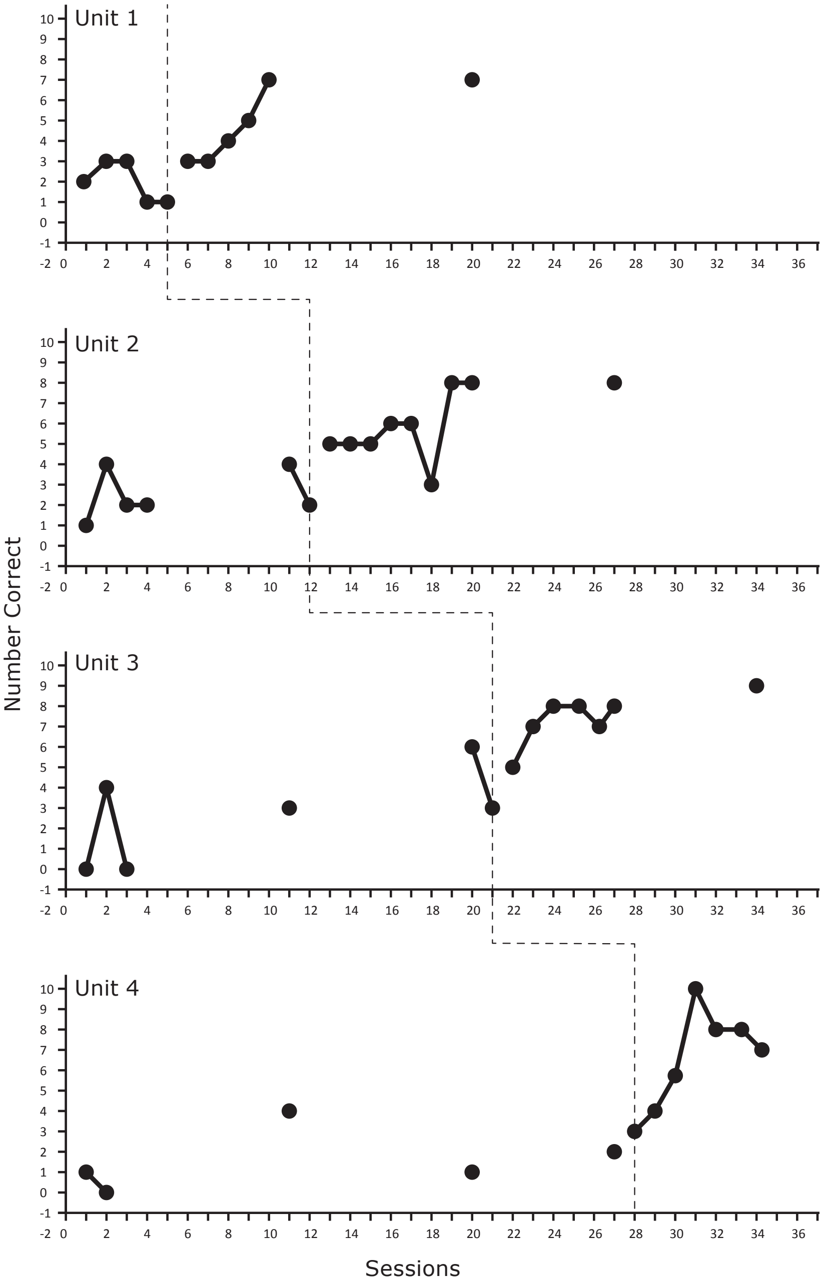
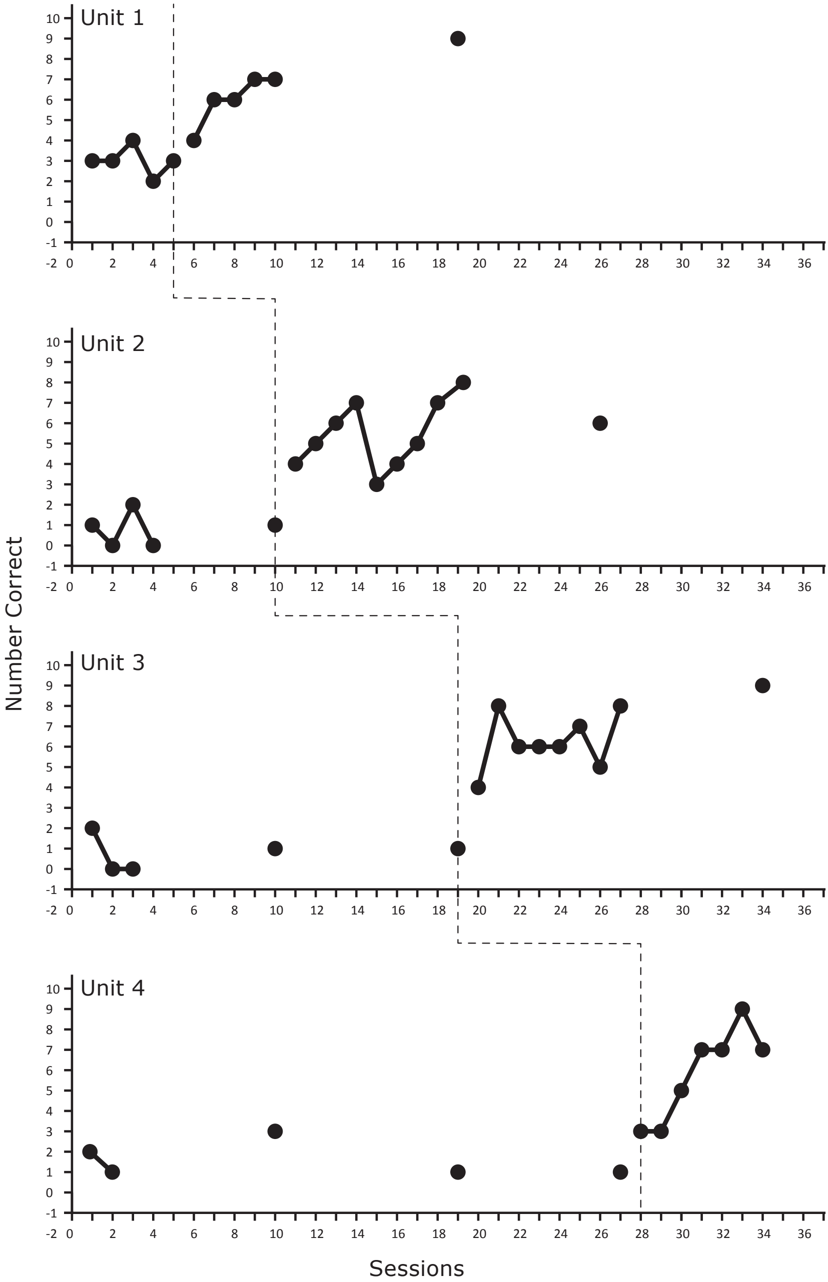


Figure 3. Brent's number of assessment items correct



correct answer. For example, Nancy consistently responded correctly in Unit 2 to five assessment items following instruction completing concept statements such as "Rocks (change) to make new rocks," "This picture shows (wing and water)," and "Land can (change)."

Another potential limitation of the study, each lesson consisted of an intervention package. All lessons included both systematic instruction procedures as well as at least one hands on activity or experiment (e.g., replicating forces of wind and water). Therefore, the researchers are unable to discern if one specific practice or all of the practices together were responsible for the increase in correct responses made by participants following the introduction of the intervention across all units.

A final limitation of the study includes the lack of a series of data points immediately preceding introduction of the intervention for Units 2, 3, and 4 across all participants. New standards developed by What Works Clearinghouse (Kratochwill et al., 2010) recommend that for multiple probe designs (a) each phase of the experiment must contain at least five data points, (b) within each phase, there should be no more than eight sessions/days without a data point (probe), and (c) each tier must include a series of data points, minimum of three, immediately prior to the introduction of the intervention.

Implications for Practice

Although only three students participated in this study, all inquiry lessons were taught within a whole class science group. The teacher implemented the task-analytic lessons to a group of seven students, all with severe developmental disabilities. Often a concern to educators implementing highly effective, evidence-based instructional strategies is that majority of the research with this population of students has been conducted in single-case research designs with a very limited number of students. While this study evaluated the data of three specific students within the larger group of students in this class, all seven students participated in each lesson implemented. The teacher followed the same procedures of instruction for each student, allowing each child an opportunity to participate in the inquiry science lesson. Another positive aspect of this study is that all three participants did show gains in content knowledge, despite whole-group instruction, rather than 1:1 instruction in isolation from their peers. This is an important finding since teachers are required to cover a large amount of content within each school day and individual instruction for each student would limit the content a teacher could cover over a school year.

Another concern in the field of special education and general curriculum access is the lack of teachers who are considered "highly qualified" in the area of elementary science being asked to teach the content. According to NCLB (2002) for a teacher to attain "highly qualified" status a teacher must be a state licensed teacher who holds at least a bachelor's degree from a university or college and demonstrate competencies in the core content areas in which they provide instruction. This demonstration often includes a passing score on a standardized test (e.g., PRAXIS). In this study, the teacher was state licensed, held a Master's degree in Special Education, but was not "highly qualified" to teach science.

This study provided the teacher with a curriculum, *Early Science*, in which lessons were task analyzed, embedded with systematic instruction strategies (e.g., time delay, concept training), and consisted of scripted narratives of content specific information (e.g., description of why you can only see part of the moon, even though it is always round) allowing her to implement grade-aligned science curriculum with fidelity. In a review of the literature, Courtade, Spooner, and Browder (2007) found only three of the eight science standards, defined by the National Science Education Standards (NRC, 1996), were taught to students with severe disabilities within the published literature. While the previous decades lack of emphasis on teaching academics to this population may have had the greatest influence on their findings, it is worth noting that special education teachers' knowledge of science content also may have contributed to this outcome. Scripted lesson plans and/or lesson plans developed within the framework of a task analysis with specific content related information may be a way to help teachers provide science instruction using evidence-based instruction paired with sound science content, hence providing student a more well-rounded science education.

Suggestions for Future Research

One interesting finding of this study was the similar responses to the social validity measures for the teacher and students. Both the teacher and two students responded that they did not feel that the lessons provided opportunities to generalize skills learned to other settings or situations across the school day. One suggestion for future research to promote generalization is to implement these lessons or lessons based on a similar framework (i.e., task analytic with embedded systematic instruction) in a general education setting. While this study was conducted in a special education classroom, due to the current practices of the school system in which this study was conducted, further replications should be conducted to find appropriate ways to included students with severe disabilities in general curriculum science classrooms, using evidence-based practices for this population of students. Jimenez, Browder, et al. (2012) conducted a study in which middle school students participated in inclusive science inquiry lessons with peer-mediated systematic instruction, additional research should be conducted to promote elementary inclusive science inquiry instruction. Furthermore, considerations for implementing the curriculum in an inclusive setting should include establishing a criterion for students to demonstrate acquisition of skills to progress through the inquiry lessons and a procedure for what to do if a student does not meet this criterion.

In addition, the participants of this study all had significant communication and behavioral (i.e., motivation) issues that often had impeded their ability to participate in academic lessons and "show what they know." While the current research on teaching academic skills to students with severe developmental disabilities is limited, the research on teaching academics, including science, is sparser for this population of students. More research is needed to provide effective and feasible modes of academic instruction for students with more severe disabilities.

As a final recommendation, future researchers should establish a criterion to demonstrate "mastery" of the science content. Because a key component of this intervention was the participant's progression through each lesson across the four science units that mirror the typical progression in a general education science classroom, criteria were established for participants to progress to the next lesson (i.e., answering one out of two assessment items related to that lesson) and not to demonstrate "mastery" of the science content. Although participants were only required to correctly respond to a total of six assessment items per unit, all three participants responded above this criterion. On average, participants correctly responded to approximately 75% of assessment items for each Unit. In many school systems, a 75% constitutes a grade of C, which is considered a "passing" grade. In addition to establishing a "mastery criterion," future researchers may also want to consider collecting data pertaining to some of the salient features of an inquiry lesson (e.g., making a prediction, conducting an experiment, revising their prediction).

In summary, this study demonstrates that students with severe developmental disabilities can learn science vocabulary and content via inquiry-based lessons. Additionally, this study shows that special education teachers, who do not meet "highly-qualified" criteria of NCLB in the curricular area of science, can implement inquiry-based lessons with a high level of fidelity. Finally, this study demonstrates that within these inquiry-based lessons, teachers can embed evidence-based systematic instruction procedures (i.e., time delay and task analytic instruction).

References

Azrin, N. H., & Armstrong, P. M. (1973). The "mini-meal"—A method for teaching eating skills to the profoundly retarded. *Mental Retardation*, *11*, 9-11.

Azrin, N. H., & Foxx, R. M. (1971). A rapid method of toilet training the institutionalized retarded. *Journal of Applied Behavior Analysis*, *4*, 88-89.

Azrin, N. H., Schaeffer, R. M., & Wesolowski, M. D. (1976). A rapid method of teaching profoundly retarded persons to dress via a reinforcement-guidance method. *Mental Retardation*, *14*(6), 29-33.

Bannerman, D. J., Sheldon, J. B., & Sherman, J. A. (1991). Teaching adults with severe and profound retardation to exit their homes upon hearing the fire alarm. *Journal of Applied Behavior Analysis*, *24*, 571-577.

Billingsley, F., White, O., & Munson, R. (1980). Procedural reliability: A rationale and an example. *Behavioral Assessment*, *2*, 229-241.

Browder, D. M., Ahlgrim-Delzell, L., Spooner, F., Mims, P. J., & Baker, J. (2009). Using time delay to teach literacy to students with severe developmental disabilities. *Exceptional Children*, *75*, 343-364.

Browder, D. M., Spooner, F., Ahlgrim-Delzell, L., Harris, A., & Wakeman, S. (2008). A meta-analysis on teaching mathematics to students with significant cognitive disabilities. *Exceptional Children*, *74*, 407-432.

Browder, D. M., Trela, K., Courtade, G. R., Jimenez, B. A., Knight, V., & Flowers, C. (2012). Teaching mathematics and science standards to students with moderate and severe developmental disabilities. *The Journal of Special Education*, *46*, 26-35.

Browder, D. M., Wakeman, S. Y., Spooner, F., Ahlgrim-Delzell, L., & Algozzine, B. (2006). Research on reading instruction for individuals with significant cognitive disabilities. *Exceptional Children*, *72*, 392-408.

Collins, B. C. (Ed.). (2007). *Moderate and severe disabilities: A foundational approach*. Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Collins, B. C., & Stinson, D. M. (1995). Teaching generalized reading of product warning labels to adolescents with mental disabilities through the use of key words. *Exceptionality*, *5*, 163-181.

Cook, B. G., & Cook, L. (in press). Unraveling evidence-based practices: First steps toward evidence-based special education. *The Journal of Special Education*. doi: 10.1177/0022466911420877.

Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (2nd ed.). Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Courtade, G. R., Browder, D. M., Spooner, F., & DiBiase, W. (2010). Training teachers to use an inquiry-based task analysis to teach science to students with moderate and severe disabilities. *Education and Training in Autism and Developmental Disabilities*, *45*, 378-399.

Courtade, G., Spooner, F., & Browder, D. M. (2007). Review of studies with students with significant cognitive disabilities which link to science standards. *Research and Practice for Persons with Severe Disabilities*, *32*, 43-49.

Drascow, E., Wolery, M., Halle, J., & Hajiaghamohseni, Z. (2011). Systematic instruction for students with severe disabilities. In J. M. Kauffman & D. P. Hallahan (Eds.), *Handbook of special education* (pp. 516-531). New York, NY: Routledge.

Flores, M. M., & Ganz, J. B. (2007). Effectiveness of direct instruction for teaching statement inference, use of facts, and analogies to students with developmental disabilities and reading delays. *Focus on Autism and Other Developmental Disabilities*, *22*, 244–251.

Fuller, P. R. (1949). Operant conditioning of a vegetative human organism. *American Journal of Psychology*, *62*, 587-590.

Gast, D. L. (2010). *Single-subject research in behavioral sciences*. New York, NY: Routledge.

Gast, D. L., Winterling, V., Wolery, M., & Farmer, J. A. (1992). Teaching first-aid skills to students with moderate handicaps in small group instruction. *Education & Treatment of Children*, *15*, 101-124.

Horner, R. D., & Baer, D. M. (1978). Multiple-probe technique: A variation of the multiple baseline. *Journal of Applied Behavior Analysis*, *11*, 189-196.

Horner, R. H., Carr, E. G., Halle, J., McGee, G., Odom, S., & Wolery, M. (2005). The use of single-subject research to identify evidence-based practice in special education. *Exceptional Children*, *71*, 165-180.

Individuals with Disabilities Education Improvement Act of 2004, PL 108-466, 20 U. S. C. §1400, H. R. 1350.

Jameson, J. M., McDonnell, J., Johnson, J. W., Riesen, T., & Polychronis, S. (2007). A comparison of one to one embedded instruction in the general education classroom and one to one massed practice instruction in the special education classroom. *Education & Treatment of Children*, *30*, 23-44.

Jameson, J. M., McDonnell, J., Polychronis, S., & Riesen, T. (2008). Embedded, constant time delay instruction by peers without disabilities in general education classrooms. *Intellectual and Developmental Disabilities*, *46*, 346-363.

Jimenez, B. A., Browder, D. M., & Courtade, G. R. (2009). An exploratory study of self-directed science concept learning by students with moderate developmental disabilities. *Research and Practice for Persons with Severe Disabilities*, *34*(2), 33-46.

Jimenez, B. A., Browder, D. M., Spooner, F., & DiBiase, W. (2012). Inclusive inquiry science using peer-mediated embedded instruction for students with moderate intellectual disabilities. *Exceptional Children*, *38*, 301-317.

Jimenez, B., Knight, V., & Browder, D. M. (2012). *Early science*. Verona, WI: Attainment Company.

Knight, V. F., Smith, B. R, Spooner, F., & Browder, D. M. (2011). Using explicit instruction to teach science descriptors to students with autism spectrum disorders. *Journal of Autism and Developmental Disorders*. Advance online publication. doi: 10.1007/s10803-011-1258-1.

Knight, V. F., Spooner, F., Browder, D. M., Smith, B. R., & Wood, C. L. (2011). *Using graphic organizers and systematic instruction to teach science concepts to students with autism spectrum disorder.* Manuscript submitted for publication.

Kratochwill, T. R., Hitchcock, J., Horner, R. H., Levin, J. R., Odom, S. L., Rindskopf, D. M., & Shadish, W. R. (2010). *Single-case designs technical documentation*. Retrieved from What Works Clearinghouse website: http://ies.ed.gov/ncee/wwc/pdf/wwc_scd.pdf.

McDonnell, J., Johnson, J. W., Polychronis, S., Riesen, T., Jameson, M., & Kercher, K. (2006). Comparison of one-to-one embedded instruction in general education classes with small group instruction in special education classes. *Education and Training in Developmental Disabilities*, *41*, 125-138.

McDonnell, J. J., & O'Neill, R. (2003). A Perspective on single/within subject research methods and "scientifically based research." *Research and Practice for Persons with Severe Disabilities*, *28*, 138-142.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

No Child Left Behind Act of 2001, Pub. L. No. 107-110, 115 Stat. 1425 (2002).

Odom, S. L., Brantlinger, E., Gersten, R., Horner, R. H., Thompson, B., & Harris, K. R. (2005). Research in special education: Scientific methods and evidence-based practices. *Exceptional Children*, *71*, 137-148.

Snell, M. E. (Ed.). (1983). *Systematic instruction of the moderately and severely handicapped* (2nd ed.). Columbus, OH: Merrill.

Snell, M. F., & Gast, D. L. (1981). Applying time delay procedures to the instruction of the severely handicapped. *Journal of the Association for Persons with Severe Handicaps*, *6*(3), 3–14.

Spooner, F., & Browder, D. M. (2003). Scientifically based research in education and students with low incidence disabilities. *Research and Practice for Persons with Severe Disabilities*, *28*, 117-125.

Spooner, F., Knight, V., Browder, D. M., Jimenez, B., & DiBiase, W. (2011). Evaluating evidence-based practices in teaching science content to students with severe developmental disabilities. *Research and Practice for Persons with Severe Disabilities*, *36*, 62-75.

Spooner, F., Knight, V. F., Browder, D. M., & Smith, B. R. (2011). Evidence-based practices for teaching academic skills to students with severe developmental disabilities. *Remedial and Special Education*. Advance online publication. doi:10.1177/0741932511421634.

Spooner, F., Stem, B., & Test, D. W. (1989). Teaching first aid skills to adolescents who are moderately mentally handicapped. *Education and Training in Mental Retardation*, *24*, 341-351.

Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. *Journal of Applied Behavior Analysis*, *10*, 349-367.

Tankersley, M., Harjusola-Webb, S., & Landrum, T. J. (2008). Using single-subject research to establish the evidence base of special education. *Intervention in School and Clinic*, *44*, 83-90.

Tawney, J. W., & Gast, D. L. (1984). *Single subject research in special education*. Columbus, OH: Merrill.

Touchette, P. (1971). Transfer of stimulus control: Measuring the moment of transfer. *Journal of the Experimental Analysis of Behavior*, *6*, 223-232.

Winterling, V., Gast, D. L., Wolery, M., & Farmer, J. A. (1992). Teaching safety skills to high school students with moderate disabilities. *Journal of Applied Behavior Analysis*, *25*, 217-227.

Wolery, M., Bailey, D. B., & Sugai, G. M. (1988). *Effective teaching: Principles and procedures of applied behavior analysis with exceptional students*. Boston, MA: Allyn & Bacon.