

An Exploratory Study of Self-Directed Science Concept Learning by Students with Moderate Intellectual Disabilities

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Abstract:

This investigation focused on the effects of a treatment package including multiple exemplar training, time delay, and a self-directed learning prompt (KWHL chart) on students' ability to complete an inquiry lesson independently and generalize to untrained materials. Three middle school students with moderate intellectual disabilities learned to self-direct themselves through a 15-step task analysis to complete inquiry lessons in chemistry and physical science. All three students achieved mastery across materials, science concepts, and instructional settings, but unanticipated generalization weakened the demonstration of experimental control. The results provide a potential method for students with moderate intellectual disabilities to learn science concepts.

Keywords: severe intellectual disability | inquiry science | general curriculum access

Article:

As part of Project 2061 (1989), the American Association for the Advancement of Science published Science for All Americans to articulate the goal of scientific literacy for all high school graduates. The National Research Council (NRC) clarified this goal by creating the National Science Education Standards (1996), outlining eight content standards for this literacy, including (a) unifying concepts and processes in science, (b) science as inquiry, (c) physical science, (d) life science, (e) earth and space science, (f) science and technology, (g) science in personal and social perspectives, and (h) history and nature of science. Standard B (Science as inquiry) promoted the development of students' abilities to discover science and to gain a deeper understanding of science content.

Educators are beginning to consider how to apply these content standards to the education of students with moderate and severe intellectual disabilities (Spooner, DiBiase, & Courtade-Little, 2006). Traditional textbooks on educating students with moderate and severe disabilities have

not addressed the topic of science, and textbooks on science education have not addressed planning for students who may need adaptations and accommodations (Bass, Carin, & Contant, 2008; Collins, 2006; Snell & Brown, 2006; Westling & Fox, 2004). Some authors recently have described ways to adapt science content (Cooper-Duffy & Perlmutter, 2006), but the need exists for research to demonstrate effective interventions for this academic learning.

Current research reflects extremely limited coverage of science. A comprehensive literature review of studies with a link to science content found that science has been taught mainly in the context of functional skills such as personal health (e.g., first aid) and weather for students with moderate and severe disabilities (Courtade, Spooner, & Browder, 2007). Although some research on functional living skills overlaps with the subject of science, these studies address only a small portion of the national science content standards or most states' standards in science.

This limited science literature also includes studies focused on the acquisition of science vocabulary terms (e.g., recognizing science sight words). For example, Browder and Shear (1996) taught students with developmental disabilities to read weather-related sight words from a newspaper. Johnson and McDonnell (2004) taught general educators to embed sight word instruction for several content areas including science when instructing students with moderate developmental disabilities in inclusive settings. Although the acquisition of new vocabulary terms in science is important, vocabulary is not the only focus of science instruction. In contrast, the NRC promotes the active investigation of science so students gain in-depth science understanding (National Science Education Standards, 1996).

One of the challenges in promoting this active investigation is that teachers may find that an inquiry-based approach is difficult to implement in their classrooms (Keys & Kennedy, 1999; Roehrig & Luft, 2004). Inquiry-based science instruction has been defined as “a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories” (NRC, 1996, p. 214). Teachers of students with moderate and severe disabilities may be especially challenged given their general lack of preparation in science instruction. Courtade, Browder, Spooner, and DiBiase (in press) developed a method to prepare teachers of students with developmental disabilities to implement an inquiry-based lesson by following a task analysis. The participating teachers were able to address a middle school science curriculum (e.g., forces of motion, chemistry) by using this inquiry-based task analysis as a framework for the lessons. The students also increased their independent responses on student versions of the inquiry task analysis. One limitation of the study was that while students made independent responses, they were only able to do so after the teacher set up the next step (e.g., asking “How are these materials the same?”). This created some dependence on the teacher's directing the inquiry process by not allowing students to have full control over inquiry science learning.

A limitation of the research to date on science for students with moderate and severe intellectual disabilities has been the absence of demonstrations of the acquisition of science concepts. One possible way to address concept learning would be to teach students a specific concept through a process of investigation (e.g., finding out what occurs when the solute sugar is added to the solvent water) and then to teach the vocabulary needed to label what was observed (e.g., “A solute added to a solvent forms a solution”). To check for generalization of learning, the teacher would have the student identify the target concept with a variety of materials used across investigations. Using a variety of examples to promote generalization is known as multiple exemplar training.

For students with moderate and severe disabilities, multiple exemplar training has been used to teach daily living skills (Taylor, Collins, Schuster, & Kleinert, 2002), appropriate behavior of children with autism (Gena, Krantz, McClannahan, & Poulson, 1996), vocational skills (Horner, Eberhard, & Sheehan, 1986), and other functional and communication skills. Multiple exemplar training also has been part of a treatment packages in teaching functional academics. For example, Karsh and Repp (1992) included multiple exemplars with systematic variation in the task demonstration model to teach digital clock times. McDonnell and Ferguson (1989) used a variety of sites to teach ATM use. Multiple exemplar training was also used to teach academic concepts to students with high-incidence disabilities in the form of explicit instruction (Miller & Hudson, 2007). In contrast, applications of multiple exemplar strategies to teach academic knowledge (e.g., a science concept) versus specific skill performance (e.g., finding a clock time, using an ATM) are not found in the literature for students with moderate and severe disabilities, probably because the focus on their academic learning is more recent.

Besides the lack of focus on science concepts, a second limitation of the science research to date with students with moderate and severe disabilities was that the learning was almost always teacher directed (e.g., Courtade et al., in press). For example, the teacher presented the vocabulary sight word or set up the next step of the inquiry task analysis. In contrast, the goal of inquiry is student-directed learning. Some research has shown that students with disabilities can acquire academic skills through self-directed learning (Agran, King-Sears, Wehmeyer, & Copeland, 2003). For example, Agran, Blanchard, Wehmeyer, and Hughes (2001) examined the effects of self-directed learning strategies on students’ academic, study, and social skills. Academically related skills were taught in various settings (i.e., Biology, English, History classes) and included such behaviors as carrying a day planner to class, recording assignments, scheduling time to complete assignments, completing assignments, and turning in completed assignments. Each student received instruction on how to self-monitor, self-evaluate, and self-regulate their progress. Similarly in 2006, Agran, Cavin, Wehmeyer, and Palmer investigated the effects of the Self-Determined Learning Model of Instruction on academic achievement with three junior high school students with moderate to severe disabilities. Target goals were selected by students pertaining to scientific inquiry, body system and functions, and map skills. These academic skills were measured by students’ ability to identify self-directed learning strategies

that would assist them in the attainment of their target goal (e.g., for science inquiry, the student would identify activities done in a laboratory, such as gather materials or record information in log).

Although these studies focused on academically related social behaviors, self-regulated learning strategies may also have applicability to the processes of inquiry science. One such strategy might be to teach students to use a KWHL strategy that involves asking (a) what do we know (K), (b) what do we want to know (W), (c) how do we find out (H), and what have we learned (L)? The KWHL strategy can be used across content areas in general education including science teacher resources. For example, the Institute for Inquiry (National Science Foundation, 2009) promotes the use of this strategy to teach science as well as English language arts (<http://www.exploratorium.edu/ifi/index.html>). The North Carolina State University (2009) Teacher Resource Room provides teachers with a chart and directions to use this strategy while teaching to state standards (<http://www.ncsu.edu/midlink/tch.wk.rm.htm>). Using the KWHL approach in science instruction with students with moderate developmental disabilities may provide general curriculum access in ways that are consistent with teaching methods in general curriculum classrooms, thereby creating greater opportunities for inclusive education.

The purpose of the current study was to examine the effects of a multicomponent training package on students' ability to self-direct an inquiry process, to generalize the use of a self-directed learning prompt to an untrained setting, and to generalize a learned concept to untrained materials. The overall objective of this study was to identify methods that would allow students with severe disabilities to access science instruction in the general education classroom. The following primary research questions were addressed: What is the effect of a treatment package including multiple exemplar training, time delay, and a self-directed learning prompt (KWHL chart) on students' ability to complete an inquiry lesson independently? What is the effect of a treatment package including multiple exemplar training, time delay, and a self-directed learning prompt (KWHL chart) on students' ability to generalize the concept to untrained materials? And what is the effect of acquisition of generalized use of a KWHL chart on its use in a general education science lesson?

Methods

Participants and Setting

This study was conducted in a large urban school system in the southeastern United States. One special education teacher participant was recruited on the basis of her student population, interest, and prior participation in research studies with the authors. Student participants were identified by asking the teacher to nominate three students on her caseload who met the following eligibility criteria: (a) full scale IQ ≥ 55 , (b) adequate vision and hearing to interact with the materials, (c) an ability to communicate verbally or with an augmentative communication system, and (d) consistent attendance (absent less than two times per month).

Consent was obtained for each student as well as from the special education and general education science teacher. Students continued to receive any additional instruction specified by their IEP.

There were a total of three students in this study. The students' grade levels ranged from sixth grade to seventh grade, with two students in sixth grade and the other in seventh grade. The students' IQs ranged from 48 to 54 with a mean of 51.3. All of the participants primarily received services in the same self-contained classroom for students with moderate to severe intellectual disabilities with ongoing opportunities for inclusion. This study targeted learning content linked to a seventh grade general science class the students attended. Silvia was a seventh grade, 13-year-old young woman with an intellectual disability who participated in the study. She was able to identify over 40 functional sight words and was able to identify most picture symbols. Silvia communicated using verbal responses and could generate questions regarding information she was curious about. She was very social, enjoyed "small-talk" with peers and adults, and was able to demonstrate knowledge of content through verbal interactions, writing words (from a model), or selection of picture symbols. The second participant was Calvin. He was a sixth grade, 11-year-old young man with an intellectual disability. Calvin was able to identify approximately 15Y20 sight words and over 50 picture symbols. To communicate his needs and wants, Calvin used verbal responses and could generate questions to gain additional information as needed. Calvin enjoyed interaction with peers but especially looked for adult feedback through conversations about prior events. He was able to demonstrate knowledge of content through verbal interactions, writing words (from a model), or selection of picture symbols. Finally, Unice was a sixth grade, 12-year-old young woman with an intellectual disability who was able to identify a few sight words, mostly her name and very familiar instructional words (e.g., days of the week, month of the year, friend's names). She was able to identify approximately 10Y15 picture symbols consistently. Unice was a very quiet and shy student but enjoyed interaction with adults. To communicate her needs and wants, she would use verbal communication but typically used a pointing response to picture symbols to demonstrate knowledge of new content.

The initial trainings took place in the special education classroom during three individual sessions (1:1) taught by the lead researcher (i.e., first author) who was not their teacher. All three students also were observed for generalization of their use of a KWHL chart in the seventh grade general education science class during an inquiry lesson cotaught by their special education teacher and the science teacher. All three students were in the same seventh grade science class at the same time. Students had attended this class primarily for social inclusion about 10 times before the initiation of this study. This science class had approximately 20 students enrolled.

Materials and Science Concepts

Students received a science storybook (see Figure 1) and KWHL (what we know, want to know, how to find out, what was learned) workbook to go with each science concept. The science

storybook was composed of one story to guide each experiment (the story was repeated for each experiment within a concept). Two science concepts were taught over the course of the study; two storybooks were created to teach these concepts. The science concepts were chemical reactions (Concept 1: “Solutes dissolve faster in hot liquids”) and precipitation (Concept 2: “It precipitates when the liquid in clouds get heavy”). For each science concept taught, three variations in materials were used for each experiment. Concept 1 instruction involved experiments using hot versus cold liquids (solvent) to dissolve a solid (solute) and required students to identify what solvent (i.e., water, red colored liquid, yellow colored liquid) would dissolve the solute (i.e., bouillon cube, sugar cube, rock salt) faster. The solvents were colored to vary an irrelevant feature (i.e., color) but were all liquids (relevant feature.) The solutes had different shapes and sizes (irrelevant features) but were all dry solids (relevant feature). The three variations of the experiment included bouillon cube in water (A), sugar cube in red liquid water (B), and rock salt in yellow liquid water (C). Students put the solute into warm versus cold versions of the liquid to discover the concept.



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 Science Unit 2 - Precipitation

 We have weather everyday. The clouds create different types of

 precipitation Have you ever watched the weather on the news report? Sometimes they

 tell us the chance of precipitation. That mean the chance that it will

 rain,

 snow,

 or sleet. Rain is a form of precipitation. When the air is

 cold enough, it may snow.

 Snow is a form of precipitation too. Sleet is

 little ball of ice that fall from the

 clouds. Sleet is a form of precipitation. Something happens to the clouds for them



create precipitation. Why do you think it rains, snows, or sleet? Let's find out! We need



to ask:



What happens when the liquid in clouds get heavy?




Figure 1. Sample storybook page.

Concept 2 (i.e., precipitation) was taught using an experiment with sponges serving as models of clouds. The variations in the materials for the experiment included having sponges that were different sizes, textures, and colors (i.e., small blue kitchen sponge, large light blue car wash sponge, large yellow kitchen sponge), but all sponges were able to absorb moisture, varying from a little to a large amount of moisture (relevant stimuli). The “precipitation” also varied the form of moisture (irrelevant stimuli), but all were forms that came from clouds (relevant stimuli). The variations in precipitation included mock rain (water), snow (dry powder that when water is added becomes “snow”), and sleet (ice pellets). During the experiment, the student filled one “cloud” (sponge) with a small amount of precipitation (e.g., snow) but filled the other “cloud” (sponge) until it was saturated. The three variations of the experiment included a small kitchen sponge with rain (water; materials D), a carwash sponge with snow (premade “snow”; materials E), and a large kitchen sponge with sleet (ice; materials F).

In the general education class, observations focused on the same experiments using the same materials but were conducted during whatever activities were planned by the teaching team for the day. Teaching teams followed their typical lesson schedule and embedded opportunities for students to initiate use of their KWHL workbook during the natural course of the lesson.

The KWHL workbooks were created to fit within three-ring binders. Each page of the workbook was designed to guide the student to follow the steps of the inquiry lesson independently (see Figure 2). The KWHL workbooks were developed by the researchers and reviewed by a science expert who validated their use as a tool for guiding inquiry-based science instruction.

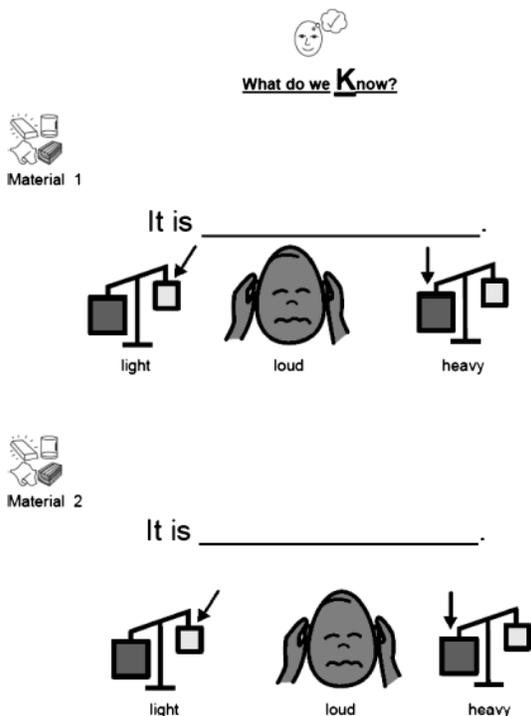


Figure 2. KWHL sample work page for Steps 1, 2, and 3 of the science inquiry task analysis used to answer “what we know” about the materials used in the experiment. This particular page is used to describe the two “clouds” used during Concept 2. Student can describe the “cloud” (sponge) as light (without or little precipitation), heavy (full of precipitation), or loud (distracter). The concept taught during this lesson is “We have precipitation when clouds are heavy.”

KWHL Chart			
 What do we K now?	 What do we W ant to know?	 How can we find out?	 What did we L earn?
Student's name		Prediction	

Figure 3. KWHL chart.

Dependent Variables and Data Collection Procedures The research team developed a task analysis that focused on the use of a KWHL chart (see Figure 3) to self-direct an inquiry-based science experiment. Most steps required communication between the student and the researcher or the general education teacher about the materials and concepts of the experiment (see Table 1). Task analytic assessment was used to measure this dependent variable. During baseline, the student was given the opportunity to perform each and every step within 5 seconds without prompts or feedback. During intervention, data were taken during instruction. Each step of the task analysis was scored as independent correct in book (ICB), incorrect in book (IB), independent correct verbally (ICV), incorrect verbally (IV), no response (NR), or prompted correct (P). Only ICB were coded as independent correct answers. Because of the student’s inexperience with the self-directed use of a workbook, it was important to capture verbal responses to gauge content acquisition apart from knowledge of how to use the workbook.

During the general education classroom instruction, the same task analysis and coding method were used to measure the second dependent variable of self-directed inquiry. Only unprompted correct responses in the book (ICB) were graphed. The intervention continued, and data were collected by the researcher over three school days per week until the student met the criteria for mastery of 100% for three consecutive days. There were three sets of materials for the experiment for both concepts, six sets of materials total (three per concept). Participants were trained using the first two experiments while the third set of materials for the experiment was used as a generalization probe.

The third dependent variable was the student's ability to generalize use of a KWHL chart to inquiry lessons in a general education science class. Students took their storybook and KWHL workbook relevant to the science concept (i.e., chemical reaction, precipitation) to the science class. Two measures were used in this observation. The first was the replication of the task analysis of the self-direct inquiry using the same activity used in the special education class. The researcher, who served only as an observer in this setting, recorded each step as correct, incorrect, or not observed. No prompts or feedback were given. The number of steps the student initiated in this context was graphed. A second measure was a simple frequency count for the student's ongoing use of the KWHL chart (a form of self-instruction) during ongoing science lessons (i.e., not lessons that had been pretaught in the special education class). The researcher recorded all questions or references the student made to the KWHL chart during the lesson.

Table 1. Science Inquiry Task Analysis (Student Behaviors) Using KWHL Workbook

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1. Points to K, reads "What do we know?"
 2. Answers "What do we know" question by using experiment Material 1 (e.g., "One cup of water here is cold")
 3. Answers "What do we know" question by using experiment Material 2 (e.g., "One cup of water here is hot")
 4. Point to W, reads "What do we want to know?"
 5. Answers "What do we want to know" question using story prompt (e.g., "What will happen to the solute in hot or cold liquids?")
 6. Point to H, reads "How will we find out?"
 7. Answers "How will we find out" question by choosing from a selection of materials to perform the experiment (e.g., chooses tool to stir liquid) Conduct experiment (participate in experiment as directed by teacher or researcher)
 8. Makes prediction and places Velcro sentence to last page of student book (e.g., "I think the solute will dissolve faster in the hot liquid")
 9. Point to L on chart, reads "What did we learn?"
 10. Answers "What did we learn" question (same materials as Step 3) (e.g., "The liquid in cup 1 was cold")
 11. Answers "What did we learn" question (same materials as Step 3) (e.g., "The liquid in cup 2 was hot")
 12. Answer "What did we learn" question by stating what is the same (e.g., "Both solutes were put in a liquid")

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13. Answer “What did we learn” question by stating what is different (e.g., “One liquid was cold, the other liquid was hot”)
 14. Reviews prediction (check or x) (e.g., places check mark if prediction was correct, or places X if prediction was incorrect, and changes their prediction)
 15. Fill in blank on Concept Statement Solutes dissolve faster in ____ liquids. (hot)

Procedure

Baseline

During baseline, all three students were taught together in a small group format in the special education classroom. The researcher read the science story, used the KWHL chart during instruction, and asked students to perform the inquiry experiment including using the book to summarize their responses. The researcher taught the experiment addressing the science concept by going through each step of the task analysis while waiting 5 seconds for students to respond to each question. If a student omitted a response or made an error, the teacher set up the materials for the next response but did not provide prompts or verbal comments except “keep going.” During baseline, the researcher probed all six sets of materials (A-C for Concept 1 and DYF for Concept 2.)

Intervention

After all students completed baseline probes for all six sets of materials (three variations for each experiment), intervention began in the special education class. The researcher provided the intervention separately to each student in an individual science tutorial. During the tutorial, the researcher read the science story, supplied the KWHL workbook, and asked inquiry-based questions. The researcher referred to the KWHL chart by asking questions (e.g., How would you like to learn more about precipitation?) and pointing to the corresponding letter (H for “how”). The researcher then waited for the student to initiate finding the Hon their book, answering the question for that portion of the lesson, and then filling in their personal KWHL chart within their workbook. For the first variation of Experiment 1 (Concept 1) and using material Set A, the researcher applied a constant time delay method and demonstrated each step of the lesson following the task analysis with no time in between steps (zero delay training). Each student was capable of imitating the modeled steps and responded using their replica set of materials A. No data were taken during these zero delay trainings as the students did not have the opportunity to make unprompted correct responses. Beginning with the fourth lesson on Set A, the researcher used a 5-second delay before giving the model of the correct response (i.e., waited 5 seconds to give each participant time to complete steps of the task). Once the students were able to complete the task analysis independently for material Set A (bouillon cube in water), the remaining material sets for the concept (material Sets B and C) were probed to determine if students generalized the responses. It was hypothesized that students would need training on at least two sets; therefore, the researcher planned to repeat the zero delay model for 1 day on material Set B

and to provide no prompts on Set C. The researcher praised students for completing each step of the task analysis on the days when the zero seconds delay was used. Beginning with the 5-second delay trials, students only received praise for independent correct responses. If an error occurred, the researcher modeled the response and said, “Try again, the correct answer is I” and had students respond again.

This strategy was repeated for the second concept (precipitation) with 4 days at zero delay followed by 5-second delay on subsequent days on the first set of materials (D), which were a sponge and water for rain. Again, it was hypothesized that students would need 1 day of zero delay modeling to learn the second set of materials (Set E: different sponge and snow) and no training to respond correctly to the last set (F: different sponge and sleet).

Self-directed learning

Self-directed learning was embedded in the task analysis through students’ use of the KWHL chart. Students were taught to self-direct by flipping pages of the workbook, stating a response, and then filling in their individual KWHL chart, which promoted their management of the lesson independently once the instructional prompts were faded. The students were told they could use their workbooks in their general education science class while receiving the same group instruction the entire class received.

Experimental Design

A single-subject experimental design was used to evaluate the effect of the treatment package on the acquisition and generalization of the science task analysis. A multiple probe design across two science concepts (chemical reactions and precipitation) was used (within participant replication) with concurrent between participant replications for the three students who received the intervention (Gast, 2010). We used probes of three variations of materials (A, B, C and D, E, F) for each participant to demonstrate generalization of each concept. We hypothesized that students would need training on two of the three sets of materials and then generalize to a third variation of materials without training. We assumed students would not generalize to a new concept until trained with the materials and an application of task analytic instruction for that concept. During baseline, all six variations (AYF) of materials were probed (three sets for each of the two concepts). Instruction then began on the first set of materials (Set A, bouillon cube and water) for Concept 1 (chemical reactions). Once students had mastered all steps for the first set of materials (A), all three sets of materials for Concept 1 were probed (A, B, C). When students mastered all three sets of materials for Concept 1, all sets of materials for both concepts were again probed (AYF). Following these probes, instruction began on the first set of materials (D) for Concept 2, then probes of all three sets of materials (D, E, F) were conducted, with instruction on subsequent sets of materials (E then F) as needed.

In addition to the probes conducted in the special education classroom, two probes were conducted in the general education classroom. One probe was conducted during the second week

of intervention (fourth data session) in the general education classroom; this probe was conducted to ensure that the instruction occurring in the general education classroom would not compromise the validity of the study. Finally, an additional probe was conducted in the general education classroom at the conclusion of the intervention to demonstrate student maintenance KWHL responses and their ability to generalize these responses in a general education science classroom. Only one maintenance probe was conducted in the general education classroom because of the end of the school year with only one opportunity available to observe a science lesson.

In addition to the probes of lesson mastery, observations were made of the generalization of the KWHL chart across both lessons and concepts. The KWHL responses were graphed separately from the other responses on the task analysis as it was hypothesized that these responses would generalize across all six lessons early in instruction.

Interobserver Agreement and Procedural Fidelity

Interobserver agreement (IOA) reliability for student response data collection was taken on at least one session of all three lessons taught within a concept by a university researcher or graduate assistant who was blind to the hypotheses of the study. IOA was conducted on the experimenter's recording of student performance on the 15-step task analysis for each teaching trial. IOA was computed as agreements divided by agreements plus disagreements. Reliability taken on 25% of data collection sessions was consistently at 100%. In addition, procedural fidelity of implementation of the lessons taught was taken on at least one sessions of all three lessons taught within a concept by the same university researcher and graduate assistant. Procedural fidelity was measured by recording the number of steps of the task analysis that were presented to the student using the correct procedures, divided by the total number of steps (15).

Social Validity

At the completion of the study, both the general and the special education teacher were asked to complete a brief adapted intervention rating profile (Snyder, 2002) to indicate level of satisfaction with the training and instructional materials. The survey was read aloud to the special education students. Teachers responded to 14 items about the intervention using a 4-point Likert scale (i.e., 1 = disagree, 4 = agree). At the completion of the study, all three students were asked to complete a brief rating profile to indicate their level of satisfaction with the training and instructional materials. Students responded to eight items about the intervention using a four-point Likert scale (i.e., 1 = disagree; 4 = agree).

Results

IOA and Procedural Fidelity

IOA taken on 7 (25%) of 28 student response data collection sessions was consistently at 100%. Procedural fidelity of the implementation of the lesson was measured on 7 (25%) of 28 sessions with 100% accuracy for all observations.

Student Achievement

Figures 4Y6 show the number of steps correct for the three participants during baseline and intervention phases for the self-directed science inquiry lesson and the use of the KWHL chart. Figure 7 shows the number of steps correct for the three participants during baseline and intervention phases for the self-directed use of the KWHL chart across both science concepts and materials. Note that a different symbol is used on the graph for each set of materials and for the general education context. No data were taken on student performance during the first three sessions of intervention because zero time delay trials were being used to facilitate instruction. The duration of the interventions spanned 8 weeks (including maintenance data and generalization into the general education classroom).

Silvia (refer to Figure 4) did not get any steps correct in the initial baseline phases for the materials in Concepts 1 or 2. She learned all 15 steps for Concept 1 in four sessions with materials A and did not need instruction on materials B or C. In the seventh intervention session, she also correctly implemented 14/15 steps during the generalization measure in the general education science class and 15/15 steps 2 weeks postintervention in the general science class (see large circle). Silvia also had unanticipated generalization across concepts. That is, she was able to complete all steps of the task analysis through self-direction with her KWHL notebook before intervention with Concept 2 (precipitation). She had mastered the four-step KWHL chart during intervention sessions of the first concept and generalized its use across the five remaining materials (B and C for Concept 1 and DYF for Concept 2). As shown in Figure 7, Silvia also was able to generalize use of the KWHL chart to the general science class within a group of peers without disabilities (Session 7); she maintained chart use during the generalization probes 2 weeks postintervention.

Calvin (refer to Figure 5) had zero steps correct in the initial baseline phase for all sets of materials for Concept 1 and Concept 2. He learned all 15 steps for Concept 1 in five sessions and consistently generalized across materials B and C of that concept. After learning Concept 1, Calvin also demonstrated unanticipated generalization before intervention for 10 steps of the task analysis for Concept 2. He mastered the remaining steps in the first training session for Concept 2. Calvin consistently generalized across materials D, E, and F for Concept 2. Calvin also demonstrated mastery of the self-directed KWHL chart within five sessions of the first concept and generalized its use across all materials and to his general science class.

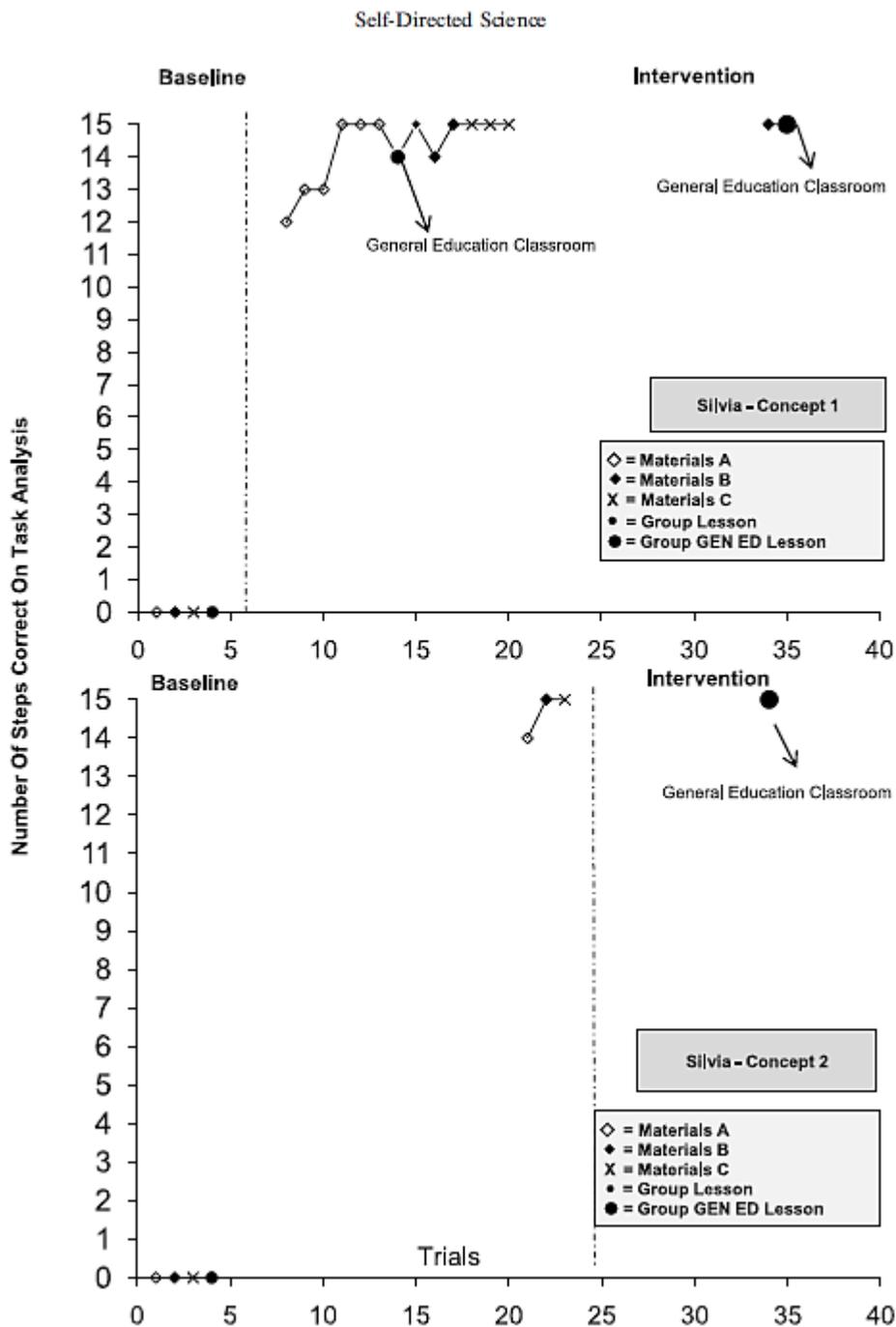


Figure 4. Number of steps correct on the self-directed science inquiry experiments (Silvia).

Unice (refer to Figure 6) had 0 correct responses in the initial baseline phases of Concept 1 and Concept 2. She acquired all 15 steps of the task analysis for Concept

1 immediately after intervention for materials A. Like Calvin and Silvia, she also had unanticipated generalization to the second concept after receiving intervention on the first

concept then mastered all steps with intervention. Unice showed consistent generalization of the task analysis across materials BYC for Concept 1 and materials DYF for Concept 2. She also demonstrated mastery of the self-directed KWHL chart immediately after intervention and generalized its use across materials for both concepts. Unice also completed four out of four of the KWHL steps when given the opportunity to use it in her general science class.

Social Validity

Both the general education teacher and the special education teacher reported strong agreement (Likert scale score of 4) on all 14 survey questions regarding acceptability of intervention goals, acceptability of procedures, and acceptability of outcomes. Student surveys indicated that students found the intervention to be a positive way to learn science. Students also liked working with the KWHL books and thought it would be beneficial to other students.

Discussion

All three students acquired and self-directed the use of a science task analysis across science concepts. What was unanticipated was how little instruction the students needed once given the self-directed strategy of following the KWHL chart. Although it was hypothesized that students would need training on at least two sets of materials to generalize the concept, one set of materials was sufficient for generalization of the concept across different materials. For example, once they understood that solutes dissolved more quickly in the hot solution, they recognized this principle whether the solute was a sugar cube, a bouillon, or a rock salt and regardless of the color of the solution. That is, they had mastered the concept versus simply memorizing the correct response for one set of materials.

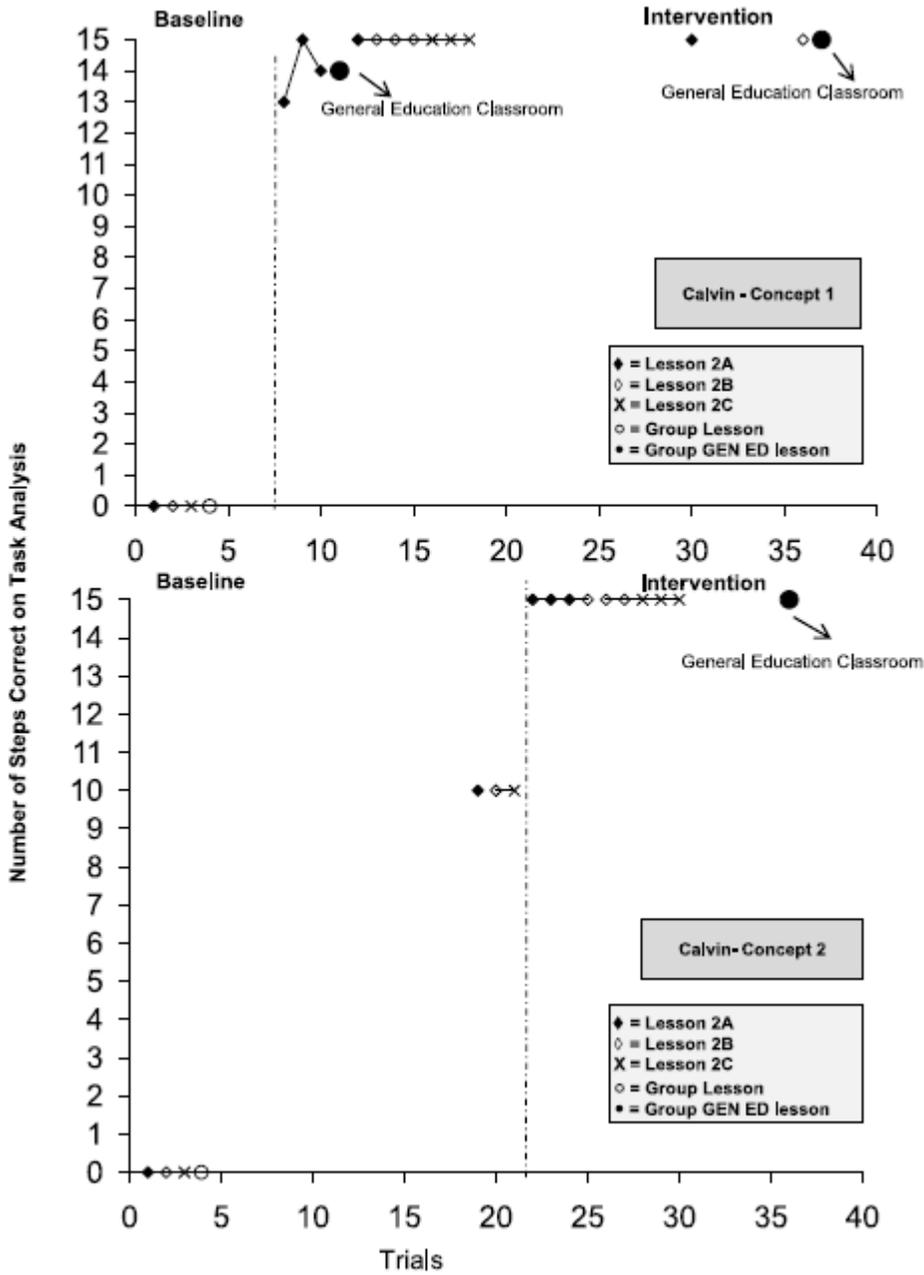


Figure 5. Number of steps correct on the self-directed science inquiry experiments (Calvin).

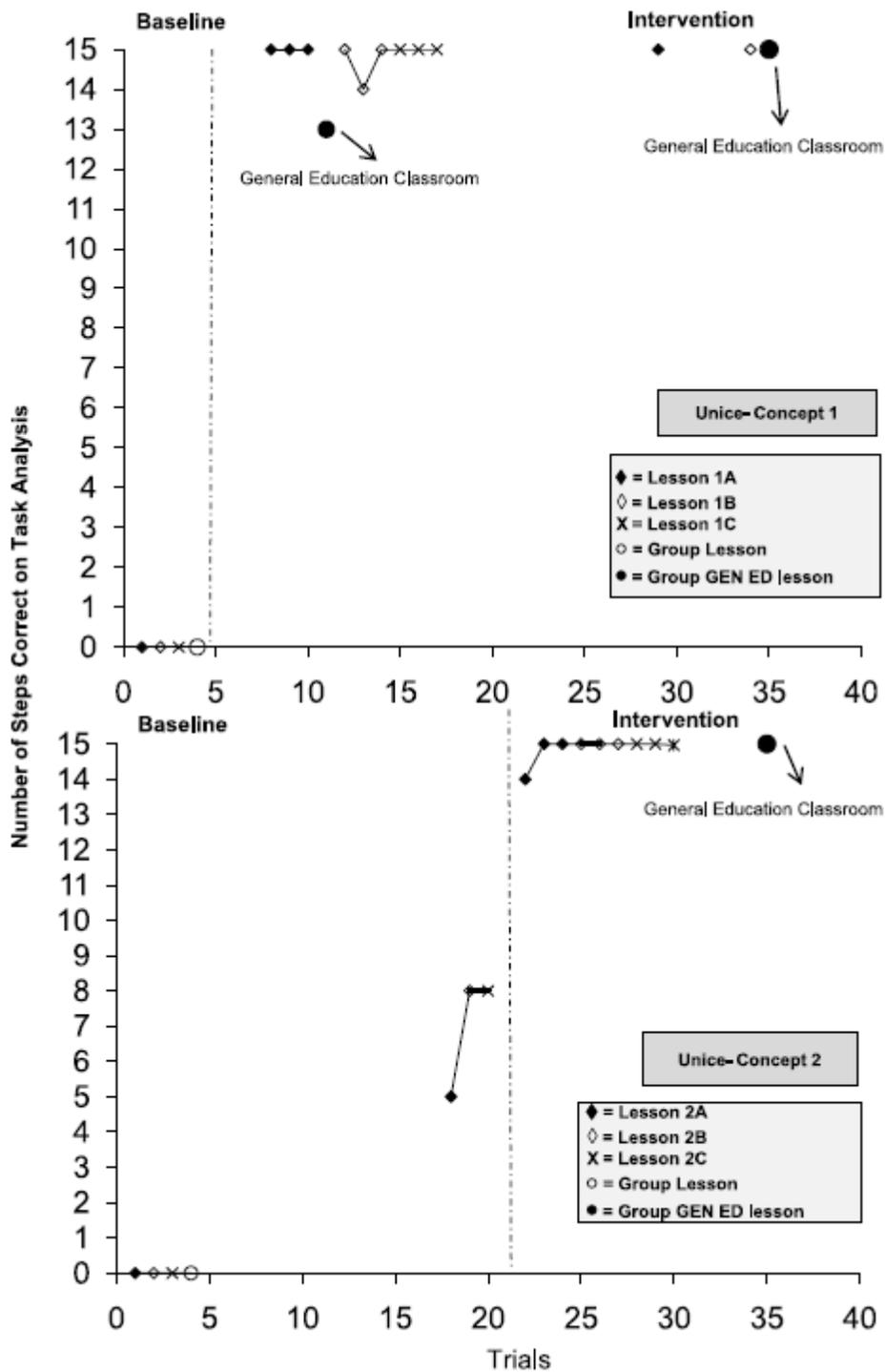


Figure 6. Number of steps correct on the self-directed science inquiry experiments (Unice).

What was even more surprising was that the students were able to surmise a new untaught concept using their self-directed KWHL strategy. That is, although the students had not been taught the new concept, they appeared able to use reasoning to probe the story for themselves, to

investigate the materials, and to use their charts to begin identifying the concept. For example, Silvia taught herself the entire task analysis for the second concept. While completing the task analysis during concept two, Silvia often made connections between Concept 1 questions and similar questions in Concept 2 (e.g., Material 1 is hot; Material 1 is heavy; Step 1 of task analysis: description of materials). Calvin and Unice were able to determine some of the responses for themselves and then quickly learned the rest once they received intervention for Concept 2. In future replications, the teacher might instruct the students to ask someone for help to fill in their missing responses rather than moving into teacher-directed task analytic instruction. With the addition of help seeking, it would be interesting to determine if students would be able to use the KWHL chart across a variety of content (e.g., other science concepts, other content areas like language arts).

Several researchers have suggested that self-directed learning can be a highly effective strategy. For example, regulating antecedent cues can foster social responses (Hughes et al., 2000), increase daily living skills (Trask-Tyler, Grossi, & Heward, 1994), and enhance work performance (Browder & Minarovic, 2000). Self-delivered instructional training can also promote social competence (Hughes, Harmer, Killian, & Niarhos, 1995) and increase and improve academic responses (Agran et al., 2006).

The use of the KWHL chart was developed to serve as an antecedent cue. That is, students were taught to use the cues of their KWHL chart to review the key points of a known concept during an inquiry lesson. The KWHL chart appears to have added value for generalization. By determining what they knew and what they wanted to learn and by discovering how to find out more information and review what they had learned, all three students acquired information about a new concept, and one mastered it.

Perhaps the most important finding is that the students were also able to generalize the use of the chart to a general science class where students were using the same materials and experiments. What is not clear is whether the students could have generalized their KWHL charts to new science concepts in the general education class without one-to-one instruction. It also is not clear whether the self-directed strategy needed to be taught in a separate context first or whether it could have been embedded in the general science class from the onset (Johnson & McDonnell, 2004). To embed the strategy, students might need some initial support from a peer or teacher to know how to use the KWHL chart. For example, the students in the current study needed from one to five sessions to master chart use. If all students in the class were using some form of KWHL chart, this would provide a strategy for keeping up with changing content.

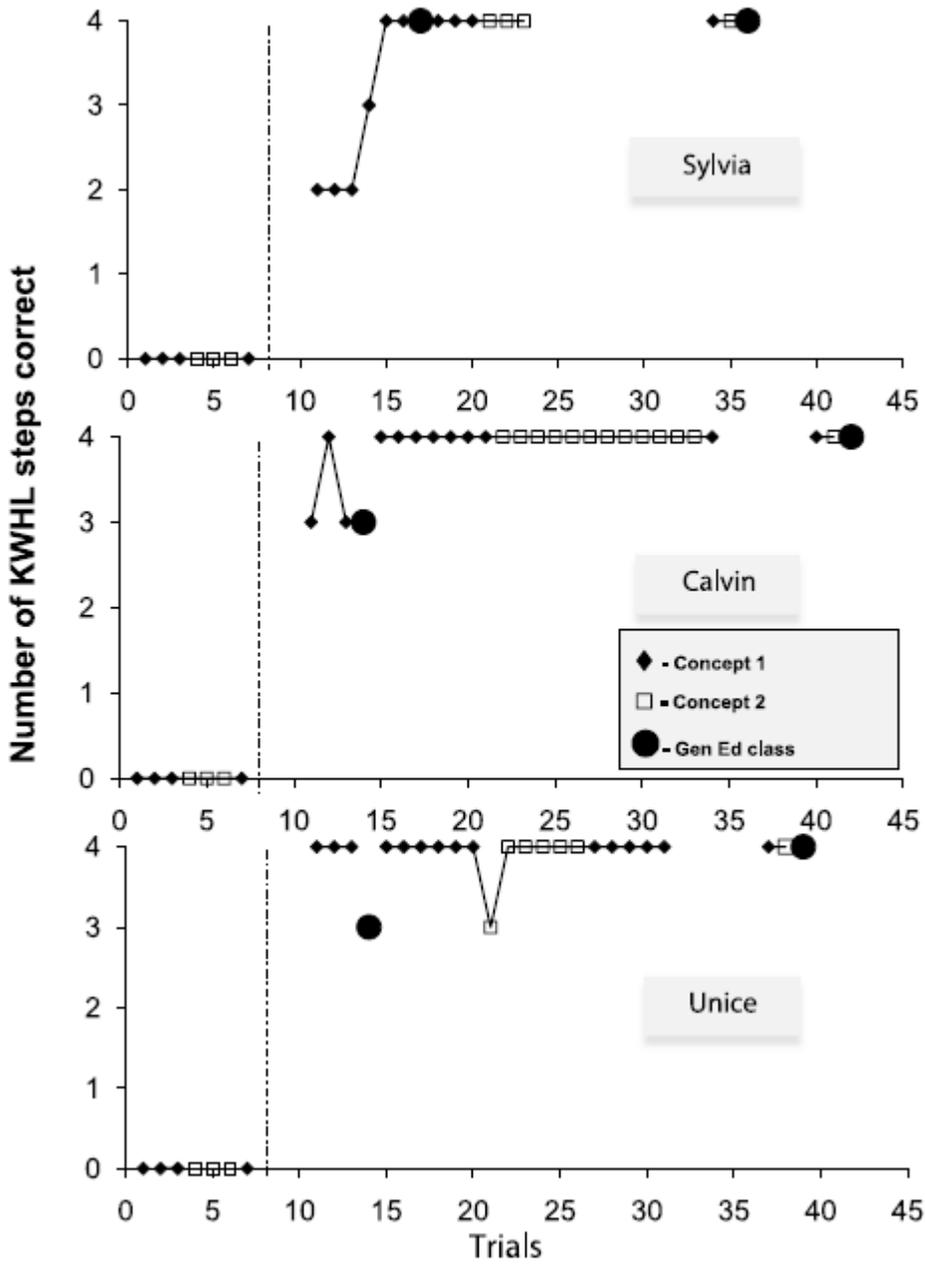


Figure 7. Number of steps correct on the use of the KWHL chart by all students.

A qualitative study by Dymond et al. (2006) suggests that embedding the KWHL chart from the onset in the general education class might be feasible. Dymond et al. examined the use of a participatory action research approach (Greenwood & Levin, 1998) to examine the process of redesigning a science high school course to incorporate the principles of Universal Design for Learning. Dymond et al. found that the Universal Design for Learning planning promoted social relationships and participation of students with significant cognitive disabilities in the general science class. One principle of universal design of instruction is to provide multiple means for

students to engage with learning and to make responses (CAST, 2008). A KWHL chart provides a means for students to engage with learning and to make responses. To build upon the research of Dymond et al., teachers might try using a KWHL strategy for academic student achievement (e.g., notebooks like those used in the current study).

Although this study focused on generalization of only two basic concepts, this study expanded the types of responses typically expected for students with moderate and severe intellectual disabilities in science. Prior research has focused primarily on recognizing science vocabulary sight words (Browder & Shear, 1996; Collins & Stinson, 1995; Jameson, McDonnell, Johnson, Riesen, & Polychronis, 2007), which is recall learning. In this study, students used concept across materials that required not only recall (e.g., to fill in their charts) but also application, a higher level of comprehension. Although some students with more significant challenges might require more extensive instruction, this study explored a way to promote concept learning rather than simple vocabulary use as a goal for science. Much more research is needed on how students with intellectual disabilities acquire science concepts. One resource for developing this research is the work on science concepts with students with high-incidence disabilities (e.g., Mastropieri, Scruggs, Boon, & Carter, 2001; McCarthy, 2005). For example, Mastropieri et al. (2001) taught the concepts of density and buoyancy through an inquiry-based learning activity involving bottles of water and oil and a series of questions leading the students through the experiment. This study by Mastropieri et al. is one example of research that provides low-incidence researchers with a starting point on providing science concept instruction to students with intellectual disabilities.

Although this study holds promise on how students with moderate intellectual disabilities may acquire science concepts, there are clear limitations in the design that should be noted. This study provided concurrent replications (across students) in which three students generalized a science concept after one-to-one instruction with a KWHL chart. Although staggered replications across two concepts were implemented for each student, the students' unanticipated generalization weakened the demonstration of a functional relationship between the intervention and the outcomes. Thus, following intervention, the students showed mastery with generalization across materials and settings for Concept 1, which suggested that they also generalized across concepts as a result of the intervention. In future replications, it is recommended that a different type of single-subject design (e.g., multiple baseline) be used. Specifically, we recommend that the intervention be staggered across students perhaps by choosing students in different schools or classes as participants. Because of the unanticipated generalization of the concepts, a ceiling on student learning was created. In future research, it is recommended that the baseline condition includes a larger array of concepts using the "big ideas" of a general science concept. Through such an approach, it would be feasible to discover the potential achievement level for individual students with disabilities in grade level content. For example, the students could have been assessed on 10 exemplars from the concept on chemical reactions rather than one. Finally, the participants in this study had some communication and academic skills that enhanced acquisition

for the KWHL chart. Students without these skills might need alternative methods to respond (e.g., with assistive technology) and more trials to reach mastery. In summary, this study explored a way to teach students with moderate intellectual disabilities to self-direct science concept learning. Little research has been conducted in the area of science instruction for this population. Although the design was weakened by unanticipated generalization, this study adds to the science research base by describing an instructional strategy that can be used for concept learning during an inquiry-based lesson. Replication of these findings using a different design would strengthen these results. Students were successful at learning how to self-direct themselves through new science content using systematic instruction and a KWHL chart. Students showed mastery with generalization across materials and settings, and results suggest they also showed mastery across concepts as a result of the intervention. Continued research on secondary science instruction is needed to expand access to complex concepts and inclusive education for students with moderate and severe intellectual disabilities.

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