Using systematic instruction to teach science to students with severe disabilities

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Using Systematic Instruction to Teach Science to Students with Severe Disabilities

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JAMES MADISON UNIVERSITY

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Abstract

Science content is still a commonly over-looked academic content area for students with severe disabilities despite recent research. The purpose of this study was to show that students with severe disabilities can learn science content in a whole group setting when taught using applied behavior analytic principles, such as prompting and fading techniques. Four elementary-aged students with severe disabilities between 1st and 5th grade were taught science content using group lessons and effects were measured by a multiple baseline design across units. Participants were taught content from three different units: Energy, weather, and plants; the science content selected aligned with Virginia’s Alternative Standards of Learning (ASOL) and helped complete two of the participants’ Virginia Alternate Assessment Program (VAAP) portfolios. Each unit consisted of five vocabulary words and their definitions and three concept questions (i.e., key ideas of the unit). Science content was taught to all four participants in group lessons using systematic instruction utilizing errorless prompting methods such as constant time delay and activities that related to the unit content. Probe trials were used to determine baseline and intervention effects.
Using Systematic Instruction to Teach Science to Students with Severe Disabilities

Introduction

Academic instruction for students with severe disabilities has changed dramatically since the introduction of special education services; one of the academic content areas that has undergone the most change is science instruction (Spooner et al., 2011). First, it is important to discuss individuals with severe disabilities and the education services provided to this population. There is not a comprehensive definition of a severe disability according to the Individual Disabilities Education Act (IDEA, 2004). U.S. Code: Title 29, the laws that outline labor in the United States, defines an individual with a significant disability as having impairments in three primary areas: 1) having a severe impairment (physical or mental) that seriously limits functional capabilities; 2) multiple vocational rehabilitation services required over an extended period of time; and 3) has minimally one physical or mental disabilities determined by an appropriate vocational assessment (Vocational Rehabilitation and Other Rehabilitation Services, 2015). Students who are considered to have severe disabilities typically do not participate in general curriculum assessments; instead, this population of students is included in adapted curricula. For the state of Virginia, there are the adapted standards of learning (ASOL) and the Virginia Alternative Assessment Program (VAAP), which are used to align instruction and assess yearly progress.

Historically, science instruction was either left out of academic instruction or was lumped in with hygiene skills for students with severe disabilities who are on adapted curricula (Spooner et al., 2011). Science instruction for students with moderate to severe disabilities has gone by the wayside for a number of reasons, but one of the main reasons is because it has been previously thought that science concepts, particularly inquiry-based concepts, are too complex for students
with moderate and severe disabilities. Research dating back to the 1980’s has shown that
students with severe disabilities not only have the ability to learn science content, but also are
able to use the knowledge in an applied way (Spooner et al., 1989). More recent research has
started to look at science content that aligns with the National Research Council’s National
Science Education Standards (NSES), particularly content that falls outside of the Personal and
Social Perspectives standard (Spooner et al., 1989; National Research Council, 1996). The
National Research Council’s NSES were created for states to use as collective standards and the
seven national content standards are: science as inquiry, physical science, life science, Earth and
space science, science and technology, science in personal and social perspectives, and history of
nature of science (National Research Council, 1996).

Spooner et al. (2011) offer a list of rationale for teaching students with severe disabilities
science content and those rationale are: students receive full educational opportunity of their
school, promotes understanding of the natural world and provides a format for posing questions,
and No Child Left Behind (NCLB) requires accountability for this subject. With these rationale,
research methods, and national science standards on which to base teaching, the last thing to
address is how to teach science content to students with moderate and severe disabilities.

A common practice for teaching students with severe disabilities is to use an instructional
method called systematic instruction; this strategy can be used to teach a variety of skills
including academics, self-help, and communication (Collins, 2012). Systematic instruction is
founded in behavior principles and is composed of components that make an instructional
package (Collins, 2012). The different components of a systematic instruction plan (SIP) are: the
target skill, teaching procedure, prompting strategy, plans for generalization and maintenance,
and data collection (Collins, 2012). The term systematic instruction plan is used in the field of
special education, but in applied behavior analysis treatment plans are called skill acquisition plans (Collins, 2012; BACB, 2014). The Behavior Analyst Certification Board (BACB) defines the components of a skill acquisition plan as: treatment setting, instructional methods to be used, operational definition for each skill, describe data collection procedures, and proposed goals and objectives (BACB, 2014).

The target skill for a SIP can be derived directly from assessments or from goals identified in an individualized education plans, or IEP (Collins, 2012). Target skills can be any behavior, simple or complex, that a student needs to increase or decrease (Collins, 2012). For the purposes of this study, the focus of the research, literature review, and target skills will be related to science content.

The first step in creating a systematic instruction plan is to consider a teaching procedure. Teaching procedures are the ways in which the target skill will be taught, corrected, and reinforced. Under systematic instruction there are three ways in which skills can be taught: discrete trials, task analysis, and incidental teaching (Collins, 2012). Discrete trial training is used when teaching a single, or discrete, behavior (Collins, 2012). When a skill requires that a chain of behaviors be performed in order to complete the skill, then a task analysis is used (Collins, 2012). A task analysis involves breaking down the chained behavior into small, teachable steps (Collins, 2012). The steps can be taught as a whole (i.e., total task), by teaching one step at a time starting with the first step (i.e., forward chain), or by teaching one step at a time starting with the last step in the chain (i.e., backwards chain; Collins, 2012). Incidental teaching is best used for behaviors that happen frequently throughout the day or cannot be easily or safely contrived (e.g., teaching replacement behaviors for maladaptive behaviors; Collins, 2012). The teaching procedure also needs to address the way in which the teacher will reinforce
correct responses and correct errors (Collins, 2012). For correct responses, learners are rewarded with reinforcement that is preferred (e.g., teacher praise, clapping, high five, edible). When a student makes an incorrect response, the instructor presents an error correction procedure that shows the student the correct response and gives him or her an opportunity to practice the correct response (Collins, 2012).

There are five different prompting strategies to choose from when creating a SIP (Collins, 2012). The five prompting strategies are: most-to-least (MTL), system of least prompts (SLP), progressive time delay (PTD), constant time delay (CTD), and simultaneous prompting (SP; Collins, 2012). System of least prompts is more commonly referred to as least to most in applied settings (Collins, 2012). MTL and SLP procedures use a hierarchy of prompts (i.e., independent, verbal, gesture, model, physical) that either progress from the most intrusive to the least intrusive or the least intrusive prompt to the most intrusive, respectively (Collins, 2012). PTD, CTD, and SP procedures each use a controlling prompt and fade that prompt by delivering it after the discriminative stimulus at increasing time delays (Collins, 2012). Progressive time delay begins with a 0 s time delay after the instructional stimulus and slowly increases until the student has reached the fluent mastery (e.g., 0 s, 1 s, 2 s, 3 s, 4 s; Collins, 2012). Constant time delay, unlike progressive, only has two prompt levels: 0 s time delay and the fluent mastery time delay (e.g., 4 s; Collins, 2012). Simultaneous prompting includes instructional sessions and probes sessions (Collins, 2012). Probe sessions are done before the instructional sessions and are used as a type of baseline (seeing what the learner knows; Collins, 2012). Instructional sessions are conducted on a 0 s time delay (Collins, 2012). Probe sessions determine the need for instructional sessions; there is immediate data showing if a student has learned a skill, which means that he or she does not need to be taught (i.e., instructional session).
The final component of SIPs is a plan for maintenance and generalization of the skill taught (Collins, 2012). Plans for generalization and maintenance are included in the SIP in order to make the skill more functional for the individual (Collins, 2012). Generalization plans are used to help the student use the skill across settings, people, and places (Collins, 2012). Maintenance is the continuation of a skill across time; plans for maintenance try to ensure that the skill learned will continue after explicit instruction ends (Collins, 2012).

One of the most important parts of systematic instruction is the use of continuous, immediate data collection (Collins, 2012). The reason it is important to collect data in this manner is to assess whether the instructional package is effective or not. The collection of data and the subsequent graphing of this data is what guides instruction. Instructors need to graph the data collected in order to make data-based decisions about the SIP (Collins, 2012). Data will reveal if the student is progressing adequately, is not progressing, or the data is variable (Collins, 2012). The way in which data are taken depends on the teaching procedure (Collins, 2012). SLP procedures require that instructors record the most intrusive prompt used per trial, whereas MTL procedures only require a mark indicating whether the response was independent or not (this is typically denoted as a plus or a minus; Collins, 2012). Time delay procedure data collection calls for the measurement of five types of responses: correct response before prompt, incorrect response before prompt, correct response after prompt, incorrect response after prompt and no response (Collins, 2012).

Spooner, Knight, Browder, Jimenez, and DiBiase (2011) conducted a comprehensive review of literature that focused on science instruction for students with severe disabilities. This study determined that systematic instruction is an evidence-based practice in teaching science content to students with severe disabilities (Spooner et al., 2011). With this knowledge, this
study will use systematic instruction to teach students with moderate to severe disabilities science content that aligns with Virginia Alternative Assessment Program (VAAP) goals, individual’s IEP goals, and NSES standards.

The current study looks to extend previous research by teaching grade-level science concepts and vocabulary using spaced trial systematic instruction in small group lessons to elementary students with severe developmental disabilities. The intervention was designed across three different units of elementary science content. Another purpose was to extend the prior research to elementary school students because most research has been implemented with middle and high school students. The research questions were (a) was systematic instruction in small group lessons effective for elementary-aged students, (b) did elementary-aged students with severe disabilities acquire standards-based science content knowledge using systematic instruction, and (c) were the procedures socially valid?

**Literature Review**

The literature describing the use of systematic instruction for students with severe disabilities is well documented, but the use of systematic instruction for science content is not as established (Spooner et al., 2011). This review of meaningful literature will examine the use of systematic instruction for students with severe disabilities and will highlight studies that included science content. Spooner and colleagues conducted a review of literature in 2011; the articles in this review include articles from this compilation, studies from before the Spooner et al. (2011) article, and studies since the publication of the Spooner et al. (2011) article. This review will be organized into three themes: comprehensive reviews, science content studies, and studies using systematic instruction for students with severe disabilities.
Comprehensive Reviews

Spooner, Knight, Browder, Jimenez, and DiBiase (2011) conducted a comprehensive review of literature from 1985-May 2009 to assess the degree to which science content was being taught to students with severe disabilities and what procedures were used to teach the content. One of the purposes of this review was to examine the instructional methods the studies examined used to teach students with moderate to severe disabilities science content. Systematic instruction emerged as a common instructional technique used and evidence of this method as an effective instructional package was demonstrated (Spooner et al., 2011). The authors also present a conceptual model of science content in which inquiry is labeled as the top priority when teaching students with severe disabilities (Spooner et al., 2011). The research method was divided into three sections: literature search procedures, determination of an evidence-based practice for teaching science, and interrater reliability on quality indicators (QIs) and characteristics of studies (Spooner et al., 2011). The authors compiled a total of seventeen articles; fourteen of the seventeen were either high quality (five) or acceptable quality (nine) as evidenced by QI scores (Spooner et al., 2011). Systematic instruction emerged as an evidence-based practice for teaching academic content through this review (Spooner et al., 2011). Spooner and colleagues (2011) also found that two components of systematic instruction (i.e., task analysis and time delay) were especially effective at teaching science content.

Spooner et al. (2011) provide the evidence for the methodology that will be utilized in this study and offer specific components of systematic instruction that are most effective for students with moderate to severe disabilities. Spooner et al. (2011) recommend that future research build on the research showing students can learn science vocabulary and definitions by demonstrating that students can apply the concept during a hands-on activity. This study will
include lessons with hands-on activities where systematic instruction trials are embedded into the activities. This study will also continue to investigate the use of systematic instruction to teach science content from National Science Education Standards (NSES) other than the Personal and Social Perspectives standard, which Spooner et al. (2011) stress in their article.

The Spooner et al. (2011) review was an expansion of the Courtade, Spooner, and Browder (2007) evaluation of science standards-based research studies. Courtade et al. (2007) selected the studies based on the use of National Science Education Standards (NSES). This study reviewed eleven total studies and of those eleven studies eight used the Science in Personal and Social Perspectives content standard, which contains content related to personal health and environmental responsiveness (Courtade et al., 2007; National Research Council, 1996). Courtade and collaborators (2007) urged further research on how to teach science content, particularly content that falls outside the Personal and Social Perspectives standard, to individuals with severe disabilities.

The implications derived from this study are similar to the rationales from Spooner et al. (2011). Courtade et al. (2007) found that studies that included errorless learning techniques, such as time delay procedures, were most effective for students with moderate to severe disabilities. Systematic instruction can include errorless learning if the skill is taught using most-to-least prompting or time delay procedures (Collins, 2012). Errorless procedures implement the controlling prompt (prompt that will ensure a correct response from the student) as the first prompt; as long as the appropriate controlling prompt is selected (i.e., the controlling prompt consistently results in correct responses by the learner), then students are not able to make errors or build misconceptions that have to be untaught (Collins, 2012). This evidence will be taken into account when planning science content lessons.
Science Content Studies

The studies in this section are studies that included science content and employed systematic instruction as the instructional procedure.

Smith, Spooner, Jimenez, and Browder (2013) utilized a multiple probe design across behaviors to analyze the effects of the Early Science curriculum developed by Jimenez, Knight, and Browder. The study contained three elementary aged students with severe disabilities and observed inquiry-based lessons from units within the Early Science curriculum (Smith et al., 2013). The lessons were delivered to the whole class (seven students), but probe sessions with the three participants took place in a private room (Smith et al., 2013). Data was collected using unit assessment probes; these probe sessions occurred after the teacher repeated the same science lesson three consecutive days which averaged to about one probe per week (Smith et al., 2013). Before instruction on a new unit began, experimenters assessed participant responses across all four units used for the study (Smith et al., 2013). Visual analysis of the graphed data shows that all participants increased his or her number of correct responses above baseline levels during the intervention phases per unit; this indicates that the use of the Early Science curriculum lessons has a functional relationship to increased science content knowledge for the students with severe disabilities. This study found that whole-group instruction using task analysis shows that systematic instruction can be effective for teaching science content to students with severe disabilities. Smith et al. (2013) used a multiple probe design to display their findings; their methodology and data presentation were clear and align well with teaching multiple content goals. Smith et al. (2013) recommend that future research include mastery for criterion for the science content.
Jimenez and Browder (2009) further extended the concept of self-directed learning in their study describing a treatment package that included multiple exemplar training, time delay procedures, and the use of a KWHL chart. The treatment package was used to teach three middle school-aged students with moderate intellectual disabilities how to independently complete a science inquiry lesson (Jimenez & Browder, 2009). Jimenez and Browder (2009) used the instructional package to teach students how to independently navigate through an inquiry lesson, but also wanted to measure how these skills generalized to untrained materials. The authors taught the participants how to self-direct themselves through a fifteen-step task analysis that described how to use a KWHL (what we know, what we want to know, how we will learn it, what have we learned) chart (Jimenez & Browder, 2009). Science storybooks, adapted stories that define and describe the unit, and KWHL charts were given to participants for both of the science concepts taught in this study (Jimenez & Browder, 2009). The researchers used six sets of materials (multiple exemplar training) with three sets being designed for each science concept and implemented a constant time delay procedure (Jimenez & Browder, 2009). Jimenez and Browder (2009) used a multiple probe design across two science concepts and used with concurrent between participant replications for three students to summarize their findings. Results of this intervention showed that the study was successful at completing the inquiry lesson as well as generalizing the use of the KWHL chart to other concepts in the general education science class (Jimenez & Browder, 2009).

The evidence from this study shows that students with moderate to severe disabilities are able to participate in general curriculum activities such as inquiry lessons with appropriate adaptations. The use of adapted stories, task analyses, and KWHL charts allowed the participants to access the same content as their typically developing peers and engage in social interaction
with these peers. Jimenez and Browder (2009) pointed out that there was unexpected
generalization of concepts that weakened the effect of the design and suggest that future research
employ a different design than the one used. One recommendation the author’s make for future
research is to utilize a different single subject design, such as a multiple baseline design, to limit
generalization effects (Jimenez & Browder, 2009). The treatment package implemented had
many complicated components and the authors did not conduct a component analysis to
determine if there was one element of the intervention that was more effective than others;
without this analysis it is unclear as to what component (multiple exemplar training, science
stories with KWHL chart, or time delay) was the cause for learning.

Knight, Spooner, Browder, Smith, and Wood (2013) combined systematic instruction and
graphic organizers to teach vocabulary and comprehension of science content to students with
autism spectrum disorder (ASD) and intellectual disability. The authors used a multiple probe
design to display the data of three middle school participants (Knight et al., 2013). Knight and
colleagues (2013) implemented a teaching procedure that included constant time delay, direct
instruction, multiple exemplars of teacher-directed graphic organizers, and a sixteen-step task
analysis (used to score correct responses by the student). The instruction package was used to
teach the concept of convection (Knight et al., 2013). A functional relationship between the
variables of this study was determined by visual analysis of the data from this study; this analysis
provides proof of significant improvement from baseline. Knight et al. (2013) provide evidence
towards the use of graphic organizers as an addition to systematic instruction. The findings of
this study also align with previous research that demonstrates constant time delay as an evidence-
based practice for teaching vocabulary (Knight et al., 2013).
Knight and colleague’s (2013) research had a focus on effective practices for individuals with ASD, but the findings from this study can easily be applied to the larger population of students with moderate to severe disabilities. Knight et al. (2013) did not complete a component analysis of their treatment package, which results in incomplete knowledge of what parts of the intervention were successful. The incorporation of visual aides, such as graphic organizers, in addition to systematic instruction led to meaningful results from all participants; this instructional method is noted as a potentially meaningful addition to systematic instruction.

Courtade, Browder, Spooner, and DiBiase (2010) conducted a study that looked at teacher behavior when teaching science to students with moderate and severe disabilities. Courtade et al. (2010) developed and trained four special education teachers on a task analysis to use when conducting inquiry-based science lessons. The researchers measured fidelity of implementation, if the teachers varied the science content taught (generalization), students’ acquisition of inquiry skills, and students’ use of science content vocabulary (Courtade et al., 2010). The results of the study show that the multi-component training package was effective at teaching teachers how to conduct an inquiry-based lesson to students with moderate and severe disabilities and the skills learned did generalize to untrained science content (Courtade et al., 2010). Intervention did have a positive outcome for students as well; all of the students increased in the number of correct responses and two students showed evidence of generalizing science content vocabulary (Courtade et al., 2010). Courtade et al. (2010) provided an effective task analysis for teaching chained, complex behaviors (e.g., inquiry skills) that also taught students inquiry skills and helped students generalize the use of science content words.
Studies Using Systematic Instruction

The studies in this section were included because each used systematic instruction in the instructional package and further identify systematic instruction as an evidence-based practice for teaching academic content to students with severe disabilities.

Jameson, McDonnell, Johnson, Riesen, and Polychronis (2007) conducted a study that included four middle school-aged participants and employed an alternating treatment design to compare effectiveness between embedded instruction in the general education classroom and massed practice instruction in the special education classroom. Jameson et al. (2007) measured percent correct responses during probes, total trials to criterion, and included a social validity assessment administered to the special education teacher and paraprofessional included in the study. For the one-to-one embedded instruction condition, the researchers provided the implementers with an instructional script to use during naturally occurring opportunities throughout the school day (e.g., transitions; Jameson et al., 2007). Instructional sets included flash cards and were presented at least three times per session; the instructional sets were presented the same number of times in each condition (Jameson et al., 2007). The discrete trial instructional procedure was comprised of constant time delay procedures, differential reinforcement, and error correction (Jameson et al., 2007). The one-to-one massed condition procedure was the same as the one-to-one embedded condition with exception to location (in the special education classroom) and distribution (massed rather than spaced; Jameson et al., 2007). The results of the study concluded that embedded instruction is an effective instructional strategy for students with developmental disabilities included in the general education classroom (Jameson et al., 2007). All participants reached criterion under both conditions, however, two of the four students met criterion in less trials under the massed instruction condition.
The findings from this study are important because they identified embedded instruction as a valid, effective teaching strategy for students with developmental disabilities. Evidence supporting embedded instruction holds particular value because it is an instructional method that can be implemented in both general education classrooms, as shown in this study, as well as special education classrooms.

McDonnell, Johnson, Polychronis, Riesen, Jameson, and Kercher (2006) used an alternating treatment design to compare one-to-one embedded instruction in general education classes to small group instruction in special education classes. The study included four participants who were enrolled in at least two general education classes and participated in the general education curriculum (McDonnell, et al., 2006). Participants were taught to expressively define five vocabulary words using an instructional package that included constant time delay, differential reinforcement, and error correction procedures (McDonnell, et al., 2006). Instructional procedures were identical in both conditions; the only thing that changed was the setting and format in which the procedures were delivered (McDonnell, et al., 2006). The small group consisted of a target participant and two randomly selected peers from the special education class and used an intrasequential format with spaced trials (McDonnell, et al., 2006). Results from this study demonstrated that embedded instruction was as effective as small-group instruction as shown by number of trials to criterion and generalization of skills (McDonnell, et al., 2006). Visual analysis of the graphed data determined a functional relationship between variables because levels for all participants increased from baseline in both instructional packages.

Not all of the content taught in this study was science content, but it was included because some of the vocabulary words selected were science content terms (e.g., atom, cell, food
McDonnell et al. (2006) included constant time delay in the instructional procedure and found evidence of its effectiveness in teaching vocabulary definitions. This study further demonstrates time delay as an efficient, effective instructional method for students with severe disabilities.

Jameson, McDonnell, Polychronis, and Riesen (2008) studied the effects that embedded peer instruction had on learning academic with three students with severe cognitive disabilities. The study, using a two parallel multiple-probe-across-participants design, sought to further extend research on embedded instruction using constant time delay and peer instruction (Jameson et al., 2008). Jameson and colleagues (2008) point towards other studies only looking at constant time delay, an effective practice in teaching academic content to students with severe disabilities, implemented by paraprofessionals and licensed teachers and justify the need for the use of peer instruction to foster both social interaction and academic success. The methodology for this study included peer tutor training on an embedded instruction manual that contained a description of constant time delay procedures, a description of embedded instruction, an instructional script, and a data collection sheet (Jameson et al., 2008). Each participant had two sets of instructional stimuli (flashcards) based in the identified skill; one set was a training set and the other was a generalization set (Jameson et al., 2008). The use of peer instruction was found to have a high degree of procedural fidelity and all participants showed meaningful change in skill acquisition (Jameson et al., 2008).

Only one participant was taught academic skills that related to science content (participant Amelia learned the effects of smoking on organs of the human body), but this study has important implications for instruction delivery (Jameson et al., 2008). This study aligns with findings from other studies that measured the use of constant time delay as the instructional
method for teaching vocabulary via flashcards. The authors note that more research was needed to observe the effects of embedded instruction and constant time delay on skills other than discrete skills (Jameson et al., 2008).

Agran, Cavin, Wehmeyer, and Palmer (2006) employed a multiple baseline across individuals to measure the effects of the Self-Determined Learning Model of Instruction (SDLMI) on the acquisition of academic skills pertaining to science and social studies. The study included three participants with moderate to severe disabilities who attended middle school (Agran et al., 2006). Consistent with the self-determined model, students selected the target goals, which related to participating in lab activities, map skills, and identifying body systems (Agran et al., 2006). Students utilized self-directed learning strategies, such as self-regulated problem solving and goal setting, to access content in the general education setting. The results of the study argue that students with moderate to severe disabilities are able to engage in student-directed learning strategies that give access to general education curricula with efficiency and accuracy (Agran et al., 2006). Visual analysis of the data reveals that the use of SDLMI was effective for the participants in this study.

This study was included in this literature review because the dependent measures were complex, chained behaviors which had not been discussed in the research above. The content taught using this model of instruction contained science content, as well as science inclusion in the case of the participant who wanted to participate in lab activities. The SDLMI model will not be used in this study, but the implications of using self-directed teaching is noted as a meaningful way for students to engage in the general curriculum.

Agran, Wehmeyer, Cavin, and Palmer (2010) studied communication and functional advancement for students with severe disabilities by measuring active engagement in the general
education classroom. The Self-Determined Learning Model of Instruction (SDLMI) was used to promote access to the general education classroom and curriculum in three middle school participants (Agran et al., 2010). Again, the SDLMI is a three-phase instructional model that involves “teaching students a self-regulated problem solving process to allow them to set goals, plan courses of action to achieve these goals, self evaluate their progress, and adjust or modify their goals or plans as needed” (Agran et al., 2010). Agran et al. (2010) employed a multiple baseline design across participants to display the percent of correct responses. All participants showed a clear increase in performance of the target behaviors (Agran et al., 2010).

Although the skills taught to the three participants in this study loosely, if at all, align with science content, the skill of teaching the problem-solving steps for asking questions, an important inquiry skill, was taught (Agran et al., 2010). This article demonstrates that process skills, similar to inquiry-based skills, are teachable to students with severe disabilities, which had been historically refuted prior to recent research (Agran et al., 2010).

Browder and Shear (1996) analyzed the effectiveness of a variation on discrete trial, called interspersal of known items, on the acquisition and maintenance of sight words. Three middle school participants were included in this study and were taught functional sight words to aid in reading the newspaper weather report (Browder & Shear, 1996). The instructional treatment package included interspersal of known items and a five-step error correction procedure; the package was taught in a rapid drill technique (Browder & Shear, 1996). Rapid drill technique differs from time delay procedures in that the rapid drilling pace is dictated by the student because if the responses are correct then praise is reserved until the end of the session whereas time delay procedures are controlled by teacher prompt delays and time spent praising (Browder & Shear, 1996). Browder and Shear (1996) used a multiple probe across participants to
evaluate the effectiveness of the treatment package. Visual analysis of the graphs reveals that the intervention was markedly successful in teaching these students with developmental and behavior disorders sight words. The discussion section of this study details that the students learned the ten sight words ranging from two to six weeks as compared to the total sight word learning of thirty words prior to the study; this amount of learning is significant because it shows how quickly this technique teaches new content (Browder & Shear, 1996).

This study taught science skills through systematic instruction. The interspersal rapid drill treatment package was shown to be effective at teaching students with developmental and behavior disorders sight words. Presenting sight words in this massed way is not a new concept, but the methodology of incorporating known items and presenting error correction procedures made this instructional approach unique. This study, like others before and after it, depends on one-on-one instruction, which can be constraining for modern special education and general education classes.

Collins, Evans, Creech-Galloway, Karl, and Miller (2007) compared the effectiveness of three teaching methods on the acquisition of functional and core content sight words. Four individuals with moderate to severe disabilities across grade levels (one elementary, two middle school, one high school) participated in this study (Collins et al., 2007). The three instructional conditions were: direct massed trial instruction in the special education classroom, direct distributed trial instruction in a general education classroom, and embedded distributed trial instruction in a general education classroom (Collins et al., 2007). For the direct instruction trials, simultaneous prompting and constant time delay procedures were implemented (Collins et al., 2007). Embedded instruction was used as a contrast to systematic instruction because the sight words were taught the same way (e.g., lecture) to all the students in the general education
classroom (Collins et al., 2007). Collins et al. (2007) used an adapted alternating treatments
design replicated across three instructional conditions and four participants. The results from this
study show that all the participants progressed above baseline in all three conditions and there
was minimal evidence to suggest that one type of instruction was more efficient or effective than
another (Collins et al., 2007).

While the elementary participant was the only participant that had science content
included in his sight words, this study is relevant as it addresses the use of systematic instruction.
Results from this study did not provide evidence for systematic instruction being an effective
instructional method, but are promising because they show that sight word acquisition is possible
with repeated exposure in inclusive settings. This study also showed the convenience of
simultaneous prompting procedures and offers an example of how to incorporate it into an
instructional package.

Riesen, McDonnell, Johnson, Polychronis, and Jameson (2003) utilized an adapted
alternating treatments design to compare constant time delay to simultaneous prompting
procedures to teach participants science and history vocabulary definitions. Riesen and
colleagues (2003) introduced the two conditions within embedded instruction for four middle
school-aged students with moderate to severe disabilities. Based on academic abilities, two of the
participants were taught to expressively define selected vocabulary terms and two participants
were taught to read words selected from the vocabulary list (i.e., sight word training; Riesen et
al., 2003). The general education teachers submitted twenty content vocabulary words that each
student needed to be able to read or define; from that list ten words that the student could neither
read nor define were randomly selected (Riesen et al., 2003). Paraprofessionals were trained on
how to implement the different conditions and when to teach the target behaviors (during
naturally occurring transitions or breaks; Riesen et al., 2003). The results of the study demonstrated that both instructional procedures were effective at teaching the target skills, which contradicts previous research that found that simultaneous prompting was more effective (Riesen et al., 2003). However, in this study, constant time delay was more efficient for two students and simultaneous prompting was more efficient for the other two students; this was measured by the rate of acquisition (Riesen et al., 2003).

The study by Riesen et al. (2003) highlighted the importance of designing instructional programs with individuals in mind and not just blindly choosing a method. The findings of this study were included because they demonstrate that both simultaneous prompting and constant time delay are effective practices for teaching discrete behaviors to students with moderate to severe disabilities.

Discussion

A review of literature with direct and indirect relation to science instruction revealed a number of important trends in this field of research. The first is the use of systematic instruction was seen across the body of literature presented here showing that systematic instruction is a widely-used evidence-based strategy for teaching content to individuals with severe disabilities. Another trend is the use of time delay procedures to teach discrete skills to students with severe disabilities; time delay procedures implement a 0 s delay as the first instructional prompt, which almost eliminates student error. Many of the studies examined (Jameson et al., 2007; McDonnell et al., 2006; Jameson et al., 2008;) used constant time delay to teach students academic content using flashcards and found success in this technique. Most of the participants from the studies examined are middle school-aged and older, but there is evidence of science instruction in younger ages being an effective practice (Smith et al., 2013; Collins et al., 2007; Polychronis et
The use of visual models such as KWHL and graphic organizers were used to support comprehension of content for students with moderate to severe disabilities (Jimenez & Browder, 2009; Knight et al., 2013).

The research being presented here will expand upon the use of systematic instruction to teach science content to elementary-aged students with severe disabilities. The intervention will use components such as time delay procedures and simultaneous prompting as a result of the evidence compiled during this review. Chained behaviors will also be taught and measured using task analyses in this study to expand upon the limited findings (Courtade et al., 2010). This study will also build off recommendations for future research described in Spooner et al. (2011), Smith et al. (2013), and Jimenez and Browder (2009).

**Method**

**Participants**

Four students with disabilities who are primarily taught in a self-contained classroom were selected through convenience sampling. The special education teacher and one of the classroom paraprofessionals participated in this study. Science instruction had not been introduced in the classroom during the 2015-2016 academic school year. For the privacy of all participants in this study, no real names were used to describe student or adult participants in this study.

There were a total of four student participants. These students were selected to participate because all four students were receiving special education services in a self-contained classroom. All four of the students were on the Virginia adapted curriculum, but three of the four students (Sophia, Finn, and Don) were required to complete the Virginia Alternative Assessment Program.
(VAAP) because of their age. The VAAP begins in third grade, but science content is not assessed until fifth grade.

Sophia was a 5th grade, 11-year-old girl with Down syndrome. Sophia was a loveable, friendly young girl who primarily communicated vocally despite unintelligible speech except for short, single word utterances. She had access to an iPad to communicate with, but was not yet using this device consistently or fluently. She received speech therapy services four days a week and therapy focused on the use of her device. Sophia was one of two students in this study participating in the VAAP and had science content goals. Sophia was highly motivated by watching her favorite television show on the internet and social attention from her teachers and peers.

Finn was a 10-year-old fifth grade student diagnosed with autism spectrum disorder (ASD) and had a secondary disability of speech/language impairment. Finn was a frequently happy child who enjoyed drawing and watching videos on the internet during his free time. The most recent cognitive evaluation summarized that cognitive evaluation skills were moderately impaired on an abbreviated measure. Finn was also found to be mildly impaired in adaptive skills and his visual motor skills were below average from same aged peers. Finn communicated vocally, but frequently engaged in repetitive vocal stereotypy. Finn’s vocal stereotypy was repetitive, persistent vocalizations of sounds, screeches/squeals, and phrases from television and movie scenes (i.e., scripting). Vocal stereotypy was the primary behavior concern. Finn could read short passages, but was easily distracted and engaged in vocal stereotypy. Finn was highly motivated by access to edibles (e.g., Skittles) and access to tangibles (e.g., small toys, videos). Finn was also took part in the VAAP and had science content goals selected from this assessment.
Don was a fourth grade, 9-year-old student diagnosed with ASD with a secondary diagnosis of speech and language impairment. Don was a funny, verbal student who enjoys peer and teacher attention and was skilled at completing familiar, large puzzles. According to most recent testing, Don was found to have a significant cognitive disability and was well below that of his same aged peers in crystallized reasoning (the ability to recall facts), planning abilities, short-term memory, and was unable to receive a score for visual processing. Don worked hard during academics, but typically needed a high level of assistance on new or difficult tasks (e.g., writing). During free time, Don enjoyed time on the computer and commonly engaged in repetitive hand flapping and vocalizations. Don completed a VAAP portfolio for academic content, but did not have science goals because he was in fourth grade.

Dyson was the final student participant. Dyson was a 7-year-old boy diagnosed with ASD with a secondary diagnosis of speech and language impairment. Dyson was born a month and a half prematurely, which is a contribution to his developmental delays. Dyson was included in his general education first grade classroom during morning calendar time (approximately thirty minutes) where the general education teacher engaged with the class in identifying the weather of the day, observing patterns, and discussing calendar events (e.g., the date, upcoming holidays). Dyson was a vocal student who frequently asked questions and liked to talk about topics such as farm equipment (e.g., tractors) and home appliances (e.g., water heaters). Dyson was highly motivated by access to internet videos and access to edibles (e.g., Skittles). Dyson did not participate in the VAAP.

The special education teacher and paraprofessional assisted in baseline data collection and probe session data collection during the intervention. The special education teacher had been a special educator at this setting for four years and remained in the self-contained classroom
throughout the day. She was very familiar with ABA procedures such as prompting and fading due to continued education and training in the implementation of a behavior-based curriculum in her classroom.

The paraprofessional had recently passed her assessments to become a registered behavior technician (RBT) and was well versed with the instructional procedures (e.g., prompting) used in systematic instruction. She was the permanent paraprofessional for the self-contained classroom and thoroughly knew each of the student participants.

**Setting**

This study was conducted in an elementary school located in a rural area of Virginia. The population of the school was primarily Caucasian. The school served students from early childhood special education (ECSE) to fifth grade and included approximately 580 students.

The self-contained special education classroom was the setting for all measures. The classroom served seven students with ASD and one student with Down syndrome. The students not included in this study were primarily served in their general education setting. The lead special education teacher and three paraprofessionals constituted the staff of the classroom. Two of the paraprofessionals rotated throughout the school to provide services to students in their inclusive settings. The special educator and paraprofessional who participated in the study remained in the classroom all day to provide services to the four self-contained students.

Unit lessons were taught either in the circle time area (an area with a projector and a rug with seating for the students) or at a rectangular table surrounded by six chairs. The rectangular table was primarily used for the hands-on activities whereas the rug area was used for rehearsing the content. This setting was selected because students were familiar with this setting and there
were multiple places within the classroom where the lessons and probe sessions could be conducted. Additionally, student reinforcers (e.g., computer) were at hand.

**Experimental Procedures**

A multiple baseline design across units with replication across students was employed (Johnston & Pennypacker, 2009). The second unit did not begin until there was a clear change in level or trend for all participants; this decision was due to time constraints. Instruction was implemented with all four students in a small group format. Staggering the procedures in the experiment demonstrated control by showing that the first unit did not generalize skills to other science concepts. The lead researcher, the special education teacher, and the classroom paraprofessional were responsible for collecting the dependent measures. In addition to science instruction, student participants continued to receive any instruction as specified by their IEP.

**Procedure.** Sessions began with a small group lesson with rehearsal of the content using systematic instruction with spaced trail distribution. The lead researcher would have the students sit in front of her and would deliver the content dependent on each student’s current level. For example, Finn might have been on a 4 s delay for vocabulary whereas Dyson was on a 0 s delay because in-lesson data showed that Dyson had met drop back criteria. After the review of the unit content, students would then move into an activity that supported the content being learned. Probe sessions were conducted after the lead researcher concluded the group lesson. Maintenance lessons followed this same format with the exception of the beginning of the lesson. The previous unit or units’ content would be rehearsed first using a 0 s delay and then the current unit’s content would be explored.

**Dependent Variables.** Researcher measured the acquisition of vocabulary words, vocabulary definitions, and unit concept questions using baseline and probe sessions. The
curriculum framework for the ASOL goals identified for Sophia and Finn directly structured the science content (i.e., vocabulary, definitions, and concepts) for this study. Probe sessions were used to demonstrate experimental control of the unit content; reinforcement or error correction procedures were not conducted during the probe session, which provides evidence that the change in behavior was from the small group lessons. Baseline and probe sessions included 13 trials (5 vocabulary words, 5 definitions, and 3 concept questions) per unit totaling 39 trials per session. The lead researcher trained the special educator and paraprofessional on how to implement baseline and probe sessions prior to implementation.

**Baseline.** Baseline consisted of a minimum of five data points to determine stability in responding. Student participants were asked to identify science vocabulary words, select the vocabulary word that matched the read-aloud definition, and answer concept questions for each instructional session. The vocabulary words were printed onto note cards that were laminated. The concept questions were presented as a multiple-choice quiz with three answer choices. Two quizzes with the same answer choices in different positions were originally created to counterbalance responses so that students were not learning to pick one spot, but instead found the correct answer. Problem behaviors arose which resulted in more variations of the same quiz being made. Participant responses were not praised or corrected by implementers, but participation was reinforced. When the baseline session was over, the implementer gave the student a non-specific statement such as, “Thank you for participating. You’ve earned your break.”

**Probe sessions.** Probe sessions were conducted in the same manner as baseline sessions (i.e., participants were not praised or corrected by implementers).
**Maintenance.** Maintenance lessons were conducted every third lesson. The lessons utilized a 0 s delay for all students for all content of previous units. Maintenance lessons were delivered before the lesson on the current unit.

**Observation Procedures and Reliability.** Sessions were observed by a graduate student of the College of Education who is also enrolled in a master’s degree program in education with a behavior specialist focus. She measured interobserver agreement, fidelity of lesson implementation, and fidelity of probe session implementation. Checklists were created to measure teaching fidelity by the lead researcher and probe session implementation fidelity across all data takers. The graduate assistant measured teaching fidelity. The lead researcher and the graduate student assessed probe session fidelity and interobserver agreement (IOA). Trial by trial IOA was used to calculate reliability between observers (Cooper, Heron, & Heward, 2007).

**Social Validity.** The special education teacher and paraprofessional answered a social validity questionnaire created by the researcher (See Appendix B) upon completion of the study. This measure was used to assess if the effects of this study were meaningful for the teachers and if they would be likely to implement science instruction in a similar way in the future.

**Independent Variables.** All of the students were taught the unit content using a constant time delay prompting method. The baseline and probe sessions did not contain prompting or reinforcement or error correction procedures whereas in-lesson SIPS did include these elements. The researcher, special education teacher, and paraprofessional collected data after each unit lesson. The criterion for mastery of the science content was 11/13 trials correct for two consecutive sessions. If the group has not reached a clear change in level or trend, students who had mastered the science content continued in the group lessons.

**Systematic Instruction.** Systematic instruction plans (SIP) were made for each student
for each unit. The SIPS were used during lessons by the lead researcher. The content was taught directly at the circle time area and also embedded into the hands-on activities that followed the rehearsal component of the lesson. All of the plans used constant time delay to teach the science content (i.e., vocabulary, definitions, and concepts) to all the students. Data was collected during lessons to assess how students were acquiring the science content knowledge. The student advanced to a 4 s time delay prompt if he or she answered 80% or more of in-lesson trials for 2 consecutive lessons, but dropped back to a 0 s delay if he or she correctly answered 60% or less of trials for 2 consecutive lessons.

Reinforcement and error correction procedures were included in the SIPS. Reinforcement for all students included specific verbal praise (e.g., “Excellent Sophia! You use more force to move larger, heavier objects!”) and access to an immediate tangible (e.g., skittle, tickle). The error correction procedure involved the lead researcher interrupting the incorrect response and redirecting the student to the correct answer (i.e., pointing to the correct answer) then the lead researcher would shuffle the cards or remove the quiz, deliver the same trial again, and use a 0 s delay prompt to ensure a correct response.

**Science Units.** The lead researcher and the special education teacher collaborated to determine the units to be taught. The units aligned with the VAAP goals chosen for Sophia and Finn. Three science units were taught in the study: energy, plants, and weather.

The first science unit was on energy. The energy unit contained five vocabulary words and their definitions (See Appendix A), and three concept questions. This basic structure held constant across all units. The three concepts learned were: friction slows down objects in motion, larger objects require more force to move them, and identifying states of energy (e.g., potential or kinetic). Applications of the concepts were seen in activities involving ramps with vehicles,
swinging, and watching videos of roller coasters and racecars.

The second unit was on weather. The selected VAAP goal pertained to weather phenomena; the measures selected for the unit align with this objective. The concepts were: hurricanes form over water, tornadoes form during thunderstorms, and weather is always changing. Students applied their knowledge of weather concepts by labeling pictures of weather phenomena, comparing and contrasting videos of weather phenomena, and observing and predicting weather.

Plant anatomy was the final unit in this study. The main goal of this unit was for students to identify plant parts and know the function of each part. The concepts for this unit were common plants are made up of four parts, plant make their own food, and each plant part helps keep the plant alive. Application of the concepts included students labeling plant parts on a model of a plant, and observation and discussion about a plant growing in a see-through container.

Each unit had different lessons that contained the elements detailed above. The structure of a typical lesson (i.e., not a maintenance lesson) began with a group rehearsal of all the content for the current unit using a spaced trial format. After the review of the vocabulary, definitions, and concepts, students then engaged with a hands-on or interactive activity. Activities were planned to help students apply the content of the unit in fun, meaningful ways. After the activity ended, the students were told which teacher they would work with for the probe session. Here is a sample energy lesson: discrete trials of the content was delivered in a spaced format to each student at the rug area and then the four participants interacted with different ramps to observe the effects of friction at the group table. While the students were playing with the ramps the lead researcher embedded discrete trials into the activity. For example, Sophia would be playing on
the ramp with folded paper on it (clear representation of friction) and the lead researcher would ask, “Oh no! What happened to your car?” Sophia would respond with something similar to “it stopped” at which time the lead researcher would say, “You’re right! Friction made the car stop. Which word means makes an object stop moving?”

**Data Analysis.** The data collected during baseline and probe sessions was represented on line graphs. The lead researcher then used visual analysis to determine if meaningful change occurred (Parsonson, 2003). Analyzing the trend (change in slope) of the data path, the level (high or low rate of behavior), and the variability in the data determined overall effect of the intervention.

**Results**

The research questions that guided this study were (a) was systematic instruction in small group lessons effective for elementary-aged students, (b) did elementary-aged students with severe disabilities acquire standards-based science content knowledge using systematic instruction, and (c) were the procedures socially valid? This section will describe the results for all of the dependent measures from this study while also answering the research questions. Places where data were not connected represented a group lesson and probe session that the participant missed.

**Baseline**

Baseline consisted of at least five data points before the intervention began. Sophia’s (See Figure 1) baseline data for unit 1 were stable at a low level with an increasing trend. Unit 2 had stable, mid-level responding with a slight increasing trend. Sophia’s data for unit 3 were variable with an increasing trend at mid level.
Finn (See Figure 2) had mid-level, stable responding with an increasing trend for unit 1. Baseline data for unit 2 were mid-level and variable with a slight increasing trend. Finn’s unit 3 data were stable at mid-level with no trend.

Don’s (See Figure 3) baseline data for unit 1 were stable at a low level with no trend. Don had stable, mid-level responding with a slight increasing trend. Unit 3 data were stable at mid level with a slight increasing trend.

Dyson (See Figure 4) had low level, stable responding with an increasing trend in unit 1. Baseline data for unit 2 were stable at a low level with no clear trend. Unit 3 data were stable at middle level with an increasing trend.

**Intervention**

Intervention began in unit 1 after five baseline data points independent of stable responding due to time constraints. Sophia’s intervention data for unit 1 continued from the increasing trend from baseline into stable, mid-level responding. Change was immediately evident in unit 2. Unit 2 intervention data was stable at a high level with an increasing trend. Sophia was absent during one of the unit 2 lessons and received only 8 lessons where her peers received 9. Sophia’s intervention data for unit 3 remained at mid-level responding with stable responding and an increasing trend.

Finn’s intervention data for unit 1 were stable at mid level with an increasing trend. Unit 2 data were stable at a high level with an increasing trend. Finn met mastery of science content during unit 2 with two consecutive days of 12/13 trials correct. Finn’s unit 3 data were stable at a high level with a rapidly increasing trend.

Don’s unit 1 intervention data were stable and rapidly increasing. The level of data was not clear due to the steep change in slope. Don met mastery of the science content during unit 1.
Unit 2 data were stable at mid level with an increasing trend. The data for unit 3 were stable at a higher level than baseline and had an increasing trend. Don was absent for 2 of the 6 lessons for unit 3.

Intervention data for Dyson in unit 1 were stable at mid level with an increasing trend. Dyson’s unit 2 data showed stable responses at mid level with an increasing trend. His unit 3 data were stable at a higher level than baseline with an increasing trend.

**Maintenance**

Maintenance lessons were delivered every third lesson; maintenance lessons were conducted using a 0 s delay before the lesson on the current unit occurred. Maintenance lessons were not conducted for unit 3 due to time constraints. Sophia maintained responding of unit 1 with stable, mid level responding and an increasing trend. Sophia met mastery of science content during maintenance of unit 1. Unit 2 data were stable at the same level as intervention data with no clear trend.

Finn’s maintenance data for unit 1 were variable at mid level with an increasing trend. Finn met mastery of the science content during maintenance of unit 1. Finn’s responses during maintenance were stable at a high level with no trend.

Don’s unit 1 maintenance data were at a lower level than intervention data, but were higher than baseline levels; this demonstrated maintenance of the content. Unit 2 maintenance data were stable and remained at the same high level as intervention with no trend.

Dyson maintained responding for unit 1. Although data were variable, there was not an evident change in level and there was an increasing trend. Unit 2 maintenance data were stable at a high level with an increasing trend.
Social Validity and Reliability

Trial by trial interobserver agreement was used to calculate reliability of data taking during baseline and probe sessions (Cooper, Heron, & Heward, 2007). This method of calculation was used because it is a more conservative measure of fidelity (Cooper, Heron, & Heward, 2007). Interobserver agreement was calculated on 21% of Sophia’s sessions across all units. There was 98.6% agreement for units 1 and 2 (range 92-100%) and 96% agreement for unit 3 (range 84-100%). Interobserver agreement was calculated on 25% of sessions for units 1 and 2 and 21% of sessions for Finn. There was 100% agreement for all of Finn’s sessions. Interobserver agreement was calculated on 22% of sessions across all units for Don. There was 98.6% agreement for units 1 and 3 (range 92-100%) and 96% agreement for unit 2 (range 84-100%). Interobserver agreement was calculated on 25% of Dyson’s sessions for units 1 and 2 and 21% of sessions for unit 3. There was 100% agreement for units 1 and 3 and 98.6% agreement for unit 2 (range 92-100%). The high level of agreement across all participants demonstrated that the clarity of definitions and procedures was sufficient for this study.

Teaching fidelity was assessed on 20% of the sessions. The lessons were implemented with 98% fidelity (range 93.75-100%). Deductions were due to the lessons going over the 35 minutes allotted.

Probe session fidelity was assessed across all data takers. The special education teacher administered the sessions with 100% accuracy on an average of 8.25 sessions (range 7-9). The paraprofessional implemented sessions with 98.2% accuracy (range 87.5-100%) on an average of 8.5 sessions (range 7-10). The lead researcher had one probe session fidelity form completed on an average of 9.5 sessions (range 9-10).
The special education teacher and paraprofessional completed the social validity measure (See Appendix B). Both participants completely agreed that there was a positive change in students’ comprehension of the science concepts, thought that the instructional method was easy to implement, there was an overall benefit from student participation, and that learning techniques such as systematic instruction has importance. The only question that received a “somewhat agree” score was the question that asked if the goals (i.e., selected content) were aligned to students’ IEP and VAAP goals. The special education teacher scored this question with a “somewhat agree” because the weather unit did not fulfill all the requirements that the VAAP needed to show mastery of the content. The unit did not fulfill all the requirements due to lack of clarity and explanation of the VAAP goal; the partial fulfillment was brought to the researcher’s attention after the cease of intervention. Overall, social validity measures indicated a high level of satisfaction and change as a result of the intervention.

**Research Questions**

The first research question asked was systematic instruction in small groups effective for elementary-aged students. This study found a functional relationship for 3 of the 4 student participants. A functional relationship was not established for Sophia. Functional relationships were found for Finn, Don, and Dyson.

The second research question asked did elementary-aged students with severe disabilities acquire standards-based science content knowledge using systematic instruction? Functional relationships being established for 3 of the 4 concluded that yes, students acquired science content knowledge through this intervention. Although a functional relationship was not determined for Sophia, there was evidence of effect in unit 2 where there was a clear change in level and trend.
The final research question asked if the intervention was socially valid. The high level of agreement on the social validity questionnaire demonstrated that the special education teacher and paraprofessional found the intervention to be socially significant.

**Discussion**

The purpose of this research was to determine the effectiveness of systematic to teach science content to elementary students with severe disabilities. This study used systematic instruction in a small group format to teach students content from three units: energy, weather, and plant anatomy. The research sought to answer if systematic instruction in small group lessons was effective for elementary-aged students and did elementary-aged students with severe disabilities acquire standards-based science content knowledge using systematic instruction. Additionally, were procedures socially valid? The results of the study concluded that the intervention was effective at teaching students with severe disabilities science content that was derived from ASOL standards. The adult participants stated that the teaching methodology used was socially valid for their students and produced meaningful change in students’ understanding of science content.

This was research conducted by a graduate student studying applied behavior analysis (ABA) and the research needed to fit within the current dimensions of ABA practice. Baer, Wolf, and Risley (1968) detailed the dimensions of an ABA study as one that is: applied, behavioral, analytic, technological, conceptually systematic, effective, and having generality. Science instruction addressed the socially significant behavior of increasing academic content knowledge for students with severe disabilities. Clear procedures for teaching, data collection, regular assessment of inter-observer agreement and implementation fidelity, and analysis of the data determined what variables caused behavior change. The multiple baseline design allowed the
researcher to observe behavior change across units, participants, and time. Experimental control was demonstrated through lack of change in other baseline measures once intervention in another unit began. This research study intended to describe the procedures in sufficient detail to be considered technological, meaning outlined clearly enough that it could be replicated in the future. This study only used evidence-based practices in both ABA and education to change behavior, which complies with the definition of conceptually systematic. Visual analysis of the data provides the consumer the opportunity to determine intervention effectiveness. Finally, generality of these skills was not directly assessed, but reports from the special education teacher and paraprofessional of students discussing the concepts learned during the intervention after the study ceased loosely shows signs of generality. The lead researcher believes that this study is systematic with the dimensions of ABA.

Problem behaviors did impact this study. One problem that arose was that students’ data during probes was not matching performance during teaching lessons. For example, Finn had highly variable data during unit 2 because it was discovered that he was answering his multiple choice quizzes on the concept questions with a pattern (ABC). One of the quizzes for unit 2 matched this pattern, which resulted in a higher level of responding that did not represent comprehension of the concepts. The lead researcher implemented a positive behavior management system to motivate students to participate to the best of their abilities during probe sessions. Students received a check for every trial if they performed “trying” behaviors. “Trying” was defined as when the student does all of the following behaviors per trial: Attend (not looking at peers/computers, not talking about other events) to the teacher while she is talking, did not respond until the teacher has finished talking, and did not use repetitive response patterns (e.g., touching the same card or same spot every time). Students would receive an X if they did not
exhibit all of the trying behaviors. If students received all 5 checks for vocabulary and definitions and all 3 checks for concept questions, then the student was rewarded with 2 minutes on their reinforcer of choice (e.g., computer). The max number of minutes students could earn on their reinforcers was 18 minutes. The implementation of this behavior system did result in a change in behavior during probe sessions, particularly for Sophia and Dyson. Sophia was highly motivated by having the physical representation of the amount of time she received on the computer whereas Dyson enjoyed giving himself checks as he was a student who craved feedback.

Finn continued to answer the concept question quizzes using a pattern. The lead researcher changed the format of his concept quiz to be separated onto note cards that would be shuffled each session. This change resulted in more consistent responding that gave the researcher a better measurement of learning.

Dyson, a student with high anxiety behaviors, experienced a medicine change halfway through the research. This change resulted in Dyson producing echoic responses on his concept quizzed. He would verbally state the correct answer while his teacher was reading, but would only circle the last answer read. To counteract this behavior, the probe session implementer circled the answer that Dyson expressively stated only after the lead researcher read all answer choices. This change resulted in a more consistent responding that demonstrated a better measurement of learning.

**Limitations**

There were some limitations of this study. The first limitation was that IOA was not conducted at the preferred level for all students on all units. This was due to the lead researcher conducting probe sessions at a high rate, which did not allow her to observe the probe sessions of
other implementers. The high level of agreement does indicate that the procedures and definitions were defined clearly enough that the intervention could be implemented with fidelity.

Another limitation was that, due to time constraints, there were times that the lead researcher had to continue onto another phase despite data with increasing trends during baselines. This is most evident in Sophia’s unit 1 baseline and intervention data. This research was conducted in small groups, which required all students to move onto new phases at the same time.

Functional relationships were determined in three of the four student participants, which limited the findings of this study.

**Contribution to Current Literature**

This study adds to the current body of literature that explores teaching science content to students with severe disabilities by describing effective procedures for elementary-aged students. Previous research was primarily conducted with students in middle and high school; this research proved that younger students are capable of learning science content.

The use of a multiple baseline design demonstrated experimental control because there was no evidence of generalization across units. Some students achieved mastery criteria during maintenance, which was an unintended effect. This finding supports the claim that, if given more time, students may have achieved mastery during intervention.

The science content was structured directly from the curriculum framework for the ASOL goals identified for Sophia and Finn. This study demonstrated that students with severe disabilities could learn explicit science content that came from strands of science other than hygiene.
In conclusion, this study determined an effective method of instruction to teach science to students with severe disabilities. Two students met mastery of science content during intervention and three students met mastery during maintenance, which indicated that the intervention was successful at teaching science content. The high degree of social validity also established that this teaching procedure was socially meaningful for the special education teacher and paraprofessional who participated in this study.
Figure 1. Sophia’s Graph. Gaps in data represent missed group lessons. Criterion for mastery of science content was 11/13 trials for 2 consecutive sessions.
Figure 2. Finn’s graph.
Figure 3. Don's graph.
Figure 4. Dyson's graph.
## Appendix A

### Definitions of Unit Vocabulary

<table>
<thead>
<tr>
<th>UNIT 1: Energy</th>
<th>UNIT 2: Plants</th>
<th>UNIT 3: Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kinetic energy</strong> - energy of motion</td>
<td><strong>Temperature</strong> - measure of amount of heat in the atmosphere</td>
<td><strong>Producer</strong> - living organism that makes its own food</td>
</tr>
<tr>
<td><strong>Potential energy</strong> - energy waiting to be used</td>
<td><strong>Precipitation</strong> - any form of water that falls from clouds to the ground</td>
<td><strong>Roots</strong> - keep the plant in the ground and take water and nutrients from the soil</td>
</tr>
<tr>
<td><strong>Force</strong> - any push or pull that causes an object to move, stop, or change</td>
<td><strong>Weather event</strong> - with thunder, lightning, and typically heavy rain fall</td>
<td><strong>Stem</strong> - provides support and allow movement of water and nutrients</td>
</tr>
<tr>
<td><strong>Friction</strong> - makes an object stop moving</td>
<td><strong>Hurricane</strong> - cyclone with heavy rain and fast wind that forms over water</td>
<td><strong>Leaf</strong> - food-producing part of plant</td>
</tr>
<tr>
<td><strong>Speed</strong> - how fast an object is moving</td>
<td><strong>Producer</strong> - living organism that makes its own food</td>
<td><strong>Flower</strong> - colorful part of plant that attracts insects</td>
</tr>
<tr>
<td><strong>Tornado</strong> - funnel-shaped windstorm that forms during thunderstorms</td>
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<td></td>
</tr>
</tbody>
</table>
### Appendix B

#### Social Validity Measure

Name: _________________________________             Date: ______________________

<table>
<thead>
<tr>
<th>Questions for Participants to Answer</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Neutral</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appropriateness of Procedures</strong></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1. The written materials were easy to read and understand.</td>
<td></td>
<td></td>
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<td>2. My researcher understood and communicated procedures and techniques effectively.</td>
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<tr>
<td><strong>Social Significance of Goals</strong></td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>3. The goals were aligned to my students’ IEP goals and VAAP goals.</td>
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<td>4. It is important to learn techniques such as this to teach children new skills.</td>
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<tr>
<td><strong>Social Importance of the Effects</strong></td>
<td>5</td>
<td>4</td>
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<tr>
<td>5. I saw a positive change in my students’ understanding of science concepts.</td>
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<td>6. I thought this instructional method was easy to implement.</td>
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<td>7. My students benefited from this instructional method.</td>
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## Appendix C

Observer: __________________  Teacher: __________________  Date: ____________

### Teaching Fidelity Form

<table>
<thead>
<tr>
<th>Teaching Procedures</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
</tr>
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<tbody>
<tr>
<td>1. Teacher begins the lesson with an introductory sentence explaining what the class is going to be doing today.</td>
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<tr>
<td>2. Teacher gains student attention before delivering a discrete trial.</td>
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<tr>
<td>3. The same discrete trial is run with each student before continuing.</td>
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<tr>
<td>4. Correction trials are implemented if the student makes an error.</td>
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<tr>
<td>5. Teacher records data immediately after discrete trial ends.</td>
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<tr>
<td>6. Teacher provides verbal, nonverbal, and/or tangible reinforcement for each correct response.</td>
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<tr>
<td>7. Students are given clear instructions on how to perform the activity.</td>
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<tr>
<td>8. During the group activity, the teacher checks in with each student every two minutes.</td>
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<tr>
<td>9. Reinforcement is delivered as per student plan and need.</td>
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<tr>
<td>10. Teacher ends the lesson on a positive note.</td>
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<tr>
<td>11. The lesson lasts no more than 35 minutes.</td>
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<tr>
<td>12. Students are told what to do next at the close of the lesson.</td>
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<tr>
<td>13. Personal conversations are minimized during student activities.</td>
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<tr>
<td>14. Teacher maintains professional behavior and language throughout the observation.</td>
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<tr>
<td>15. Teacher uses and maintains adaptive equipment or augmentative devices needed for students.</td>
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<tr>
<td>16. Teacher maintains positive communication with all students and staff.</td>
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<tr>
<td>17. Teacher had all of the materials needed for lesson prepared and available at all points during the lesson.</td>
<td></td>
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</table>

Score (out of 17)
### Appendix D

Observer: __________________ Teacher: _________________ Date: ___________

## Probe Session Fidelity Form

<table>
<thead>
<tr>
<th>Probe Session Procedures:</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teacher has all materials ready before beginning session.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Teacher gains student attention before delivering a discrete trial.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Teacher records data immediately after discrete trial ends.</td>
<td></td>
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</tr>
<tr>
<td>4. Vocabulary cards are shuffled after each trial.</td>
<td></td>
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</tr>
<tr>
<td>5. Teacher does not provide specific praise for correct or incorrect student responses (i.e., no praise for correct response and no correction for incorrect response).</td>
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<tr>
<td>6. Teacher provides student with either a yes or no token as determined by reinforcement system at the end of each trial.</td>
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<tr>
<td>7. If student receives a no token, the teacher tells the student why he/she did not earn the yes token.</td>
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<tr>
<td>8. Teacher delivers or does not deliver secondary reinforcers as defined by the reinforcement system.</td>
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</tr>
<tr>
<td>9. At end of session, teacher reviews token board and instructs student as to what he/she has earned.</td>
<td></td>
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</table>

Score (out of 9)
### Appendix E

<table>
<thead>
<tr>
<th>STUDENT:</th>
<th>Finn</th>
<th>TARGET SKILL:</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADE LEVEL:</td>
<td>5</td>
<td>DATE:</td>
<td>2/2/16</td>
</tr>
<tr>
<td>IEP GOAL:</td>
<td>Increase science content</td>
<td>SOL/VAAP GOAL:</td>
<td>Moving objects have kinetic energy, plant parts and functions, and weather phenomena</td>
</tr>
<tr>
<td>SOL/VAAP GOAL:</td>
<td>Moving objects have kinetic energy, plant parts and functions, and weather phenomena</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEACHING STRATEGY:</td>
<td>☑ DISCRETE TRIAL</td>
<td>TASK ANALYSIS:</td>
<td>SELECT FROM BELOW</td>
</tr>
<tr>
<td></td>
<td>☑ INCIDENTAL</td>
<td>TOTAL TASK:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEACHING</td>
<td>FORWARD CHAIN:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BACKWARD CHAIN:</td>
<td></td>
</tr>
<tr>
<td>PROMPTING STRATEGY:</td>
<td></td>
<td>☑ MOST TO LEAST</td>
<td>LEAST TO MOST</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PTD:</td>
<td>CTD:</td>
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<tr>
<td></td>
<td></td>
<td>SIMULTANEOUS:</td>
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<tr>
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<tbody>
<tr>
<td>CORRECT RESPONSE:</td>
<td>Student will expressively state the word written on the flash card</td>
<td></td>
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</tbody>
</table>

| DATA COLLECTION: | ☑ +/- | | |
| CRITERIA TO ADVANCE: | 80% independent on 2 consecutive sessions | | |
| CRITERIA TO DROP BACK: | 60% independence on 2 consecutive sessions | | |

#### TEACHING PROCEDURE

Teacher will have vocabulary cards and reinforcers ready before calling on student. Place all 5 vocabulary cards on a magnet board.

When the teacher begins the lesson, state, "first we are going to practice our vocabulary words. When I say the word I want you to find it."

Student responds correctly: Implement RP

Student responds incorrectly: Implement CP

**Reinforcement Procedure:** after each correct response, give specific verbal praise. After completion of whole session, give 1 skittle.

**Correction Procedure:** If student does not give a correct response, say the word and have the student echo. Present the vocabulary word again with 0-s delay and have student echo.

#### PLAN FOR GENERALIZATION:
Across instructors; different fonts

#### PLAN FOR MAINTENANCE:
Over-teaching; maintenance probes
Appendix F

<table>
<thead>
<tr>
<th>STUDENT:</th>
<th>Finn</th>
<th>TARGET SKILL:</th>
<th>Vocabulary</th>
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<td>GRADE LEVEL:</td>
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<td>Moving objects have kinetic energy, plant parts and functions, and weather phenomena</td>
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**TASK ANALYSIS**
- Select from below:
  - Total Task
  - Forward Chain
  - Backward Chain

**PROMPT STRATEGY:**
- Most to Least
- Least to Most
- PTD
- CTD
- Simultaneous Prompting

**STIMULUS SETS:**
1. Energy vocabulary
2. Weather vocabulary
3. Plant vocabulary

**CORRECT RESPONSE:**
Student will point to the vocabulary word that matches the vocabulary word read aloud by the instructor.

**DATA COLLECTION:**
- +/-
- Most Intrusive Prompt Needed

**CRITERIA TO ADVANCE:**
- 80% independent for 2 consecutive sessions

**CRITERIA TO DROP BACK:**
N/A

**TEACHING PROCEDURE**
Teacher will have vocabulary cards ready before calling student over. Place all 5 vocabulary cards on a magnet board.

When the teacher begins the session, state, "When I say the word I want you to find it."

Student responds correctly: NO AFFECT

Student responds incorrectly: NO AFFECT

DO NOT REINFORCE OR CORRECT RESPONSES, simply move on to next trial

Praise student with neutral statement such as, "Thank you for helping me! You're all done now. You can go do classroom activity or reinforcer."

**PLAN FOR GENERALIZATION:**
Different instructors

**PLAN FOR MAINTENANCE:**
Maintenance probe

<table>
<thead>
<tr>
<th>Date:</th>
<th>Staff:</th>
<th>Stimulus Set:</th>
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References


