Evaluating Evidence-Based Practice in Teaching Science Content to Students with Severe Developmental Disabilities

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Abstract:

A comprehensive review of the literature was conducted for articles published between 1985 and May 2009 to (a) examine the degree to which science content was taught to students with severe developmental disabilities and (b) and evaluate instructional procedures in science as evidence-based practices. The review was organized by a conceptual model developed for science content. Seventeen experiments were analyzed for research quality where science content was taught to this population; 14 of these studies were viewed to be of high or adequate quality. In general, we found systematic instruction as an overarching instructional package to be an evidence-based practice for teaching science content. Furthermore, components of systematic instruction (i.e., task analytic instruction and time delay) were analyzed. We discuss the outcomes to reflect how to teach science, what science content to teach, why to teach science, and recommendations for future research and practice.

Keywords: students with severe developmental disabilities | science evidenced-based practices | teaching science to students with severe developmental disabilities | comprehensive literature review of teaching science skills to students with severe developmental disabilities

Article:

Until the last decade, there have been few resources on teaching science to students with severe developmental disabilities. In a comprehensive review of the research, Courtade, Spooner, and Browder (2007) found only 11 experiments with any "link" to the National Science Education Standards (NSES, National Research Council "NRC", 1996). These studies linked because the target-dependent variable matched some of the content recommended by the NSES as judged by a science content expert. Most of these studies were not intended to demonstrate science learning per se but instead targeted skills of daily living with some overlap with science. For this reason, 8 of the 11 studies would be considered to fall under the NSES standard on science in personal and social perspectives. Methods to teach other standards such as inquiry, physical science, life science, earth and space science, and science and technology have not received much attention.

To provide more focus on science instruction, educators need (a) a rationale for teaching science, (b) guidelines for selecting content and goals for achievement, and (c) methods that will be effective for science learning. Perhaps the most important rationale for teaching science is to include students with severe developmental disabilities in the full educational opportunity of their schools. For example, in a notable early article on this topic, Siegel- Causey, McMorris, McGowen, and Sands-Buss (1998) described how to include students with severe disabilities in general science classes. These authors discussed a four-step inclusion strategy, which incorporated planning, selecting classes, accommodating, and collaborating for a junior high school student. The authors also reported that both the educators and student benefited because of the opportunity to attend general education classes at his neighborhood school. Besides promoting educational opportunity, some other reasons to teach science to all students, including those with severe disabilities, are to promote wonder and understanding of the natural world. Science also provides a format for posing questions and sharing discoveries. For example, students may gain understanding of why earthquakes occur while working with models in earth science, or they may experience the wonder of seeing a life cycle through a classroom butterfly project. Students can have the opportunity to pose questions (e.g., Why did the building shake?) or make predictions (e.g., What day will the butterflies appear?). A final reason for providing the opportunity for science learning is that science, like reading and mathematics, is one of the three academic areas for which schools must report accountability (No Child Left Behind Act, 2002).

The content for science instruction is typically prescribed by the state's science standards and the curriculum selected for the grade level in which the student is enrolled. One of the challenges in promoting science learning for students with severe disabilities is to identify priorities within this content. Although some students may achieve grade level expectations, others need targets for alternate achievement. The NSES place a priority on inquiry-based science learning. The NRC defines inquiry 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).

Conceptual Model of Science for Students With Severe Developmental Disabilities

We propose that inquiry also be the priority within science learning for students with severe disabilities. For example, students should learn the skills necessary to interpret the world around them by asking questions such as "How did the puddle of water disappear from the morning to the afternoon?" using inquiry skills to develop steps to make a prediction, experiment, and find answers to their questions. Although learning about topics like chemical reactions, human cells, and what plants need to survive are valuable, what is even more important is the acquisition of skills the student can use both in and outside of school to learn about the natural environment. Students need the opportunity to learn to make predictions and pose questions and then engage with materials to test these predictions or find answers. Figure 1 provides a diagram of how the "why" and "what" of teaching science to students with severe disabilities can be conceptualized. The large inquiry circle within the science content illustrates its priority status among the science standards (the other standards are shown below the large inquiry circle). By focusing on inquiry, students develop the ability to pose questions and share discoveries (circle to the right), which contributes to wonder and understanding of the natural world, and ultimately promotes quality of life (see Figure 1).

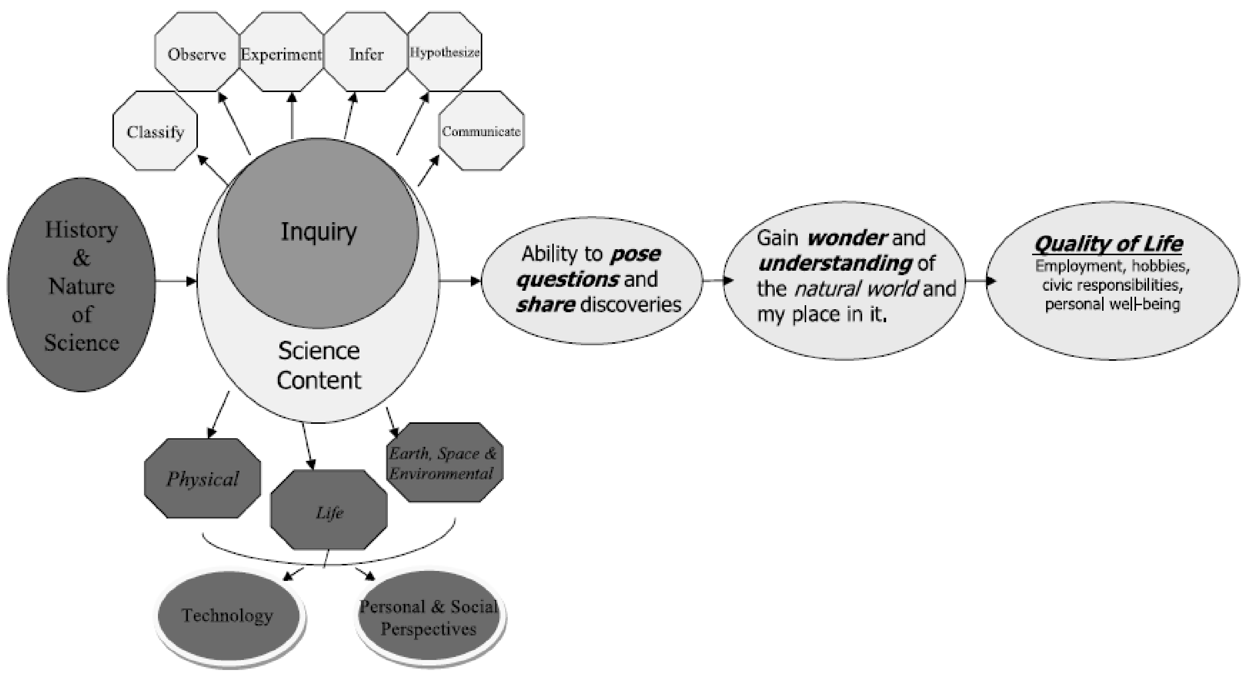

Figure 1. Conceptual model of science for students with severe developmental disabilities.

Besides having a rationale for teaching science and some guidance for selecting content, educators also need methods that are likely to be effective for science learning by students with severe developmental disabilities. In the last decade, interest in teaching science to students with severe disabilities has grown as evidenced by both book chapters (Cooper-Duffy & Perlmutter, 2006; Spooner, DiBiase, & Courtade-Little, 2006) and several new studies (e.g., Jameson, McDonnell, Johnson, Riesen, & Polychronis, 2007; Jameson, McDonnell, Polychronis, & Riesen, 2008; McDonnell, Johnson, Polychronis, Riesen,&Kercher, 2006; Riesen,McDonnell, Johnson, Polychronis, & Jameson, 2003). Overall, these new studies are not categorically different from earlier work (focus on skill acquisition, used systematic instruction as basic instructional practice). On the other hand, because these newer studies are post No Child Left Behind Act (2002), they tend to include more general education teachers as the person responsible for delivery of instruction and include skills that address a broader range of science standards.

Evidence-Based Practices

Although many guidelines for teaching science have practical appeal, educators also need information on which methods have been shown to be effective. Interventions that can be supported by a body of high-quality studies are known as “evidence-based practices” (EBP; Odom et al., 2005). Odom et al. set the framework for the development of research quality indicators (QIs) and guidelines to evaluate practices across different methodologies (e.g., qualitative, Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005; group experimental and quasiexperimental, Gersten et al., 2005; single-subject, Horner et al., 2005), which are used in special education research. Although there are multiple guidelines for defining this research quality, most are specific to the type of research design. For single-subject research, the guidelines proposed by Horner et al. have most often been applied to these types of studies (e.g., Browder, Ahlgrim-Delzell, Spooner, Mims,& Baker, 2009; Chard, Ketterlin- Geller, Baker, Doabler, & Apichatabutra, 2009; Lane, Kalberg, & Shepcard, 2009; Test, Richter, Knight, & Spooner, 2010). These guidelines are especially relevant to identifying EBPs for students with severe disabilities because so much of the research uses single-subject research designs (McDonnell & O’Neill, 2003; Spooner & Browder, 2003).

In a recent review, Courtade et al. (2007) examined the literature from 1985 to 2005 for the degree to which there was evidence that science had been taught to students with severe developmental disabilities. For the 20 years that were studied, 11 experiments were found, which taught content referenced to the NSES (NRC, 1996, science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspectives, and history and nature of science). Of the 11 experiments that were documented, eight of these experiments had content (i.e., skills taught) represented in the standard on science in personal and social perspectives, content standard F (e.g., safety, health, exercise, and nutrition). This review suggested that systematic instruction was an EBP, but no formal analysis of EBP was conducted due to the limited scope of the literature in science at that time.

With the increased focus on teaching academic content to students with severe disabilities, new research in science has occurred since the Courtade et al. (2007) review. The purpose of this paper is to extend the prior review by Courtade et al. (2007) to identify this newer literature and also to evaluate these studies to identify if systematic instruction is an EBP for teaching science. Extending the Courtade et al. review was a two-step process. First, studies needed to be located where science content was taught to students with severe developmental disabilities (e.g., study included at least one participant with a moderate to severe disability, primary dependent variable included measures of achievement of science-related skills as indicated by NSES). Some of these newer studies have targeted dependent variables like vocabulary words and conducting experiments variables that are derived from the general science curriculum-like science vocabulary words and skills for conducting experiments. That is, there are now studies in which the content was more specifically related to science education curriculum or curricular goals than what the prior review found. The second task was then to determine if a sufficient number of these studies met criterion to draw the conclusion that systematic instruction was an EBP. When these newer studies are combined with the prior studies identified by Courtade et al. (2007), there now is a sufficient pool of research on which to apply the Horner et al. (2005) criteria to identify EBPs for teaching science.

Method

Literature Search Procedures

To determine the evidence base for teaching science to students with severe developmental disabilities, we first developed a conceptual framework for teaching science to this population. To do this, a team of experts, including experts in the field of severe disabilities and a science education researcher, met to discuss the purpose and overall outcomes of teaching science to students with severe disabilities (a list of the experts and their credentials can be made available by the senior author).

Next, we developed an operational definition of systematic instruction based on a number of references in the literature (e.g., Collins, 2007; Snell, 1983; Stokes & Baer, 1977; Wolery, Bailey, & Sugai, 1988). The operational definition was developed to evaluate whether the studies in this review used systematic instruction. For the purposes of this study, systematic instruction incorporates (a) instruction of socially meaningful skills, (b) by defining target skills which are observable and measureable, (c) using data to demonstrate that skills were acquired as a result of the intervention, (d) using behavioral principles to promote transfer of stimulus control including differential reinforcement, systematic prompting and fading, and error correction, and (e) producing behavior change that can be generalized to other contexts, skills, people, and/or materials.

After we operationally defined systematic instruction, we then used a list of terms similar to the terms used in the Courtade et al. (2007) review to update and expand the extant list of 11 articles. Search terms in science were derived from the eight Science Content Standards identified by the NSES. We added some additional terms to the list of terms (e.g., access to general curriculum) to gather a comprehensive list of articles. The list of terms were established and confirmed by both an expert in severe disabilities and a science content expert. The final list of 27 terms were derived from NSES content standards (e.g., inquiry and physical science) and key science terms (e.g., motion, sun, and moon) and were used in combination with describing the student population (e.g., moderate mental retardation, severe disabilities, and autism). A complete list of terms can be made available by the senior author. Based on the list of key terms, a literature search was conducted using InfoTrac, Masterfile Premier, ERIC, PsychINFO, and Academic Search Elite electronic databases.

A comprehensive list of 17 articles for teaching science content to students with severe disabilities was compiled, and all studies were retained for analysis. The original 11 studies from Courtade et al. also appeared in the new list that resulted from the current search. The list included the 11 studies from the Courtade et al. (2007) review based on their inclusion criteria, which was a clear focus on the acquisition of science skills with the exclusion of studies if the skill would not typically be taught within the general education classroom (e.g., crossing the street); however, safety skill instruction more closely aligned to what is taught in a general education classroom was included (e.g., verbally describe surroundings when lost; relative position in physical science). The inclusion criteria for the six additional studies were based on the same criteria as Courtade et al., as well as the requirement of acquisition of science skills aligned to general curriculum science standards. All studies from the prior review, as well as the new studies included in this review, met the following inclusion criteria: (a) used a single-subject design that can demonstrate experimental control, (b) published in a peer reviewed journal in English between the years of 1985 and May 2009, (c) included at least one school-aged participant who could be classified as having a severe developmental disability (e.g., student has an IQ of 55 or below, and/or a participant description of the student as having a severe developmental disability), and (d) included an intervention which focused on teaching science content to the students, even if it was not the focus of the study (i.e., a study which evaluated embedded instruction across content areas). Studies were excluded based on the following: (a) studies that included a science key term but did not measure a science skill as a dependent variable (e.g., a study that evaluated computer-assisted instruction to teach functional sight words), (b) studies that evaluated “participation” in science content if the reviewers could not determine an operational definition of the skill from the article (e.g., participation according to the article meant listening to a lecture), and (c) studies in which the science skill under investigation would not generally be taught in a general education classroom (e.g., fire safety skills were excluded).

After a comprehensive list of the articles was determined, we coded the studies using the QIs for single subject design (Horner et al., 2005). The procedures used for this part of the coding process were similar to those used to evaluate the application of the Horner et al. QIs in the article on time delay by Browder et al. (2009). Although Horner et al. is the best available criteria for evaluating an EBP using single-subject studies, the QIs may need to be refined. For example, Cook, Tankersley, and Landrum (2009) asked special education scholars to apply the QIs to a group of empirical literature, and the reviewers had several recommendations for changes. Reviewers recommended operationally defining the indicators, adding and deleting certain elements and weighting the QIs in order of significance. For example, Horner et al. (2005) recommend that within the participant description, studies should include the test(s) used to classify a student’s disability. For purposes of this review, tests for classification were not considered to be an essential indicator of quality. In addition, for the social validity indicator, the importance of the dependent variable could either be described or inferred. The ability of a teacher to implement the intervention was added to the cost-effective and practical criteria, as this was determined to be indication of cost and practicality.

Second, each experiment was coded on the following:

(a) the instruction used (i.e., the independent variable), (b) the specific response (i.e., dependent variable), (c) the science content standard (e.g., according to definitions and descriptions by the NSES, such as Science and Inquiry), (d) the person responsible for the primary instruction used in the study, (e) the context of the study (e.g., general education classroom), (f) training for generalization and maintenance across settings, materials, and people, and (g) other benefits to instruction (e.g., promotion of self-determination and use of assistive and other technologies).

Using the coding form, experiments were read and coded by doctoral students in the dissertation phase of the special education program. There was one primary coder for each of the studies, and a second coder to determine reliability. After the studies were hand coded, the data were entered into a statistical database program (SPSS, 2004). Frequencies and types of each of the above study characteristics were calculated.

Table 1. QIs Identified in Science Literature

Indicator	Spooner et al. (1989)a	Gast et al. (1992)a	Marchand-Martella et al. (1992)	Watson et al. (1992)	Winterling et al. (1992)b	Collins and Stinson (1995)b	Browder and Shear (1996)a	Collins and Griffen (1996)b	Utley et al. (2001)	Taber et al.(2002)b	Riesen et al.(2003)b	Taber et al.(2003)b	Agran et al. (2006)b	McDonnell et al. (2006)b	Collins et al.(2007)b	Jameson et al. (2007)a	Jameson et al. (2008)a
Participants																	
Described sufficiently	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Selection described sufficiently	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Setting																	
Setting described sufficiently	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
DV																	
Described with replicable precision	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Quantifiable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Measurement described to replicable precision	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Measurement occurred repeatedly	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Interobserver agreement	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y

data reported																	
IV																	
Described with replicable precision	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Systematically manipulated	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Procedural fidelity described	Y	Y	Y	N	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	Y	Y
Baseline Procedures Phase provided evidence of pattern, prior to intervention	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Described with replicable precision	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Results																	
Three demonstrations of experimental effect	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Design controlled threats to internal validity	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Effects replicated, indicate external validity	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Social Validity																	
DV socially important	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Magnitude of change in DV due to intervention socially important	Y	Y	N	N	N	N	Y	N	N	Y	N	Y	Y	N	N	Y	Y
IV is cost effective/practical	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
IV is implemented over	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

time, typical contexts/typical agents																	
Indicators met/Total indicators	20/20	20/20	16/20	9/20	19/20	19/20	20/20	19/20	12/20	19/20	19/20	19/20	19/20	19/20	19/20	20/20	20/20
	7/7	7/7	6/7	2/7	7/7	7/7	7/7	7/7	3/7	6/7	7/7	6/7	6/7	7/7	7/7	7/7	7/7

Note. Y = yes, N = no, DV = dependent variable, IV = independent variable. [a] High quality of evidence (as defined by NSTTAC). [b] Acceptable level of evidence.

Determination of an EBP for Teaching Science

After coding the studies, our objective was to determine if systematic instructional procedures implemented in the investigations could be considered as EBPs. The determination of whether systematic instruction was an EBP was derived from the Horner et al. (2005) criteria using the National Secondary Transition Technical Assistance Center's (NSTTAC, 2010; Test et al., 2009) decision rules for conducting a literature review. According to NSTTAC, high-quality studies must meet all QIs, whereas acceptable studies meet all QIs except Study 2 (participant selection), Study 11 (procedural fidelity), and one of Studies 17Y20 (social validity).

In addition, the research team agreed that, to qualify as a quality study, the study had to meet all of the items listed under the indicator for results, graph, and design. In other words, the results indicator was considered critical. For example, a study would only qualify if all of the items under the results indicator were met (e.g.,Marchand-Martella, Martella, Christensen, Agran, & Young, 1992).

When the "quality" studies (NSTTAC, 2010, Test et al., 2009) were identified, they were then reviewed to determine if they met the criteria for an EBP according to Horner et al.: (a) the number of quality studies was at least 5, (b) the number of researchers represented in this set of experiments was at least 3, (c) the number of participants across this set of studies was at least 20, and (d) the number of geographic locations represented was at least 3. According to NSTTAC (2010) decision rules, single-subject designs have a "strong" level of evidence of causal inference if (a) there are five high-quality studies (i.e., studies that meet all QIs), (b) three independent research teams, (c) the studies demonstrate a functional relationship, and (d) there is no contradictory evidence from a study reflecting strong evidence. In addition, NSTTAC notes that there is a "moderate" level of evidence of causal inference for a group of single-subject studies, which (a) include three high-quality or acceptable studies (i.e., acceptable studies meet all QIs except Studies 2 and 11 and one of Studies 10Y17), (b) have one to two independent research teams, and (c) must demonstrate a functional relationship.

Once the quality and acceptable studies were determined, information for characteristics of only the quality studies was evaluated. To make the determination of whether the intervention used in the quality studies was evidence-based to teach science content, the researchers used the decision rules from NSTTAC, as described in the previous paragraph.

We analyzed the 17 studies. Of these, five studies were determined to have a “strong” level of evidence, and an additional nine appeared to meet a “moderate” level of evidence. These 14 studies were then considered to determine whether systematic instruction could be considered an EBP for teaching science content to students with severe disabilities. Once the experiments were read and coded, a table of indicators and studies meeting each indicator as shown in Table 1 was created (see Table 1).

Interrater Reliability on QIs and Characteristics of Studies

Interrater reliability was established on all of the 17 experiments included in the review. A doctoral student served as the second rater and independently coded the experiments. Each experiment was compared item-by-item recording agreements and disagreements. Interrater reliability was calculated for both the QIs according to Horner et al. (2005) as well as the descriptive findings of the studies. Through consensus, all disagreements were resolved. Mean interrater reliability for the QIs was 94.1%, with a range of 80Y100% for individual items within an indicator. Mean interrater reliability for the descriptive findings of the studies was 97%, with a range of 85-100%.

Results

Quality of the Single-Subject Studies

A total of 17 studies met the original inclusion criteria for interventions on teaching science to students with severe developmental disabilities. Descriptive information on the QIs is included in Table 1. Of the original 17 studies, 14 studies were either high quality (i.e., five studies) or acceptable quality (i.e., nine studies) to be included in the subsequent analysis to determine if systematic instruction should be considered an EBP for teaching science to students with severe disabilities. As can be observed from Table 1, 3 of the 17 studies (i.e., Marchand-Martella et al., 1992; Utley et al., 2001;Watson, Bain, & Houghton, 1992) did not qualify in the highquality or acceptable quality range as either insufficient information about the study was available in the published report of the investigation (e.g., social validity, interobserver agreement) or there was an unclear demonstration of effect. We further analyzed the 14 studies in commenting on instruction components (independent and dependent variables), characteristics of the studies (e.g., science standards addressed, person responsible for delivery of instruction, context of study), and methodological limitations.

Instructional Components

Independent variables

Of the quality and acceptable studies, all 14 were conducted using systematic instruction. For example, six studies used task analytic instruction (Browder & Shear, 1996; Gast, Winterling, Wolery, & Farmer, 1992; Spooner, Stem, & Test, 1989; Taber, Alberto, Hughes, & Seltzer, 2002; Taber, Alberto, Seltzer, & Hughes, 2003; Winterling, Gast, Wolery, & Farmer, 1992), seven used constant time delay (Collins & Griffen, 1996; Collins, Evans, Creech-Galloway, Karl, & Miller, 2007; Jameson et al., 2007, 2008; McDonnell et al., 2006; Riesen et al., 2003; Winterling et al., 1992), and one used progressive time delay (Collins & Stinson, 1995). Systematic instruction embedded into a general education lesson was used in 5 of the 14 quality studies (Collins et al., 2007; Jameson et al., 2007, 2008; McDonnell et al., 2006; Riesen et al., 2003). Twelve of the 14 quality studies used multiple systematic instruction strategies within the same intervention (e.g., task analytic instruction, least to most prompting system, and verbal praise). Finally, no studies were located in which assistive technology was used.

Dependent variables

Of the quality and acceptable studies, 7 of the 14 measured chained skills. For example, two studies focused on first aid skills (Gast et al., 1992; Spooner et al., 1989), one study on safety skills (Winterling et al., 1992), one study on weather-related sight words (Browder & Shear, 1996), two studies on mobility or assistance when lost in the community (Taber et al., 2002, 2003), and one study on completing a task within a laboratory (Agran, Cavin, Wehmeyer, & Palmer, 2006).

Of the quality and acceptable studies, 8 of the 14 measured discrete skills. For example, two focused on reading product warning labels (Collins & Stinson, 1995; Collins & Griffen, 1996). Most studies (n = 5) included in the review focused on the acquisition of science-related vocabulary words and/or definitions (Agran et al., 2006; Collins et al., 2007; Jameson et al., 2007, 2008;McDonnell et al., 2006; Riesen et al., 2003).

Characteristics of the Study

Science standards

Of the 14 quality and acceptable studies, six of the eight science standards outlined by the NSES (NRC, 1996) were found. One study was located in which unifying concepts, as defined by NSES, was included (Riesen et al., 2003). Six studies fell within the standards of physical science, three within the standard of life science (Agran et al., 2006; Jameson et al., 2008; McDonnell et al., 2006), and three within the standard of earth and space science (Browder & Shear, 1996; Collins et al., 2007; Jameson et al., 2007). Only one study included science as inquiry (Agran et al., 2006). Finally, no studies were found in which students were taught skills that fell within the science standards of science and technology or history and nature of science. Five of the 14 studies taught one or more skills that fell within more than one standard of science defined by NSES (Agran et al., 2006; Collins et al., 2007; Jameson et al., 2007; McDonnell et al., 2006; Riesen et al., 2003).

Person responsible for the instruction

Of the quality and acceptable studies, multiple people were responsible for instruction ranging from paraprofessionals to peers (e.g., Riesen et al., 2003; McDonnell et al., 2006). For example, 10 studies were located in which the special education teacher implemented instruction (e.g., Browder & Shear, 1996; Gast et al., 1992; Taber et al., 2003), three in which the general education implemented instruction (Collins et al., 2007; Jameson et al., 2007; McDonnell et al., 2006), two in which taught by the paraprofessional (e.g., McDonnell et al., 2006; Riesen et al., 2003), and two in which a therapist (e.g., nurse, researcher) implemented the instruction (Spooner et al., 1989; Winterling et al., 1992). In one study, the student was taught to self-monitor their own science instruction (Agran et al., 2006). Three studies were found in which peers were used to implement the independent variable (Agran et al., 2006; Collins et al., 2007; Jameson et al., 2008).

Context of the study

Multiple studies (n = 10) involved teaching in two contexts (e.g., general education classroom and special education classroom). Nine studies were implemented in the special education classroom and four within the community (e.g., Collins & Stinson, 1995; Collins et al., 2007). Six quality and acceptable studies were conducted within the general education classroom (Agran et al., 2006; Collins et al., 2007; Jameson et al., 2007, 2008; McDonnell et al., 2006; Riesen et al., 2003). Additionally, science skills were taught in other school settings (e.g., computer laboratory) in 5 of the 14 quality studies (Browder & Shear, 1996; Collins & Griffen, 1996; Taber et al., 2002, 2003; Winterling et al., 1992).

Training for generalization and maintenance Generalization across materials was shown in nine studies (Browder & Shear, 1996; Collins & Stinson, 1995; Collins et al., 2007; Gast et al., 1992; Jameson et al., 2007, 2008; Riesen et al., 2003; Spooner et al., 1989;Winterling et al., 1992). Eight quality studies demonstrated generalization across people or settings (Collins & Stinson, 1995; Gast et al., 1992; Jameson et al., 2007; Spooner et al., 1989; Taber et al., 2002, 2003). Ten of the 14 quality and acceptable studies included a measure of skill maintenance (e.g., Agran et al., 2006; Spooner et al., 1989; Jameson et al., 2007).

Methodological Limitations

There were a few methodological limitations found in this review. First, researchers only provided a measure of procedural fidelity in 11 of the 14 studies (78.5%). Second, the magnitude of change in the dependent variable due to the intervention was determined to be socially important according to the author’s analysis in only 8 of the 14 studies (57%). In most cases, this was primarily due to the fact that the authors did not include a formal measure of social validity. Finally, maintenance data were gathered in 11 of the 14 studies (78.5%).

As can be observed from Table 2, the 14 studies, which were of high and acceptable quality, yield support systematic instruction as an EBP. In total, there were 10 researchers and 46 participants, and investigations were conducted across six states to satisfy the Horner et al. (2005) criteria (number of researchers = 3, number of cumulative participants = 20, number of geographic locations = 3). Table 2 depicts a breakdown of the study (e.g., author and year, independent variable, dependent variable, participants, location of the study; see Table 2).

Discussion

The purpose of our work was to document the evidence base for teaching science content to students with severe developmental disabilities by extending the original work conducted by Courtade and her colleagues through addressing the how, what, and why of science instruction in this new expanded review. First, we offer some guidance from the research on how to teach science through applying the Horner et al. (2005) QI criteria and NSTTAC (2010) guidelines for how to define an EBP. The outcomes of our analysis reveal that systematic instruction is an EBP to teach science content to students with severe developmental disabilities.

How to Teach Science

A closer examination of these outcomes suggests that some components of systematic instruction may be especially effective in the promotion of science skills. The strongest support was found for using task analytic instruction to teach chained skills and for using time delay to teach discrete skills in science. A task analysis has been used to teach chained activity (e.g., application of first aid) that includes a science concept (e.g., prevention of infection). All criteria necessary to consider task analysis as evidence base were met based on the Horner et al. (2005) criteria (i.e., 5 studies, 3 researchers, 3 geographical locations, and 20 participants; see Table 2). Second, time delay was used to teach discrete skills in eight of the science studies (e.g., product warning labels, science vocabulary definitions), across three researchers in three geographical locations; however, the Horner et al. (2005) criteria for participants are not yet met (i.e., 18 participants). Five studies used embedded time delay instruction. Embedding systematic instruction (e.g., trials of science vocabulary learning using time delay) is an especially appealing practice because it can be incorporated during lessons in the general education science class. Another option is the use of peers to promote science skills (e.g., Collins et al., 2007). Replications of these promising practices are needed to confirm their evidence base for science learning.

Table 2. High-Quality and Acceptable Quality Studies in Science

Author (year)	Independent Variable	Dependent Variable	Science Standard (NSES)	Participants in Science/Total Participants	Location of Study
Spooner et al. (1989)	SI (TA, least to most prompting,	First aid skills	Personal and social perspectives	3/3	NC

	verbal praise)				
Gast et al. (1992)	SI (TA, backward chaining)	First aid skills	Personal and social perspectives	4/4	GA
Winterling et al. (1992)	SI (TA, chaining, CTD, multiple exemplar training), simulation	Safety skills	Personal and social perspectives	4/4	GA
Collins and Stinson (1995)	SI (PTD)	Read product warning label	Personal and social perspectives	4/4	KY
Browder and Shear (1996)	SI (TA, least to most prompting)	Weather-related sight words (e.g., sunny)	Earth and space science	3/3	PA
Collins and Griffen (1996)	SI (CTD, multiple exemplars)	Response to product warning label	Personal and social perspectives	4/4	KY
Taber et al. (2002)	SI (TA, five-level prompting)	Mobility when lost in community	Physical science	14/14	GA
Riesen et al. (2003)	SI (CTD, simultaneous prompting during EI)	Sight words and vocabulary	Unifying concepts/physical science	1/4	UT
Taber et al. (2003)	SI (TA, least to most prompting)	Assistance when lost in community	Physical science	6/6	GA
Agran et al. (2006)	SDLMI	Laboratory task sequence/organ system and functions	Inquiry/life science	2/3	WY
McDonnell et al. (2006)	SI (CTD, differential reinforcement, error correction)	Science vocabulary definitions (e.g., atom-the smallest part of an element)	Unifying concepts/physical science/life science	2/3	UT
Collins et al. (2007)	SI (CTD, EI, direct massed trials, distributed trials), peer-mediated instruction	Functional and core science vocabulary (e.g., measure and precipitation)	Unifying concepts/physical/earth and space/personal and social perspectives	1/4	KY
Jameson et al. (2007)	SI (CTD, EI, massed trials)	Science vocabulary (e.g., boil and solid)	Unifying concepts/physical/earth and space	1/4	UT

Jameson et al. (2008)	SI (CTD, EI), peer-mediated instruction	Science vocabulary definitions (e.g., lungs-get less air, can get cancer)	Life science	1/2	UT
10 researchers				46/56	6 states

Note. SI = systematic instruction, TA = task analytic instruction, CTD = constant time delay, PTD = progressive time delay, EI = embedded instruction.

When these practices for teaching science are compared to the recommendations of the NSES and the conceptual model shown in Figure 1, it is apparent that past science instruction has focused primarily on the student receiving information (e.g., vocabulary) or learning a daily living skill that has some link to science (e.g., community mobility with its link to spatial planning) rather than through the process of inquiry. Inquiry is both a process for teaching science as well as a set of skills students should acquire. In contrast, the process of inquiry is typically one in which the student discovers the concept and stems from a constructivist teaching philosophy (Flick & Lederman, 2004; Matthews, 1994; Tobin, 1993). At present, there is no research with students with severe developmental disabilities demonstrating open-ended inquiry to be effective.

Instead, there is some emerging research showing that students with severe developmental disabilities may learn how to learn through what science educators call directed inquiry. For example, Agran et al. (2006) taught three junior high school students with moderate to severe intellectual disabilities to successfully engage in student directed learning (e.g., goal setting, self-monitoring, and self-instruction) to access the general curriculum. Although only one application for this self-directed learning model of instruction (SDLMI) was found that included some science learning, other studies applying SDLMI provide additional evidence for this approach (Agran, Blanchard, & Wehmeyer, 2000; Agran et al., 2006; Wehmeyer, Palmer, Agran, Mithaug, & Martin, 2000). Some new studies (not in press at the time of this review) also provide emerging support that students with severe developmental disabilities can learn to use inquiry. Courtade, Browder, Spooner, and DiBiase (2010) trained teachers to follow a task analysis to implement an inquiry-based lesson. As the teacher became more consistent in these steps, the students also increased their unprompted inquiry steps (e.g., to make a prediction). Jimenez, Browder, and Courtade (2009) evaluated the effects of a treatment package including multiple exemplar training, time delay, and a self-directed learning prompt (KWHL Chart) with three middle school students with moderate intellectual disabilities ability. The KWHL Chart is a graphic organizer used to support the inquiry lesson by prompting four questions: (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 students not only learned to independently complete an inquiry lesson but generalized to untrained materials, concepts, and instructional setting.

An important point to realize in considering these studies in which students with severe disabilities used inquiry is that, in each case, systematic instruction was applied for the students to master the self-directed learning process. In Agran et al. (2006), the trainer modeled the goal setting, self-monitoring, or self-instruction strategy, and the students had multiple opportunities to practice with instructor cues as needed prior to applying the skill during general education activities. One important skill in Agran et al.'s work is that students learned to pose questions such as "What do I know about it now?" or "What can I do to make this happen?" In Jimenez et al. (2009), the instructor used a constant time delay procedure for the student to follow a KWHL Chart. Students generalized use of the chart to the general science class. When applying systematic instruction to teach students to use inquiry, some additional responses to teach might include making and confirming predictions, asking questions about a novel material or activity, or selecting a method to test a hypothesis.

Because systematic instruction has emerged as an EBP through this review and others on teaching academic content (reading, Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; mathematics, Browder, Spooner, Ahlgrim-Delzell, Harris, & Wakeman, 2008, and science, Courtade et al., 2007), it is important to be clear in specifically defining the practice. Wolery et al. (1988) noted that systematic instruction is based on application of the principles of applied behavior analysis and that it also produces effective and generalized outcomes. Most texts in severe disabilities describe planning these components of a systematic instruction plan: (a) defining a discrete or chained response to be measured as a demonstration of learning (i.e., the objective), (b) using specific prompting and prompt fading procedures for the acquisition of these responses (including reinforcement), and (c) planning for the generalization and maintenance of the response (Collins, 2007; Snell & Brown, 2006; Westling & Fox, 2009).

What to Teach in Science

In the earlier review by Courtade et al. (2007), most of the studies were focused on teaching skills of daily living but also happened to overlap some science content. Although this continues to be an important goal and one way to approach science learning, the current review also provides emerging evidence that students with severe disabilities can learn science content derived from the general curriculum. One important aspect of this content is acquiring the vocabulary to be able to communicate science learning. Some of the new studies have focused on vocabulary that are multisyllabic like "precipitation" (Collins et al., 2007) and are abstract terms like "solid" (Jameson et al., 2007). Besides learning to recognize the word itself, it is also important to demonstrate that students have some understanding of the concept it represents. One way to do this is to have students define the words (Jameson et al., 2007; McDonnell et al., 2006). Another option is to have students demonstrate understanding of the concept through an experiment (Jimenez et al., 2009). Teaching students to identify concepts through hands-on activities is especially important to promote opportunities for inquiry and to ensure generalization beyond rote learning of terms. As this review reveals, research is only now emerging on how to teach students to engage in experiments (e.g., Agran et al., 2006; Jimenez et al., 2009). In contrast, students demonstrating concept learning through the use of hands-on science has been used in several studies for students with high incidence disabilities (Palincsar, Collins, Marono, & Magnusson, 2000; Palincsar, Magnusson, Collins, & Cutter, 2001; Scruggs & Mastropieri, 1995).

Besides focusing on both vocabulary and concept learning, consideration needs to be given to teaching the breadth of the science standards. These standards typically will be derived from the general curriculum for the student's grade. More recent studies on science are expanding the scope of science standards addressed and perhaps reflect the influence of NCLB to address science learning. Most studies in the Courtade et al. (2007) review addressed the science standard personal and social perspectives (e.g., health, safety). Recent studies evaluated skills linked to a broader range of science standards, including unifying concepts (e.g., Jameson et al., 2007; Riesen et al., 2003), physical science (e.g., Riesen et al., 2003; Taber et al., 2002), life science (e.g., Agran et al., 2006; McDonnell et al., 2006), and earth and space science (e.g., Jameson et al., 2007).

Why Teach Science

Teaching science to students with severe disabilities so that they can learn the content is not the primary reason for teaching science content. One important reason is to provide a full educational opportunity. One of the encouraging trends in the research on science for students with severe disabilities is that so many of the studies were conducted in general education settings or included generalization to a general science class. Six studies were conducted within the general education classroom (Agran et al., 2006; Collins et al., 2007; Jameson et al., 2007, 2008; McDonnell et al., 2006; Riesen et al., 2003). Multiple studies (n = 10) involved teaching in two contexts (e.g., general education classroom and special education classroom).

A second reason may be to promote learning of skills needed to function fully and safely in the community. For example, two studies focused on first aid skills (Gast et al., 1992; Spooner et al., 1989), one study on safety skills (Winterling et al., 1992), and two studies on mobility or assistance when lost in the community (Taber et al., 2002, 2003). One of the current challenges in teaching students with severe disabilities is balancing the demands of the general curriculum with needs students may have to learn life skills that may be underemphasized or overlooked in general curriculum. Science may provide a context in which students can build on conceptual learning to practice functional activities that incorporate these concepts. For example, while learning about chemical reactions, students may practice safety skills. While learning about microbes, students may practice certain health habits.

In our conceptual model, we propose a third reason, which stems from the literature on why all students learn science (NRC, 1996), that is, to promote wonder and understanding about the natural world. Although "wonder" can be a difficult concept to define and measure, to the extent that students can ask questions, make predictions, pose hypotheses, and engage in relevant conversations, they are beginning to explore the natural world. This reason for science learning is not well reflected in the literature on science learning, although there have been some studies in which students did some self-directed exploration (e.g., Agran et al., 2006) or demonstrated conceptual understanding (e.g., Jameson et al., 2007). One way to promote the benefits of science learning would be to prioritize skills that teach students how to learn about their natural world so that even after graduation students continue to have ways to explore their world. In future research, students might learn to choose what to investigate (e.g., selecting a picture for a topic), explore the topic (e.g., through hands-on experiment or Internet exploration), make comparisons about this phenomena (e.g., selecting terms to use to describe it), and report findings to the group (e.g., using new vocabulary).

Recommendations for Future Research and Practice

Recommendations for future research

Overall, the research on teaching science to students with severe disabilities is still a small collection of studies. Much more research is needed in this area of content learning. Although there are multiple studies teaching daily living or community skills with some overlap to science, more research is needed in which the specific science concept to be learned in these activities is more clearly defined. For example, could a student learn to identify some of the characteristics of simple machines through a series of cooking activities using appliances to present these concepts, or could a student learn to identify the boiling point of water during a cooking activity?

A second area for future research is to build on the research showing students can learn science vocabulary and its meaning (definitions) by demonstrating that students can recognize the concept in a hands-on activity. For example, can the student identify solids, liquids, and gases in everyday materials? Third, much more research is needed on teaching the concepts of science. One way to approach this learning is through the use of more hands-on activities such as science experiments. This can also promote studying the process of inquiry and the goal of students gaining understanding about their natural world. Whereas students may not retain all of the specific science content (e.g., what is a solute?), if they have learned how to explore materials and pose questions, these may produce lifelong learning. Finally, studies should include formal measures of social validity to help demonstrate the value of the science outcomes achieved to the students with disabilities and other stakeholders (e.g., parents and teachers).

Recommendations for practice

Systematic instruction (e.g., constant time delay and task analytic instruction) was found in this review to be an evidence-based strategy for teaching science skills to students with severe developmental disabilities. Successful practice will likely include the components of systematic instruction beginning with defining a measurable set of responses to be learned. These may include science vocabulary terms, science concept statements, and inquiry responses such as posing questions, making predictions, and conducting experiments. To teach these skills, systematic prompting can be applied. We especially recommend the use of time delay to teach the science vocabulary terms and definitions or concept statements related to the words. The steps to conduct an experiment might be taught through the use of a task analysis. Teachers should target the instruction of more complex science skills (e.g., such as the water cycle or self-direction of an inquiry based science lesson), in addition to fact-based skills (e.g., safety skills, vocabulary, and definitions). These systematic prompting strategies can be embedded in the general education lesson. It will be important to plan for the generalization and maintenance of these skills. For example, it is important to teach and test the identification of concepts across materials and activities. Whereas the research reviewed provides a fundamental beginning point for science instruction for this population, teachers will need to create applications of systematic instruction to cover the breadth and depth of science content.

Summary

Science provides a unique content area for students to learn how to direct their own learning. If inquiry is the priority of focus, students may begin to cultivate wonder and understanding about the natural world. Although this is a future goal, current research provides a model for applying systematic instruction primarily to fact-based skills like science vocabulary. Using systematic instruction in science is an EBP. What is needed now is research demonstrating that these principles can be applied to more complex science concepts and to promote generalized inquiry skills.

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