Supporting Science-Related Instruction for Students with Intellectual and Developmental Disabilities: A Review and Analysis of Research Studies

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Abstract
Broad scientific concepts are vital to individual wellbeing as a function of daily living skills. Science connects how individuals interact with the environment and how they interpret those interactions (Browder et al, 2007). According to the National Assessment of Education Progress, students with disabilities score significantly lower than students without IEPs on standardized science achievement assessments (National Center of Education Statistics, 2015). In addition, students with intellectual and developmental disabilities (IDD) are likely to be left out of opportunities to learn science content regardless of educational setting. The current study examines and analyzes published single-case research (SCR) on science and science-related achievement for students with IDD through Tau-U effect size analysis and rigor evaluation. Implications for research and teaching are discussed.

The idea of "science for all" was initially introduced by the American Association for the Advancement of Science (AAAS, 1989). While the AAAS document did not specifically refer to students with disabilities, the publications *A Framework for K-12 Science Education* by the National Research Council (NRC, 2012) and *Appendix D - All Standards, All Students: Making the Next Generation Science Standards Accessible* by the Next Generation Science Standards (NGSS) Lead States (2013a) expanded the notion of "science for all" and provided specific attention and recommendations for including students with disabilities in science classrooms. The NRC (2012), in considering diversity in science teaching, suggests that students with special needs are not excluded from appropriate science learning opportunities. Differentiation and the use of a Universal Design for Learning (UDL) framework are considered common accommodations or modifications that general education teachers use for students with disabilities (NGSS Lead States, 2013a). In illustrating connections between the NGSS and students with disabilities, a case study vignette was created to provide teachers with a) things that can do to engage students in science learning, b) a summary of research literature, and c) with contextual information based on the students included in the vignettes (NGSS Lead States, 2013b).

In the document, *Case Study 3: Students with Disabilities and the Next Generation Science Standards* (NGSS Lead States, 2013b), a 6th grade space science classroom is described with particular focus on students with disabilities including one student with Autism Spectrum Disorder (ASD), three students with specific learning disabilities (SLD), one student with emotional/behavioral disorders (EBD), and two students with intellectual disabilities. Unfortunately, the description of the students with intellectual disabilities is vague with little detail. This is a particularly important omission as characteristics related to intellectual disabilities can range from mild, which is often considered as "high incidence" disabilities (Friend & Bursuck, 2012; Gage, Lierheimer, & Goran, 2012) to moderate, severe, and profound, which are considered "low incidence" disabilities (Friend & Bursuck, 2012). Further, the scenario does not include students considered as having developmental disabilities.

While designed to be an example for providing instruction for students with disabilities using the NGSS framework, the NGSS Lead States (2013b) noted limitations inherent in the case study provided as it pertains to performance expectations and constricted illustrations of students with disabilities. Specifically,

Keywords: science education, science achievement, STEM, intellectual disabilities, developmental disabilities

the limits can be seen in supports for students with intellectual and developmental disabilities (IDD). As IDD can present across a spectrum of severity (i.e., mild, moderate, severe, and profound), the example provided in the scenario falls woefully short in illustrating a breadth of supports. The National Institute for Child Health and Human Development (NICHD, 2016) describes IDD as a) being present at birth or before the age of 18, b) negatively impacting intellectual, physical, and/or emotional development, c) effecting adaptive behavior, and d) possibly including multiple disabilities. Statistically, when focused specifically on students with IDD, the United States Department of Education (2017) report that 12% of all students with disabilities are identified with IDD. Furthermore, 80% of students across disability categories spend at least 40% of their time in general education classrooms. Those statistics support the fact that a majority of students with IDD will be in general science classrooms at some point.

Science Achievement for Students with IDD

Despite the focus on increasing science-related learning for all students, students with disabilities have struggled to make progress on standardized measures throughout multiple years. This is evidenced by science scores on the National Assessment of Educational Progress (NAEP) in that more than 66 percent of 8th grade students with disabilities scored below basic in science across the years of 2009, 2011, and 2015, (National Center for Education Statistics [NCES], 2015). That is compared to 28%, 31%, and 33% of 8th grade students without disabilities respectively (NCES, 2015). The results reported on the NAEP were not specific to students with IDD, however the overall outcomes for students with disabilities indicate little observable improvement in science achievement on standardized science assessments. Although progress on distal standardized measures has been slow, the few research studies on proximal achievement measures have been more promising. As noted by McGinnis and Kahn (2014), previous research supports disciplinary science achievement of students with mild disabilities.

In examining science and science-related studies for students with IDD a number of realities emerge regarding instruction and content. Instructionally, as mandated by the Individuals with Disabilities Education Improvement Act (IDEIA, 2004), educational content should be linked to grade-level standards. This would include general education science standards either represented by the NGSS or state initiated science standards. However, much of the limited research on science learning for students with IDD involves content that would be considered for younger students due to developmental appropriateness (Andersen & Nash, 2016; Karvonen, Wakeman, Browder, Rogers, & Flowers, 2011). For example, Riggs, Collins, Kleinert, & Knight (2013) simplified a high school heredity lesson for five students with moderate IDD by using visual supports in the form of pictures of faces with distinct differences in eye color for student predictions. The students in that study displayed moderate success. Moreover, Andersen and Nash (2016) suggest that due to the needs of students with IDD, research has mainly focused on science-related outcomes like life skills or behaviorally-based results (e.g., following the steps of an inquiry-based process). See Agran, Cavin, Wehmeyer and Palmer (2006) for examples of research with students with IDD and science-related life skills content and behavior-based outcomes (i.e., lab task sequence).

Studies on inquiry-based instruction specific for students with disabilities, the preferred method of science instruction (NGSS Lead States, 2013a; NRC, 2012), has shown mixed success (Mastropieri & Scruggs, 1994; Mastropieri, Scruggs, & Butcher, 1997; Rizzo & Taylor 2016; Scruggs, Mastropieri, Bakken, & Brigham, 1993). Conversely, the little research on inquiry-based instruction specific for students with IDD has been relatively strong and supports the use of more structured inquiry approaches (Courtade, Browder, Spooner, & DiBiase, 2010; Jimenez, Browder, Spooner, & DiBiase, 2012; Miller, Doughty, & Krockover, 2015; Miller & Taber-Doughty, 2014). These studies represented students with IDD across severity (i.e., mild, moderate, and severe) and settings (e.g., inclusive and self-contained classrooms). Additional research on science-related learning for students with IDD has focused on supports and strategies such as discrete trial teaching (Collins, Hager, & Galloway, 2011), explicit instruction (Karl, Collins, Hager, & Jones-Ault, 2013), peer-related strategies (Hudson, Browder, & Jimenez, 2014), and time delay (Courtade et al., 2010). While these examples suggest there is research to support science teaching for students with IDD, the research is disparate making aggregation necessary.

Theoretical Framework for Current Study and Research Questions

Systematic reviews and meta-analyses provide valuable information that influences research and practice as stated by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Group (Moher et al., 2009). The PRISMA Group suggest a specific procedure for conducting reviews and meta-analysis that includes the broad categories of identification, screening, eligibility, and included [manuscripts]). These categories give uniformity to the process of conducting literature reviews and meta-analyses. The suggestions and guidance provided the PRISMA Group is designed to be impactful across works for targeted topics or populations.

As it relates to science-related outcomes for students with disabilities, a number of meta-analytic works have followed the template suggested by the PRISMA Group for aggregating, organizing, and analyzing multiple studies in a standardized manner. While not an overwhelming wealth of research studies exists, there have been attempts to explore what are the elements, influences, and circumstances that provide students with disabilities effective science instruction. Previous meta-analyses on science-related outcomes for students with disabilities have focused on broad areas of student population, instructional approach, and support strategies. Therrien, Taylor, Hosp, Kaldenberg, and Gorsh,

(2011) and Therrien, Taylor, Watt, and Kaldenberg (2014) conducted population-specific meta-analyses on science instruction for students with SLD and EBD respectively. Both studies analyzed a number of characteristics across the studies examined (e.g., grade level, intervention type, and random assignment). Both studies reported that the use of mnemonic strategies had the greatest effects for supporting science achievement for students with SLD and EBD. Rizzo and Taylor (2016) conducted a meta-analysis specifically on the research related to inquiry-based instruction for students with disabilities. Consequently, they found that inquiry-based instructional approaches could be categorized by levels of supports (i.e., ranging from open inquiry to structured inquiry) and that 11 of 12 studies used some form of supported inquiry (Rizzo & Taylor, 2016). Another example of a meta-analysis that focuses on students with disabilities and strategies that support science-related outcomes is Dexter, Park, and Hughes's (2011) work on using graphic organizers for adolescents with SLD. Graphic organizers showed strong effects in helping adolescents with SLD learn science content (Dexter et al., 2011). These meta-analyses provide guidance for a) improving science-related outcomes for students with disabilities (e.g., SLD and EBD), b) considering instructional approaches (e.g., inquiry-based instruction), and c) highlighting strategies that support science learning (e.g., graphic organizers).

Utilizing the frameworks established by the PRISMA Group (Moher et al., 2009), Therrien and colleagues (2011; 2014), Rizzo and Taylor (2016), and Dexter et al. (2011) the current study focused on science-related outcomes for students with IDD. The purpose of this analysis was to synthesize the efficacy of science instruction and science-related instructional supports for students with IDD and therefore was guided by the following questions:

1. What are the study and participant specific characteristics of science-related research for students with IDD?
2. What are the study, participant and intervention effects of science-related research for students with IDD?
3. What are the educational implications of science-related research for students with IDD?

Method

Search Criteria and Procedures

We examined peer-reviewed experimental studies addressing the effects of interventions designed to enhance science achievement for students with IDD. The studies that met the following criteria were included in the review: (1) experimental studies with single-case design; (2) studies focused on content- or behavior-based classroom interventions in the areas of science designed to enhance students' science related knowledge or improve behavior in science classrooms; and (3) studies including school-aged participants (i.e., Grades K-12) who were diagnosed with IDD.

The searches were completed using ERIC, ProQuest, PsycINFO, and Google Scholar databases with manuscripts published from 2000 to 2018 using combinations of the following terms: intellectual disabilit*, mental retard*, down syndrome, developmental disabilit*, science* (science instruction, science teaching, science education, science learning, science literacy, science achievement, science classroom, science assessment, and science content), biology, chemistry, health, life science, physics, physical science; hands-on instruction, hands-on learning, discovery learning, inquiry based instruction. The electronic searches were followed by ancestral search of the reference lists of relevant literature reviews and identified studies. Lastly, hand-searches of following journals were conducted: *Journal of Science Education for Students with Disabilities*, *American Journal of Intellectual and Developmental Disabilities, Education and Training in Autism and Developmental Disabilities, Education and Treatment of Children, Research and Practice for Persons with Severe Disabilities*, *Journal of Science Education, and Journal of Research in Science Teaching.*

The initial search resulted in 48 studies identified, however, based on the thorough review to meet our inclusion criteria, 26 studies were excluded as they were qualitative, illustrative, or review types of studies, and not experimental studies. And four studies were additionally excluded because the interventions were not about science or did not evaluate science achievement or behavior in science classrooms separately. This yielded a total of 18 studies meeting all inclusion criteria which were finally included and analyzed in the review.

Data Coding

To respond to the research questions, studies were coded in four aspects: research characteristics, participant characteristics, intervention, and data characteristics. The research characteristics included five variables (i.e., dependent measure type, settings, science content, and research design); participant characteristics included seven variables (i.e., gender, grade, age, disability, severity, comorbidity, and ethnicity); and data characteristics were coded in three aspects (i.e., sessions, phase, and value) in order to calculate effect sizes. For the intervention characteristics, researchers identified instructional components consisting of interventions, and coded each intervention accordingly.

Effect Size Calculation

To examine the efficacy of interventions in the single-case studies, we calculated effect size with two metrics: percentage of nonoverlapping data (PND] and Tau-U. PND is a widely used non-parametric effect size which has been a basis of many meta-analytic studies. It represents the percentage of data points during intervention exceeding the highest data point in baseline (Scruggs, Mastropieri, & Casto, 1987). PND range from 0 to 100% with outcomes of greater than 90% considered highly effective, between 70% and 90% considered fairly effective, between 50% and 70% considered mildly effective, and less than 50% considered not observably effective (Scruggs, et al., 1987). While PND provides a size of a difference between means of baseline and intervention, we also calculated Tau-U in order to account for baseline trend in the final evaluation. Tau-U is an effect size measure that tests the degree of non-overlap between phases while controlling for baseline trends (Parker, Vannest, Davis, & Sauber, 2011). Tau-U results range from −1.0 to 1.0 with positive scores indicating improvement between phase and negative scores indicating deterioration (Ninci et al., 2015). We used an online Tau-U calculator (Vannest, Parker, Gonen, & Adiguzel, 2016) to obtain Tau-U statistics for characteristics of interest. As described by Rakap (2015), Tau-U can be interpreted as small effect (below 65%); medium effect (66% - 92%); and large effect (93% or above).

Results

We thoroughly analyzed 18 peer-reviewed studies published between 2000 and 2018 containing classroom-based science instructions for students with IDD, in the purpose of examining their characteristics (study-specific and participant-specific characteristics) and effectiveness (study, participant, and intervention type) in multiple aspects. Studies were examined for characteristics with data extracted from each study for analysis and effectiveness was evaluated for included study participants using PND and Tau-U analysis.

Characteristics of Studies and Descriptive Statistics

We examined the characteristics and calculated the descriptive statistics for the studies included in this analysis. Descriptive statistics examine the study, participant, and intervention characteristics. See Tables 1 and 2 for detailed information regarding study and participant characteristics.

Study characteristics. Study characteristics examined included setting, content, and study design. Setting results indicate that 10 of 18 studies (56%) occurred completely or partially in the general education classroom setting. Studies conducted fully or partially in self-contained classroom settings occurred in seven of the studies (39%). Four of the studies (22%) occurred in or partially in resource (i.e., pull out) settings. Two studies (11%) reported that the intervention occurred partially or fully in undescribed settings. Content results indicated that five studies (28%) examined intervention effects on the subject of Life Science/Biology. Four out of eighteen studies (22%) were conducted on elementary science content, scientific process and procedures, and/or Physical Science/Chemistry respectively. One study examined science vocabulary or Earth and Space Science (5% respectively). Fourteen of the studies (78%) examined used a multiple probe design. The remainder of the studies (4 of 18; 22%) examined utilized an alternating treatment design.

Participant characteristics. Across the eighteen studies, 54 students were included in this analysis with 24 female

Table 1. Study-Specific Characteristic.

	Characteristics			
Studies	DV	Setting	Content	Design
Agran, Cavin, Wehmeyer & Palmer (2006)	Number of steps correct on lab task sequence activity; Number of correct responses identifying the organ systems and matching it to its function	GE	LSB/ScP	MP
Collins, Evans, Creech-Galloway, Karl, & Miller (2007)	Number of correct science descriptors	GE/RC	ELS	AT
Collins, Hager, & Galloway (2011)	Percent accuracy of acquisition of core content/functional application skills	RC	PSC	MP
Courtade, Browder, Spooner, DiBiase (2010)	Number of inquiry skills completed independently	SC	ScP	MP
Heinrich, Knight, Collins, & Sprigg (2016)	Percent correct discrete skill and chained tasks	GE	ScV	MP
Hudson, Browder, & Jimenez (2014)	Number of points for correct comprehension responses	GE/O	ELS	MP
Jameson, McDonnell, Johnson, Riesen, & Polychronis (2007)	Percent correct responding during testing probes	SC/GE	PSC	AT
Jameson, McDonnell, Polychronis, & Riesen (2008)	Percent of correct responses	SC/GE	LSB	MP
Jimenez, Browder, & Courtade (2009)	Number of steps correct on task analysis	GE	PSC	MP
Jimenez, Browder, Spooner, & DiBiase (2012)	Number of independent correct responses	GE	PSC	MP
Jimenez, Lo, & Saunders (2014)	Number of points received on a quiz	SC	ELS	MP
Karl, Collins, Hager, & Jones-Ault (2013)	Percent correct on full probe and daily probe trials	GE	LSB	MP
McDonnell, Johnson, Polychronis, Risen, Kercher, & Jameson (2006)	Percent of correct responses during testing probes and naturalistic probes	SC	LSB	AT
Miller, Doughty, & Krockover (2015)	Percent of independence when completing inquiry problem-solving steps and guided science inquiry steps	RC	ScP	MP
Miller & Taber-Doughty (2014)	Percent of task analysis steps completed independently	O	ScP	MP
Riesen, McDonnell, Johnson, Polychronis, & Jameson (2003)	Percent correct responses during testing probes	GE/RC	ESS	AT
Riggs, Collins, Kleinert, & Knight (2013)	Percent of correct responses on heredity questions	SC	LSB	MP
Smith, Spooner, Jimenez, & Browder (2013)	Number correct responses on unit assessments	SC	ELS	MP

Note. DV = dependent variable; SC = self-contained classroom; GE = general education classroom; RC = resource classroom; O = others; ELS = elementary-level science; PSC = physical science/chemistry; ESS = earth/space science; LSB = life science/biology; ScP = science procedure; ScV = science vocabulary/descriptor; MP = multiple probe design; AT = alternating treatment design.

Table 2. Participant-Specific Characteristics by Study.

Studies	Gender F	Gender M	Grade(n)	Disability[a](n)	Severity(n)	Comorbid(n)	Ethnicity(n)
			Subject-Specific Characteristics				
Agran et al. (2006)	1	1	M(2)	ID(2)	Sev(2)	N(2)	NS(2)
Collins et al. (2007)	-	1	E(1)	ID(1)	Mod(1)	N(1)	NS(1)
Collins et al. (2011)	1	1	M(2)	ID(2)	Mod(2)	N(2)	NS(2)
Courtade et al. (2010)	4	4	M(8)	ID(8)	Mod(7); Sev(1)	N(8)	Bl(6); Hi(1); Wh(1)
Heinrich et al. (2016)	1	2	H(3)	ID(3)	Mod(3)	N(1); Y(2)	NS(3)
Hudson et al. (2014)	1	2	E(3)	ID(3)	Mod(3)	N(2), Y(1)	NS(3)
Jameson et al. (2007)	-	1	M(1)	ID(1)	Mod(1)	N(1)	Wh(1)
Jameson et al. (2008)	1	-	H(1)	ID(1)	Sev(1)	N(1)	Hi(1)
Jimenez et al. (2009)	2	1	M(3)	ID(3)	Mod(3)	N(3)	NS(3)
Jimenez et al. (2012)	2	3	M(5)	ID(5)	Mod(5)	N(5)	NS(5)
Jimenez et al. (2014)	1	2	E(3)	ID(3)	Mod(3)	Y(3)	Bl(3)
Karl et al. (2013)	1	3	H(4)	ID(4)	Mod(4)	N(3); Y(1)	NS(4)
McDonnell et al. (2006)	-	3	M(2); H(1)	DD(3)	Mil(2); Mod(1)	N(2); Y(1)	NS(3)
Miller et al. (2015)	2	1	H(3)	ID(3)	Mod(3)	Y(3)	Wh(2); Hi(1)
Miller & Taber-Doughty (2014)	2	1	M(3)	ID(3)	Mod(3)	Y(3)	Wh(2); Hi(1)
Riesen et al. (2003)	1	-	M(1)	ID(1)	Mod(1)	Y(1)	NS(1)
Riggs et al. (2013)	2	3	H(5)	ID(5)	Mod(5)	N(5)	NS(5)
Smith et al. (2013)	2	1	E(3)	ID(1); DD(2)	Sev(3)	Y(3)	Wh(2); Bl(1)
TOTALS/AVERAGES	24	30	E(10); M(27); H(17)	ID(49); DD(5)	Sev(7); Mil(2); Mod(45)	Y(18); N(36)	NS(32); Bl(10); Hi(4); Wh(8)

Note. n = number; F = female; M = male; E = elementary; M = middle; H = high school; ID = intellectual disability; DD = developmental disability; Mod = moderate; Sev = severe; Mil = mild; N = no; Y = yes; NS = not specified; Bl = black; Hi = Hispanic; Wh = white.
[a]Intellectual disabilities include students identified with the terms Mental Retardation and Down Syndrome.

participants (44%) and 30 males (56%). Across participants, for grade level, 10 (19%) were in elementary, 27 (50%) were in middle school, and 17 (35%) were in high school. For disability type, 49 of the 54 students (91%) were identified with intellectual disabilities and the remaining 5 students (9%) were identified with developmental disabilities. Based on severity of the disability identified for each student included in this analysis, 7 students (13%) were severe, 2 students were mild (4%), and 45 students (83%) were identified as moderate. Also, 18 students (33%) were identified as having a comorbid disability along with IDD. For race/ethnicity, results indicated that 8 students (15%) were white or Caucasian, 10 students (19%) were black or African-American, and 4 students (7%) were Hispanic. The majority of the students (32 of 54; 59%) were categorized as non-specified.

Effect Size Analysis

Data analysis consisted of evaluating individual studies, participant characteristics and study characteristics using effect size analysis via PND and Tau-U calculations. The results from the analyses are interpreted using suggestions by Scruggs, Mastropieri, Cook, and Escobar (1986) and Rakap (2015).

Study effects. Based on PND analysis, two studies had results that gleaned no observable effects. Six studies resulted in large PND effects. The remaining studies had PND effects of mild to fair effectiveness. Based on Tau-U results, three studies resulted in small effects. Six of the eighteen studies resulted in large effects. The remaining studies showed medium effects. See Table 3 for detailed PND and Tau-U study effect size results.

Study specific characteristic effects. Two of the study specific PND results indicated high effectiveness (Earth science/space science; science procedure). All other study specific characteristics resulted in effects that ranged from mild to fair. Tau-U results indicated that one characteristic (resource room) met the threshold for a small effect. Similar to PND, Earth science/space science had a large Tau-U effect. See Table 5 for detailed PND and Tau-U study specific characteristic effect size results.

Participant-specific characteristic effects. PND results suggest that all of the variables of interest had effect size statistics in the range of mildly to fairly effective. Tau-U results indicated that in the race/ethnicity variable, one of the participant characteristics, Hispanic students showed a large effect size. All other participant characteristics resulted in medium effects. See Table 4 for detailed PND and Tau-U participant specific characteristic effect size results.

Intervention effects. None of the interventions resulted in PND effects lower than mildly effective. One intervention (self-management strategies) had a PND that was considered highly effective (93.12%). Similarly, Tau-U effect sizes indicated that all of the interventions resulted in medium effects. See Table 6 for detailed PND and Tau-U intervention effect size results.

Table 3. Effect Sizes per Single Case Research Study.

Studies	Effect Size Analyses				
	PND	Tau-U	SE_{Tau-U}	CI $[LB]_{95\%}$	CI $[UB]_{95\%}$
Agran, Cavin, Wehmeyer & Palmer (2006)	98.08	0.99	0.16	0.68	1.00
Collins, Evans, Creech-Galloway, Karl, & Miller (2007)	33.81	0.34	0.14	0.06	0.62
Collins, Hager, & Galloway (2011)	30.36	0.57	0.12	0.33	0.82
Courtade, Browder, Spooner, & DiBiase (2010)	96.13	0.86	0.12	0.62	1.00
Heinrich, Knight, Collins, & Sprigg (2016)	77.21	0.78	0.15	0.48	1.08
Hudson, Browder, & Jimenez (2014)	62.50	0.78	0.14	0.50	1.00
Jameson, McDonnell, Johnson, Riesen, & Polychronis (2007)	92.86	0.93	0.30	0.34	1.00
Jameson, McDonnell, Polychronis, & Riesen (2008)	77.27	0.95	0.27	0.41	1.00
Jimenez, Browder, & Courtade (2009)	100.00	0.88	0.11	0.66	1.00
Jimenez, Browder, Spooner, & DiBiase (2012)	87.59	0.94	0.10	0.75	1.00
Jimenez, Lo, & Saunders (2014)	50.11	0.81	0.07	0.66	0.95
Karl, Collins, Hager, & Jones-Ault (2013)	62.50	0.65	0.13	0.41	0.90
McDonnell, Johnson, Polychronis, Riesen, Kercher, & Jameson (2006)	87.61	0.87	0.12	0.65	1.00
Miller, Doughty, & Krockover (2015)	78.33	0.89	0.13	0.65	1.00
Miller & Taber-Doughty (2014)	100.00	1.00	0.24	0.53	1.00
Riesen, McDonnell, Johnson, Polychronis, & Jameson (2003)	93.53	0.94	0.19	0.56	1.00
Riggs, Collins, Kleinert, & Knight (2013)	60.60	0.67	0.08	0.51	0.83
Smith, Spooner, Jimenez, & Browder (2013)	73.36	0.80	0.11	0.59	1.00
Overall Effect Sizes	**75.66**	**0.79**	**0.03**	**0.73**	**0.84**

Note. SE_{Tau-U} = Standard Error of Tau-U; Tau-U indicates combined and weighted effect size statistic; CI = Confidence Interval; LB = Lower Bound; UB = Upper Bound

Discussion

Villanueva, Taylor, Therrien, and Hand (2012) discussed the need for increased research and analysis of effective interventions for students with disabilities. The current study analyzed the efficacy of science-related instruction targeted for students with IDD. The authors examined the study and participant characteristics of published research on science-related outcomes for students with IDD. Further, study data were analyzed and effect sizes calculated into four large grouping variables (per study, study specific characteristics, participant specific characteristics, and intervention characteristics).

Study-Specific Variables

Among the six domains of science content specified (elementary-level science, physical science/chemistry, Earth science/space science, life science/biology, science procedure, science vocabulary), the largest effect size results were in Earth science/space science and science procedures (i.e., performing inquiry steps). It should be noted that there was only one study that examined Earth/space science content (Riesen, McDonnell, Johnson, Polychronis, & Jameson, 2003). As suggested by Andersen and Nash (2016) a number of studies (47%) focused on life science/biology and science procedure. Surprisingly few studies focused on science vocabulary (with moderate effects) given the heavy language demands that can be associated with science (Therrien et al., 2011). This could be due to the needs of students with IDD in that vocabulary specific to science is less important the content related to life skills (i.e., life science) or understanding inquiry processes which have been connected to critical thinking (NRC, 2012). Elementary-level science studies (n=4) had the lowest effect sizes across the six domains gleaned from the included research studies, indicating little to no effect. These findings are consistent with previous research which suggest that elementary teachers are unprepared and fearful of teaching science to students with disabilities (Kahn & Lewis, 2014; Kazempour, 2014).

Of the four settings examined, resource rooms were the least effective locations for interventions. Resource room instruction suggests that pull out science instruction may not be the most success instructional option for students with IDD. In all of the studies that used resource/pull out instructional settings, instruction occurred from either the special education teacher or a teacher aide. Science-related instruction that occurred in self-contained special education settings and general education science classrooms had similar moderate effects for students with IDD. This suggests that stable science instructional settings (i.e., one location for science-related instruction instead of pull-out/resource room instruction) results in better science-related achievement. It should be noted that science-related instruction that occurred in self-contained classrooms was not taught by a certified science educator; however, a breadth of subject areas were covered including a) science procedures (Courtade et al., 2010), b) physical science/chemistry (Jameson et al., 2007), c) life science/biology

Table 4. Effect Sizes per Subject-Specific Characteristics.

Variables	Effect Size Analyses				
	PND	Tau-U	SE_{Tau-U}	CI $[LB]_{95\%}$	CI $[UB]_{95\%}$
Gender					
Female (n=24)	78.53	0.76	0.05	0.67	0.85
Male (n=30)	77.23	0.81	0.04	0.74	0.88
Grade Level					
Elementary (Grades 1 - 5) (n=10)	59.17	0.74	0.05	0.63	0.84
Middle School (Grades 6 - 8) (n=27)	89.79	0.86	0.05	0.77	0.95
High School (Grades 9 - 12) (n=17)	69.75	0.75	0.05	0.64	0.85
Disability Diagnosis					
Intellectual Disability[a] (n=49)	77.33	0.78	0.03	0.72	0.84
Developmental Disability (n=5)	82.54	0.86	0.09	0.69	1.00
Disability Severity					
Mild (n=2)	86.96	0.87	0.14	0.59	1.00
Moderate (n=45)	76.32	0.77	0.03	0.71	0.84
Severe (n=7)	84.79	0.87	0.08	0.71	1.00
Comorbidity					
Yes (n=18)	77.35	0.83	0.05	0.74	0.93
No (n=36)	78.04	0.76	0.04	0.69	0.83
Race/Ethnicity					
African-American/Black (n=10)	79.74	0.80	0.06	0.67	0.92
Caucasian/White (n=8)	86.24	0.88	0.09	0.71	1.00
Hispanic (n=4)	89.32	0.95	0.14	0.67	1.00
Other/Not Specified (n=32)	73.66	0.78	0.03	0.71	0.84

Note. SE_{Tau-U} = Standard Error of Tau-U; Tau-U indicates combined and weighted effect size statistic; CI = Confidence Interval; LB = Lower Bound; UB = Upper Bound.
[a]Intellectual disabilities include students identified with the terms Mental Retardation and Down Syndrome.

(Jameson et al., 2008; McDonnell et al., 2006; Riggs et al., 2013), and elementary science (Jimenez et al., 2014; Smith et al., 2013).

Subject-Specific Variables

Effect sizes for male and female students were relatively even. This suggests that science-related learning happens similarly for boys and girls with IDD across the other variables. Interestingly, no matter the severity, students performed relatively equally across effect size metrics. Since IDD can present across severities (mild, moderate, and severe) as described by Friend and Bursuck (2012), the current analysis suggests that students are learning science-related skills that are appropriate for their educational needs. Comorbidity, the instance of having multiple disability diagnosis, and race/ethnicity also resulted in relatively equal effect sizes which suggest that interventions are equally effective.

Grade level differences were more evident, particularly with PND statistics. Studies conducted in middle school settings were more effective. It should also be noted that more studies took place in middle school grades than in elementary and high school. Results for students at the high school level were similar to those of elementary teachers. Consistent with the findings from Kahn and Lewis (2014), science teachers report feeling uncomfortable teaching students with disabilities and lack formal training in working with students with disabilities. Teachers also reported being least prepared to two work with students with IDD (Kahn & Lewis, 2014). While not specific to secondary teachers, the results from Kahn and Lewis (2014) support that science teachers in general do not feel prepared to teach students with IDD and that most describe their training to work with students with disabilities as “on the job”.

Intervention-Specific Variables

A vast majority of the studies included in this analysis utilized a number of interventions, supports, and strategies in combination to influence science-related learning for students with IDD. These findings support the notion that due to the complex needs of students with IDD, multiple approaches may be necessary during teaching and learning science-related skills. Most of the supports used in the research had moderate effects on the selected outcomes. Three supports indicated lower (explicit instruction) and higher (task analysis and self-management) effects as compared to the other interventions and supports analyzed. There has been a long history of previous research to support the use of explicit/scripted instruction for academic improvement across subject matter (Archer & Hughes, 2011). However, based on the studies included in this analysis, explicit/scripted instruction was the least effective intervention for science-related

Table 5. Effect Sizes per Research Study-Specific Variables.

Variables	Effect Size Analyses				
	PND	Tau-U	SE_{Tau-U}	CI $[LB]_{95\%}$	CI $[UB]_{95\%}$
Settings					
Self-contained classroom (n = 7)	78.14	0.79	0.04	0.71	0.87
General education classroom (n = 10)	79.20	0.80	0.05	0.71	0.89
Resource classroom (n = 4)	60.44	0.65	0.07	0.52	0.79
Other (n = 2)	81.25	0.84	0.12	0.60	1.00
Content					
Elementary-level science (n = 4)	59.17	0.74	0.05	0.64	0.84
Physical science/Chemistry (n = 4)	81.05	0.82	0.06	0.70	0.94
Earth science/Space science (n = 1)	93.53	0.94	0.19	0.56	1.00
Life science/Biology (n = 5)	72.62	0.76	0.05	0.65	0.86
Science procedure (n = 4)	93.76	0.91	0.07	0.77	1.00
Science vocabulary/descriptor (n = 1)	77.21	0.78	0.15	0.48	1.00
Design					
Multiple probes design (n = 14)	71.42	0.80	0.03	0.74	0.86
Alternating treatment design (n = 4)	79.16	0.72	0.08	0.56	0.87

Note. SE_{Tau-U} = Standard Error of Tau-U; Tau-U indicates combined and weighted effect size statistic; CI = Confidence Interval; LB = Lower Bound; UB = Upper Bound.

outcomes. This may be due to students with IDD experiencing difficulty in language and reading. Based on the results from our effect size analyses, providing students with IDD opportunities to use self-management supports and as well as training in task analysis procedures could enhance success with science-related curriculum.

Limitations

There are several limitations in this review including the number of studies found to analyze, the small sample size of participants, type of dependent variables analyzed, and publication bias. Even though the authors searched an 18-year window, they were only able to analyze 18 studies that met study criteria. This restricted the level of possible analysis conducted. Moreover, sample sizes across levels of some grouping variables (e.g., ethnicity) were unbalanced, resulting in some effect sizes that were over- or under- estimated; therefore, this supports the notion that research should broaden their focus to include diverse populations and science content areas. Additionally, most of the dependent measures used were researcher-developed or behavioral, which may cause larger effect sizes; because these measure types are generally more responsive to intervention of any type. Due to our inclusion criteria, we only examined single-case research design.

Unsurprising, as research for this population of students is typically single case research, errors are inherent in analyzing and comparing effect sizes across the variety of types of single-case research design. Caution is advised in interpreting results due to the inherent limitations of the analyses used. A number of researchers have highlighted the limitations of

Table 6. Effect Sizes per Instructional/Intervention-Specific Variables.

Interventions/Strategies	Effect Size Analyses				
	PND	Tau-U	SE_{Tau-U}	CI $[LB]_{95\%}$	CI $[UB]_{95\%}$
Discrete trial/1:1 instruction (n = 6)	74.13	0.79	0.14	0.51	0.94
Explicit instruction (n = 4)	54.95	0.65	0.11	0.43	0.87
Embedded instruction (n = 7)	76.52	0.80	0.18	0.44	0.96
Inquiry-based instruction (n = 4)	90.51	0.92	0.15	0.64	1.00
Peer-related strategies (n = 3)	75.79	0.89	0.17	0.55	1.00
Self-management strategies (n = 4)	94.10	0.94	0.16	0.63	1.00
Task analysis (n = 3)	90.85	0.91	0.14	0.65	1.00
Time delay/Prompting (n = 6)	74.90	0.81	0.15	0.52	0.94
Guided notes (n = 2)	75.06	0.91	0.16	0.60	0.98
Technology-related strategies (n = 2)	75.85	0.85	0.12	0.62	1.00

Note. SE_{Tau-U} = Standard Error of Tau-U; Tau-U indicates combined and weighted effect size statistic; CI = Confidence Interval; LB = Lower Bound; UB = Upper Bound

PND based on what is included (or not included) and how it is calculated. Parker, Hagan-Burke, and Vannest (2007) discuss problems with PND reliability as it a) lacks sampling distribution (i.e., it is calculated with small sample sizes that can highlight just one student) and b) it relies on one data point at baseline for calculation. Further, Alresheed, Hott, and Bano (2013) identified three specific limitations with PND calculations. They do not take into consideration (a baseline outliers, b) baseline data trends, or c) when the treatment has a detrimental effect. Limitations also exist in Tau-U calculations including difficulty in visual graphing and the overall calculation when controlling for baseline trends (Brossart, Laird, & Armstrong, 2018; Tarlow, 2017).

Implications for Practice

Aside from the limitations highlighted by the authors, the current analyses should serve as a guide and a resource for working with students with IDD to promote science-related learning. The combination of statistics reported can be used to select strategies to support students with IDD across contexts. The NGSS Lead States (2013b) provided scenario including two students with intellectual disabilities is realistic but extremely limited in describing the students and other needed contextual information. The current analysis provides information that may be helpful to science and special educators for planning and providing science instruction for students with IDD that are different from those provided in the NGSS case study. Additionally, McGinnis and Kahn (2014) suggested that researchers focus on questions that address how students with disabilities: a) are included in general education science classes, b) are learning across multiple dimensions, and c) are learning science-related skills through various approaches and strategies. The current study attempts to address the suggestions made by McGinnis and Kahn (2014).

For example, a 3rd grade teacher is planning for a lesson on Earth's systems (*NGSS: 3-ESS2-2*) and has a student with moderate IDD in class. Using the information provided in this analysis, the teacher can determine that having the student work with a peer (i.e., peer-related strategies) and using a digital tablet (i.e., technology-related support) to find audio and video that describes 3 different kinds of climates in world (*Practice: Obtaining, Evaluating, and Communicating Information*) as effective. Both peer-related strategies and technology-related supports had moderate effectiveness for students in elementary grades with IDD based on the studies included in this analysis.

As another example, a high school biology teacher is preparing to teach a heredity lesson (*HS-LS3 Heredity: Inheritance and Variation of Traits*) and has one student with mild and two students with moderate IDD in the class along with two paraprofessionals. Using this analysis as a resource guide, the biology teacher may determine to use the strategies described in the study from Riggs et al. (2013) that detail the use of discrete trial instruction (i.e., 1:1 instruction) and time delay techniques (commonly associated with discrete trial instruction) to have students demonstrate their ability to identify inherited traits (*LS3.A: Inheritance of Traits*). The teacher may also consider using supports analyzed in this study such as the use of task analysis and a digital tablet (i.e., technology-related supports) to have students follow detailed steps for creating a Punnett square (diagram to predict breeding outcome).

Across settings, gender, and ethnicity the practices analyzed mostly demonstrated effectiveness. Teachers may optimize science learning opportunities for students with IDD by including the practices and strategies reviewed in this study. Most interventions work in combination to support student learning and many work along with inquiry-based instruction (see Figure 1). Additionally, most if not all of the supports described and analyzed in the current study fit into the use of a UDL framework that emphasizes providing students with multiple means and modes of: a) representation, b) action and expression, and c) engagement. Students with IDD need more chances to learn and practice science-related skills. Unfortunately, science teachers report their unease with teaching students with disabilities and that most feel they only receive "on the job" training to do so (Kahn & Lewis, 2014). The current study serves as an introductory resource guide for science teachers;

	Agran et al. (2006)	Collins et al. (2007)	Collins et al. (2011)	Courtade et al. (2010)	Heinrich et al. (2016)	Hudson et al. (2014)	Jameson et al. (2007)	Jameson et al. (2008)	Jimenez et al. (2009)	Jimenez et al. (2012)	Jimenez et al. (2014)	Karl et al. (2013)	McDonnell et al. (2006)	Miller et al. (2015)	Miller & Taber-Doughty (2014)	Riesen et al. (2003)	Riggs et al. (2013)	Smith et al. (2013)	TOTALS:
DT			X				X		X				X				X	X	6
EX		X									X	X						X	4
EM		X			X		X	X					X			X		X	7
IB				X						X				X	X				4
PR						X		X		X									3
SM	X								X					X	X				4
TA	X			X										X					3
TD			X					X	X				X			X	X		6
TR														X				X	2
GN											X				X				2

Figure 1. Science-related research and intervention matrix for students with IDD. Figure 2. Science-related research and intervention matrix for students with ASD. DT=Discrete Trial Teaching; EX= explicit/scripted instruction; EM= embedded instruction; PR= peer-related strategies; GN= guided notes; IB= inquiry-based instruction; SM= self-management strategies; TA= task analysis; TD= time delay/prompting; TR= technology-related strategies.

particularly for those working with students with IDD. The nature of IDD is complex and no one solution or strategy or support technique is viable for all students with IDD. As an initial guide, the results presented in the current study may serve as a means to open dialogue with special education colleagues in the use of the strategies discussed or as way of broadening opportunities for science-related learning by focusing on the strengths of students with IDD (Kahn, 2018). Ultimately, by increasing access to science-related learning opportunities for students with IDD, we get closer to actual "science for all."

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