Instructional Practices for Science, Technology, Engineering, and Mathematics (STEM) Lessons for K–12 Students With Disabilities: Perceptions of Teachers From a Virginia Suburban School Division

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Abstract

This study identified key instructional practices for science, technology, engineering, and mathematics (STEM) lessons for students with disabilities (SWD) based on the perceptions of teachers. Barriers to STEM lessons for SWD were identified, as well as the professional development desired by teachers. SWD can benefit from participation in STEM lessons. STEM is an acronym that is often defined as an interdisciplinary approach to learning by incorporating at least two of the disciplines with real-world applications through problem-solving projects. STEM lessons can offer opportunities for K–12 students to engage in 21st-century skills and the 5 C's (citizenship, collaboration, communication, creativity, and critical thinking), which are skills that are desired for college and career readiness and for competition in a global economy. This basic qualitative study consisted of 13 interviews (5 elementary, 4 middle, and 4 high school) with teachers from 12 schools. Results were analyzed using deductive coding to identify instructional practices, barriers, and recommended professional development. Findings suggest that knowledge of the SWD, building relationships, use of support staff and others, intentional grouping, assigned group roles, hands-on learning, and classroom modifications helped SWD gain access to STEM lessons. In addition, student ability level, lack of adult support, and time limitations were identified as barriers for SWD's participation in STEM lessons. Finally, teachers believe that professional development is needed in teacher collaboration and student disability knowledge. Teachers want the opportunity to work together during STEM lesson

development and also during implementation of STEM lessons. Teachers also want to learn more about specific strategies for each disability category. The information gained should support teachers and school leaders with inclusivity of SWD in STEM lessons.

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General Audience Abstract

Implementation of key instructional practices for STEM lessons can improve inclusivity for SWD. Knowledge of barriers and desired professional development can also increase inclusiveness. STEM is an acronym that is often defined as an interdisciplinary approach to learning that incorporates at least two of the disciplines with real-world applications through problem-solving projects. STEM lessons can offer opportunities for K–12 students to engage in 21st-century skills and the 5 C's (citizenship, collaboration, communication, creativity, and critical thinking), which are skills that are desired for college and career readiness and for competition in a global economy. Through a basic qualitative study involving 13 teachers (5 elementary, 4 middle, and 4 high school) from 12 schools, information about SWD's participation in STEM lessons was gained. Findings suggest that knowledge of the SWD, building relationships, use of support staff and others, intentional grouping, assigned group roles, hands-on learning, and classroom modifications helped SWD gain access to STEM lessons. In addition, student ability level, lack of adult support, and time limitations were identified as barriers for SWD's participation in STEM lessons. Finally, the results revealed that teachers believe that more professional development is needed in teacher collaboration and student disability knowledge. Teachers want the opportunity to work together during STEM lesson development and also during implementation of STEM lessons. Teachers also want to learn more about specific strategies for each disability category.

DEDICATION

I dedicate this work to my three children, Joshua Kenneth, Charity Diane, and Contessa Marie. The three of you are the best decisions I have ever made in life. Your sense of adventure, kind souls, and passion inspire me to be a better person. Keep thinking, keep creating, keep helping others, and keep going after the experiences that bring you joy. By doing these things, you will make a difference in this world. Thank you for encouraging me to pursue this final degree. I will always love you with my whole heart.

I also dedicate this work to my younger and only sister, Karen Marie Carter. I miss you more than I ever thought I could.

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Overview

The purpose of this study was to identify key instructional practices teachers use for science, technology, engineering, and mathematics (STEM) lessons for students with disabilities (SWD). Furthermore, the study identified barriers for SWD and what kind of professional development is needed to help teachers provide inclusive STEM lessons for SWD. Teacher perceptions are of great value because their content knowledge and pedagogical practices are the two most important factors that contribute to STEM learning (Nite, Capraro, Capraro, Peterson, & Bicer, 2017). Educational leaders, such as school principals and central office staff, need to know what helps SWD gain access to STEM lessons and what barriers they may experience. In their leadership roles, they often select topics for professional development (PD) and continuing education that will impact the classroom. Additionally, teachers, leaders, and administrators can benefit from knowing what types of PD are needed for inclusion of SWD in STEM lessons. As a student in the Educational Leadership and Policy Studies program through Virginia Tech, the principal of an elementary school in a division that promotes STEM lessons, and a leader with a passion for SWD, it is my desire to add to the limited literature on inclusivity of SWD in STEM lessons.

Statement of the Problem

There are numerous research studies about instructional practices used for inclusion of SWD in the general education classroom (Basham, Israel, & Maynard, 2010; Basham & Marino, 2013; CAST, 2018; Israel, Wherfel, Pearson, Shehab, & Tapia, 2015; McGrath & Hughes, 2018; Robnett, 2013; Watt, Therrien, Kaldenbert, & Taylor, 2013). The Council for Exceptional Children approved 22 high-leverage practices for use with K–12 students with disabilities

(McLeskey, Maheady, Billingsley, Brownell, & Lewis, 2019). However, research on the inclusion of SWD in STEM lessons and practical instructional strategies based on teacher perceptions is limited; where research does exist, not all disciplines of STEM are included (Brown, Ernst, Clark, DeLuca, & Kelly, 2017; Fisher, 2019; Israel, Maynard, & Williamson, 2013; Kennerly & Wexler, 2013; Moorehead & Grillo, 2013). Another issue with most of the existing research is the failure to include all grade levels (elementary, middle, and high school).

The need for STEM education for SWD is two-fold. First, SWD are “significantly more likely to enroll in STEM majors,” and low-income SWD are more likely to select STEM majors, possibly to increase their chances of securing employment (Lee, 2011, p. 76). Although SWD are enrolling in STEM majors, they are less likely to have a career in STEM (Fisher, 2019). Second, the majority of SWD spend approximately 80% of their day in the general education classroom (NCES, 2019), so they need to have access to STEM lessons alongside their non-disabled peers. More research is needed on inclusive practices in STEM lessons for SWD in order to improve future career opportunities.

Significance of the Study

Expectations that SWD will be included in the general education classroom, and will be a part of the global workforce, give cause to study how teachers can help SWD gain access to STEM lessons. At the national level, the Every Student Succeeds Act, passed on March 23, 2018, provides funding for STEM education, including funds for SWD (Fisher, 2019). The Student Support and Academic Achievement Enrichment Grant “provides a provision for districts to use funds to increase access and engagement in STEM for underrepresented students” (Fisher, 2019, pp. 28–29). SWD qualify as an underrepresented group (Sukhai & Mohler, 2016).

At the state level, the Virginia Department of Education (VDOE) has charged its school divisions with preparing students to be life ready (VDOE, 2020). Divisions are encouraged to develop a profile of a Virginia graduate with an emphasis on the 5 C’s (citizenship, creativity, critical thinking, collaboration, communication). STEM lessons often include opportunities to practice the 5 C’s.

At the local level, the school division in which the study took place implemented expectations based on their strategic plan directing the need for instructional practices to include components of deeper learning, including the 5 C’s. In addition to this, teachers at the elementary level are required to teach 10 STEM lessons per year. The researcher conducted a separate study on STEM lessons through the Researcher Development Program (RDP), which was sponsored by the University Council for Educational Administration. Under the guidance of primary investigator Dr. Marlene Zakierski of Sage Colleges, 124 elementary school STEM lessons from 53 grade 5 classrooms and 14 schools were studied. The purpose of the previous study was to examine STEM lessons for components of deeper learning, 21st-century skills that overlap with the 5 C’s, and the targeted disciplines (mathematics, science, English). The results were presented during the autumn 2019 RDP poster presentations. Results were also shared with the school division elementary principals and key central office staff members (see Appendix A). The STEM lessons, which included participation of SWD, offered learning opportunities for the 5 C’s and deeper learning (see Chapter 2). Information significant to the current study indicated that STEM lessons incorporated critical thinking (90%), collaboration (50%), creativity (90%), communication (54%), and problem solving (91%). STEM lessons can provide learning opportunities for SWD to participate in local and state initiatives for the 5 C’s and Virginia’s profile of a graduate (VDOE, 2019b).

This study provides practical suggestions to help SWD gain access to STEM lessons while removing some of the barriers. Other schools may use this study to compare their ability to include SWD in STEM lessons. Administrators may be able to gain ideas about how to be more inclusive of SWD in STEM lessons. Potential needs for professional development were identified to increase access or reduce barriers to STEM lessons.

Purpose and Justification of the Study

The purpose of this study was to identify key instructional practices teachers use for STEM lessons for SWD. Furthermore, the study identified barriers that exist for SWD and the professional development needed to help teachers provide inclusive STEM lessons for SWD. The study adds to the limited available literature on specific inclusive practices for STEM participation among SWD. As stated in the study overview, teacher perceptions are of great value because teachers' content knowledge and pedagogical practices are the two most important factors that contribute to STEM learning (Nite et al., 2017). After interviews were conducted, the researcher analyzed interview transcripts to identify key strategies that help SWD participate in STEM lessons and barriers that prohibit or hinder participation in STEM lessons. As teachers are the people working directly with the students on STEM lessons, their data is considered the most salient. It is the researcher's desire to use this striking data to help SWD participate in STEM lessons by informing teachers, leaders, and key central office staff members how they can facilitate this.

Research Questions

The primary question guiding this study was, What are teacher perceptions of instructional practices for students with disabilities (SWD) for science, technology, engineering, and mathematics (STEM) lessons within a Virginia suburban school division? Secondary questions were:

1. What do teachers think helps SWD gain access to STEM lessons?
2. What do teachers think are barriers for SWD participating in STEM lessons?
3. What kind of professional development is needed to improve inclusivity of SWD in STEM lessons?

Pedagogical Framework

Pedagogical frameworks from journal articles were examined to determine what is most meaningful for teachers of STEM lessons and most applicable for SWD. For example, Wells's (2016) framework called PIRPOSAL conceptualizes hands-on learning while simultaneously gaining learning in the mind. The acronym, PIRPOSAL, outlines the process students may go through during the stages of a STEM lesson/project: P = problem identification, I = ideation, R = research, P = potential solutions, O = optimization, S = solution evaluation, A = alterations, and L = learned outcomes. While using engineering and technology, the *E* and *T* in the STEM acronym, students can learn science and mathematics skills, which can be helpful for SWD. Teachers could use this as a graphic organizer to help guide SWD through each step to help them stay on task during a STEM lesson (Fisher, 2019). SWD often lack executive functioning skills (Marino, 2010), so a step-by-step procedure could help them to follow the process for investigating and solving a problem.

Definition of Terms

Access: "All students, including those with disabilities and other diverse learning needs, [are] included in meaningful STEM education and develop expertise in STEM areas as well as 21st-century skills associated with STEM learning" (Basham et al., 2010, p. 9).

Barrier: Lack of or limited access to STEM lessons. Barriers may include lack of access to support, role models, and appropriate accommodations. Barriers can also include lack of self-advocacy and access to assistive technology (Sukhai & Mohler, 2016).

Disability: A student with a disability must be found eligible for at least one of the 13 categories in the Individuals with Disabilities Educational Act (IDEA): autism, deaf-blindness, deafness, emotional disturbance, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech or language impairment, traumatic brain injury, and visual impairment including blindness. The student must also require special education and related services to benefit from public education (Dragoo, Cole, & Library of Congress, 2019).

Science, technology, engineering, and mathematics (STEM): "An interdisciplinary (or transdisciplinary) approach that integrates knowledge from diverse academic disciplines into authentic problem- or project-based learning experiences as related to instruction in STEM content areas. Each of these is embedded within the scientific method and engineering design processes, as well as 21st-century skills" (Basham et al., 2010, p. 11).

Limitations and Delimitations

The major limitation of this study is that the data are from one suburban school division in Virginia. Urban and rural school divisions were not included in the study. Different divisions within the Commonwealth of Virginia, as well as other states, may not have the same STEM initiatives and requirements. As a former special education teacher, the researcher may have preconceived notions as to what is most helpful for SWD in the classroom. As a principal, the researcher is aware that some teachers are not always cognizant of requirements for implementing Individualized Education Plans (IEPs) for SWD in the general education setting, especially for transient students and for teachers who serve a large number of SWD. To monitor bias, the researcher avoided inserting opinions and only collected data on participant responses. In addition to this, the researcher maintained a focus on information derived from the literature. To help obtain honest opinions and viewpoints from participants, no teachers from the researcher's school participated in the study.

Delimitations were chosen by the researcher. Only general education or special education teachers from a public school district were interviewed. The results of this study addressed the gap in qualitative research on instructional practices in STEM for SWD.

Summary

This chapter provided an introduction to the focus of the study. The following points were discussed: overview of the study, statement of the problem, significance and purpose of the study, research questions, pedagogical framework, definitions of key terms, limitations, and delimitations of the study. Chapter 2 provides a broad literature review of STEM education. Included in the review are concepts of deeper learning, policy, and governance related to STEM education, workforce needs, and specific student populations participating in STEM lessons. The literature review is not exhaustive.

Chapter 2: Review of the Literature

This literature review focused on STEM education and how learning may be achieved through the use of this interdisciplinary approach. The origin of STEM was traced, as well as how it has been driven to the forefront of the American education system through policy, governance, and economic initiatives. Literature was reviewed for STEM inclusion among SWD and underrepresented females. These two subgroups were chosen because of the high percentage of SWD attending the general education program in K–12 public schools and the low number of females choosing STEM careers. Literature on student engagement was examined for indicators and links to STEM and deeper learning.

STEM has become a well-known acronym in the United States educational system as well as in other countries (Bybee, 2013). Some educators have included the arts and modified the acronym to STEAM, for science, technology, engineering, the arts, and mathematics. STEM lessons involve integrating the four individual disciplines into a single design or project, often with real-life applications (Brannen-Sarrategui, 2015; Carmichael, 2017; Lesseig, Slavit, & Nelson, 2017; Nadleson, Pfiester, Callahan, & Pyke, 2015; Stith, 2017; Zollman, 2012). For example, students may work on a design challenge as simple as building a marshmallow tower or as complicated as building a prosthetic limb (Lesseig et al., 2017). Another example of this interdisciplinary approach is a STEM lesson that challenges students to use an incline plane to design and build a maze that will keep a marble in motion at the slowest possible speed (Lesseig et al., 2017). STEM lessons combine skills and content for mathematics, science, and engineering. Technology could also be integrated depending on the objective.

The acronym for STEM was introduced in the 1990s and has emerged to represent a common instructional approach that combines two or more of each discipline in the acronym

(Bybee, 2010). Judith Ramaley, former president of Winona State University and former director of the National Science Foundation's Education and Human Resources, is frequently associated with becoming the first person to put the words science, mathematics, engineering, and technology (SMET) together as an expression, and this later came to be known by the acronym STEM (Loewus, 2015; Zollman, 2012).

This chapter is organized around STEM definitions, levels of learning, and 21st-century skills. The rational for selecting the STEM topic is followed by search criteria methods, policy and governance effects on STEM education in K–12 schools, and workforce needs that determine STEM curriculum initiatives. Finally, information about STEM engagement, STEM and SWD, females in STEM, and STEM mentorship complete the chapter.

STEM Definitions and Concepts in Education

STEM can be defined in different ways depending on the relevance to the person and field. Gerlach (2012) stated that "everyone knows what it means within their field" and that "they all have one thing in common: It is about moving forward, solving problems, learning, and pushing innovation to the next level" (p. 3). The genesis of a widely used definition of STEM comes from the Pennsylvania STEM Network, Southwest Region, where multiple researchers used information from a study conducted by Carnegie Mellon University and the Intermediate Unit 1 to frame the region's STEM needs (Pennsylvania STEM Network, n.d.). The STEM definition is often misquoted and incorrectly referenced in STEM research; however, the credited author was emailed to obtain the correct source of the definition. This definition of STEM is documented as follows:

> An interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and

> mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Hallinen, n.d., p. 6)

The definition above is most often credited to Tspuros, Kohler, and Hallinen (2009). Researchers' viewpoints differ in regard to what should be accentuated in STEM education. Balka (2011) emphasizes the need to integrate STEM concepts and solve problems, whereas Zollman (2012) stresses the importance of using STEM literacy to "satisfy our societal, economic, and personal needs" (p. 1). STEM and deeper learning share similar elements of 21st-century skills, such as collaboration, communication, critical thinking, and creativity (Brannen-Sarrategui, 2015).

Simple Learning Concept

In order to gain a clear understanding of deeper learning, one must have knowledge of what comes before this level. *Simple learning* is defined by Jensen and Nickelsen (2008) as "one-time learning, knowledge, or responses that can be learned by a naïve learner; requires no feedback or error correction; can be learned in one interaction; and has little or no ambiguity" (p. 8). Examples of simple learning include memorizing multiplication tables, vocabulary words, phone numbers, and simple directions (Brannen-Sarrategui, 2015; Jensen & Nickelsen, 2008). This basic recall does not require higher-level thinking and would be considered on the lower end of Bloom's Taxonomy. Once simple learning of a concept has been mastered, the learner can delve deeper into the topic.

Deeper Learning Concept

Jensen and Nickelsen (2008) defined *deeper learning* as the "acquisition of new content or skills that must be learned in more than one step and with multiple levels of analysis or processing so that students may apply the content/skills in ways that change thinking or influence behaviors" (p. 10). Some examples of deeper learning include negotiating, building, and solving problems (Deeper Learning Hub, 2019; Jensen & Nickelsen, 2008). The Learning Policy Institute (2019) further suggested that "curriculum, instruction, and assessment focused on deeper learning seek to support students' development of skills—such as collaboration, communication, creative problem solving—required by life in the 21st century" (p. 1). Using contemporary pedagogy practices to observe 21st-century skills in action is another way to gain knowledge about deeper learning. For students in schools where deeper learning is not part of the culture, technology can be used to reduce the gap. Jaquith and Zielezinski (2018) suggested the need for shared examples of deeper learning that are "accessible, digestible (e.g., in the form of digital learning communities, blog posts, or short informational videos), and instructive" (p. 3). Rodriguez, Bellanca, and Esparza (2017) stated that:

> Deeper learning is best advanced by explicit attention in instructional design to rich and rigorous content outcomes enhanced by each student's significant development and transfer of the age-old and long-battered skills of collaboration, communication, critical and creative thinking, problem solving, and self-directed learning. (p. 4)

The connection between deeper learning and 21st-century skills is evident. Society has a need for instructional practices that develop lifelong learning skills (Jensen & Nickelsen, 2008). Rodriguez et al. (2017) stated, "When comparing characteristics (culturally responsive teaching) with the high-expectation practices and the current need for 21st-century skills leading to deeper learning, it appears clear there are more similarities than differences" (p. 35).

The *deeper learning competencies* have proven to be effective in high schools. Warkentien, Charles, Knapp, and Silver (2017) evaluated the effects of the Hewlett Foundation's first 5 years of a deeper learning initiative to improve learning in the U.S. public education system. The research data came from a multi-year comparison between 20 “deeper learning network (DLN)” high schools and 12 high schools not in the DLN (Warkentien et al., 2017, p. 10). The results indicated that students in a DLN had increased opportunities to develop the six competencies of deeper learning, an overall increase in academic achievement, and higher college enrollment. Students in DLN high schools had more opportunities for project-based learning and collaboration with other students.

Competencies. Funded by the Hewlett Foundation, the Deeper Learning Hub (2019) proposes six competencies for deeper learning:

- Content mastery: Students apply knowledge to real-world situations.
- Effective communication: Students demonstrate skills in active listening, clear writing, and persuasive presentation.
- Collaboration: Students work with their peers, assume leadership roles, resolve conflicts, and manage projects.
- Critical thinking and problem solving: Students consider a variety of approaches to produce innovative solutions.
- Self-directed learning: Students use teacher feedback to monitor and direct their own learning, both in and out of the classroom.
- Academic mindset: Students feel a sense of belonging and motivation to persist through their school work. (p. 1)

STEM lessons can offer opportunities for deeper learning with the overlap of 21st-century skills and the 5 C’s.

Rationale for STEM Topic

One of the reasons the researcher became interested in STEM education is because of the K–12 requirements for students to be college or career ready to compete in the global workforce. Graduates are expected to have 21st-century skills including the 5 C's, which are skills that can be gained through STEM lessons. Virginia's Profile of a Graduate also recognizes the importance of workplace skills, building connections with others, and aligning personal interests with career considerations. SWD, and specifically females, must join the global workforce but remain underrepresented in STEM fields (Lee, 2011).

As the principal of an elementary school, the researcher observed high student engagement during STEM projects. In addition, SWD and females seemed to thrive in this environment. The remarkable changes observed with STEM learning validated the interest in this interdisciplinary approach to gaining 21st-century skills through deeper learning for all students. As personal experiences have resulted in a positive bias toward STEM education, multiple sources were reviewed before any conclusions were drawn.

Search Criteria for Literature Review

The preliminary search for *STEM education* focused on the origin and definition of the term and its importance in K–12 education. Google was used to search for articles, videos, and images relating to STEM education, starting in October 2017. The following search terms were identified and used: *history of STEM*, *importance of STEM education, origin of STEM*, *STEM initiatives*, and *STEM legislature*. The articles located led to information on legislation and initiatives available online. Examples include former President Obama's Educate to Innovate campaign, STEM Coalition, Every Student Succeeds Act, STEM organizations, and the United States Department of Commerce.

The research also included foundational books on STEM that were borrowed from the Virginia Tech library or purchased online. After gaining foundational knowledge in the area of STEM education, more research was found at Virginia Tech's online library using additional search terms. The EBSCOhost database was used to locate articles relating to these key words: *history of STEM education*, *STEM education*, *STEM education and engagement, STEM education and students with disabilities*, *STEM education in K–12*, *STEM governance*, *STEM legislature, STEM mentoring*, *STEM policy*, and *STEM with project-based learning*. The original search in EBSCOhost for *STEM education* yielded 30,005 results. *STEM education and students with disabilities* yielded 269 results. The search yields for the following search terms are provided in parentheses: *STEM education and engagement* (1,710), *STEM education and females* (1,231), *STEM education and governance* (89), *STEM education and legislature* (46), *STEM education and policy* (3,124), *STEM education and project-based learning* (458), and *STEM education in K–12* (1,853).

The search was narrowed down by selecting full text and scholarly (peer-reviewed) articles, with priority placed on those published between 2008 and 2018. The narrowed search for *STEM education* and *students with disabilities* decreased from 269 to 105 after duplicates were removed. The 105 journal articles came from the following databases: ERIC, MasterFile Premier Education Research Complete, Library Information Science and Technology Abstracts, CINAHL with Full Text, Associates Programs Source, Business Source Complete, Academic Search Complete, and Teacher Reference Center. For dissertations, ProQuest was used with a priority on publications from 2013 to 2020. Using the search term *STEM education* yielded 63,455 results. Addition of specific qualifiers (full text within the past 5 years for the search terms in the abstract) to the search terms *STEM education and policy* and *STEM education and* *governance* reduced the results to 154 dissertations. After reading through five dissertations, the reference lists were used to search for specific articles, along with other works cited by scholarly journal articles.

The literature review of deeper learning started with defining the term itself. New search terms *deeper learning* and *definition of* identified 117 results using EBSCOhost. Definitions of *deeper learning* were searched for using Google and Google Scholar. Foundational books on deeper learning were found using ProQuest Ebook Central on the Virginia Tech Library website, which yielded 300 results. Books were also searched for using Amazon and Google. For the term *STEM mentoring*, ProQuest dissertations yielded 42 results published within the past 5 years, and six scholarly articles published within the past 5 were found. When terms were separated, findings increased on EBSCOhost. For *STEM* + *mentoring*, with the qualifiers of peer-reviewed articles within the past 5 years, 727 hits were found. With the same qualifiers, *STEM* + *mentoring* + *21st-century skills* yielded 1,234 hits, and *STEM* + *mentoring relationship*s yielded 317 hits. The National Science Foundation was reviewed for current STEM statistics along with other current websites related to STEM mentoring and deeper learning.

Initially, exclusion criteria included articles older than 5 years and books older than 12 years. However, the search was extended to include relevant historical information. Sources that did not contain relevant information for K–12 students were excluded. Articles on college students were excluded unless the article related to preparing K–12 students for higher education, mentoring, or a teacher's effect on curriculum. Articles were excluded when the primary focus was preschool students. Articles and books with a parent focus were also excluded. Articles discussing STEAM were excluded from the literature review because the research, state policies, and funding all center around STEM. In addition, careers in the arts have not been identified as an area of urgent need for the American economy.

Policy and Governance Driving STEM Education

Policy can determine what is taught in the K–12 classroom and what is measured for school accountability (VDOE, 2018c). Judson (2012) compared state testing results for the 2009 National Assessment for Educational Progress, concluding that adding science as an accountability measure did not have a negative impact on grade four and grade eight reading and mathematics scores. In addition, fourth-grade students scored higher in states that added science as an accountability factor. All states test mathematics and science, two of the four components of STEM, but only a few use science for accountability purposes (Judson, 2012).

Carmichael (2017) reviewed STEM definitions and published materials related to STEM education for each state in the United States. Results show that 58% of states have published STEM materials on their website, and 82% have a STEM definition in policy materials. Approximately 42% of the states have written bills, executive orders, or statutes.

Regulation of STEM education depends on state and local policies, initiatives, and goals (Bybee, 2013). Virginia currently has 22 STEM academies across the state. The Virginia Department of Education (VDOE, 2018c) website lists the following requirements for approved STEM academies: job shadowing, service learning, mentorships, internships, projects, or a combination thereof. The website notes a change in focus from preparing students for a STEM-specific workforce to "STEM-literate citizens necessary for success in any 21st-century profession" (VDOE, 2018c). Local regulations and opportunities can also differ among school districts (Carmichael, 2017). One district in southwest Virginia ensures students in elementary school complete 10 STEM projects per school year. The same district also offers a Governor's

STEM Academy through their Career and Technical Center (RCPS, 2019), which includes a focus on 21st-century skills needed for the changing workforce. A district in northern Virginia offers STEM clubs, competitions, labs, and a Global Challenges Program (FCPS, 2019), whereas another district sponsors a STEM Challenge through the combined districts' Governor's School (RCS, 2019).

Virginia is one of nine states that has not adopted the Common Core State Standards Initiative. Instead, Virginia developed its own standards known as Standards of Learning (SOL). Currently students in grades 3–12 take two to four SOL standardized tests per year, including nine mathematics tests and six science tests (VDOE, 2020). The tests satisfy the requirements of the No Child Left Behind Act of 2001 and the revised Every Student Succeeds Act of 2015. SOL tests are considered high stakes because the school's accreditation status is based on established pass rates. In addition to accreditation, graduation from high school requires students to pass specified end-of-course SOL tests. With such high stakes, curriculum must be connected to the standards, which is also true for STEM lessons. An example of a grade five science SOL is 5.3, in which the student will investigate and understand how sound is created, transmitted, and used (VDOE, 2018d). Vocabulary for this SOL includes *compression waves*, *vibration*, *compression*, *wavelength*, *frequency*, and *amplitude* (VDOE, 2018d). A STEM lesson would need to include specifics about this SOL to satisfy required curriculum instruction for this area.

Projected Job Market

STEM education is also regulated by the job market (Bybee, 2013). Based on the U.S. Department of Commerce (2017a), STEM jobs have grown at three times the rate of non-STEM jobs over the past 10 years. According to the same source, STEM jobs will grow by 17%, compared with 9.8% growth for other occupations, and there will be 1.9 STEM jobs for every person compared with 3.6 people for one job in another field. In addition to the increased demand for STEM jobs, pay is predicted to be 26% higher than non-STEM positions (U.S. Department of Commerce, 2017a). Jones (2014) reported STEM wages to be nearly twice the U.S. average compared with other occupations. Based on reports from the STEM Coalition (2018), there are 26 million STEM jobs in the United States, which comprises 20% of all U.S. jobs. Given these statistics and driving forces in STEM education, equity of instructional practices is worthy of examination. Tienken (2017) proposed that "one could conjecture that skills and dispositions that are difficult to offshore—creativity, innovation, and entrepreneurship—will retain value in 2035 and beyond" (p. 46).

When combined into a STEM lesson, the individual disciplines of science, technology, engineering, and mathematics can be easily worked into a project that encourages creativity, innovation, and entrepreneurship. In 2009, with $700 million in public–private partnerships, President Obama launched Educate to Innovate. The goal was to get "all hands on deck" for STEM (Educate to Innovate, 2010). While the federal money for STEM appears to be a large amount, it is small compared with the overall funding of education. Bybee (2013) found that "the federal investment in STEM education (i.e., $3.4 billion) is less than 1% of the $1.1 trillion spent on education annually in the United States" (p. 68).

Workforce and K–12 Education

Due to the changing workforce, STEM education has become a focus in K–12 education (Brannen-Sarrategui, 2015; Bybee, 2013; Education to Innovate, 2010; Stith, 2017; Zollman, 2012). The federal STEM budget earmarks 28% of the money for workforce needs (Bybee, 2013). Rigorous standards for English and mathematics, adopted in 2009 and 2010, were put into place by the Virginia Department of Education to meet higher demands for workplace readiness and college entry (VDOE, 2020). All students need baseline skills for the changing workforce, including students with disabilities mainstreamed into regular education classrooms (Basham et al., 2010; Zollman, 2012). Deep engagement may occur when students view an activity as important to their life (Marzano, 2013). Going from a teacher-centered approach to a student-centered approach gives students choice and ownership of their learning (Brown et al., 2017). STEM lessons can provide opportunities for engagement and student creativity. America is recognized as a society that produces innovators and is “ranked first in the world on the sub-metric of innovation quality” (Tienken, 2017, p. 66). The public school curriculum and schedule should allow time for students to engage with STEM lessons to compete in a world economy. In *Education Week*, Chesloff (2013) stated,

> Investing to ensure a pipeline of workers skilled in STEM competencies is a workforce issue, an economic-development issue, and a business imperative. And the best way to ensure return on these investments is to start fostering these skills in young children. (p. 1)

STEM has been linked to economic growth (Lee, Chai, & Hong, 2019). Brannen-Sarrategui (2015) made connections between the Costa Rican economy and the workforce resulting from a national decree. The results indicated that a relationship exists between the primary school curriculum and the passing of the 2004 National Decree #31900, which mandated student participation in science fairs. Although there was not a nationally aligned science curriculum resulting from the decree, participation in the science fairs resulted in an increase in student motivation to engage in project-based learning and 21st-century skills required for the workforce (Brannen-Sarrategui, 2015). Young children have the foundation blocks for STEM; they are naturally curious and ask a lot of *why* questions. They like to build things and are willing to take risks. Couros (2015) stated, "Kids walk into schools full of wonder and questions, yet we often ask them to hold their questions for later, so we can *get through* the curriculum" (p. 4). This natural curiosity is beneficial for STEM, as STEM lessons often involve creating solutions to problems. Couros (2015) added that when students leave schools less curious, we have failed them. Students are taught compliance rather than being taught to think for themselves.

STEM Education and Student Engagement

Determining if students are engaged can be somewhat subjective. *The Glossary of Education Reform* (Hidden Curriculum, 2014) defined engagement as "the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education." STEM may lead to higher engagement. Students need to be actively engaged in order to achieve (Fredericks, Blumenfield, & Paris, 2004)—engagement is explicitly linked to student achievement (Parsons, Nuland, & Parsons, 2014). Skinner and Pitzer (2012) stated that a student's engagement is "a robust predictor of student learning, grades, achievement, test scores, retention, and graduation" (p. 21). With this much contingency on engagement, educators need to examine the curriculum format so it will keep students highly engaged. Teachers have influence over the level of engagement in the classroom (Marzano, 2013). Marzano (2013) recommended that teachers ask themselves four key questions to check for engagement:

- Do I provide a safe, caring, and energetic environment?
- Do I make things interesting?
- Do I demonstrate why the content is important?
- Do I help students realize that personal effort is the key to success? (pp. 81–82).

STEM lessons relate closely to these questions, as many involve working together in small groups on projects that are interesting to the students. For increased engagement, learning needs to be authentic, collaborative, and challenging and should involve some level of student choice (Parsons et al., 2014).

Research results from a study of fourth-grade students show young learners have potential for early engineering (English & King, 2015). With balanced scaffolding by the teacher, groups were able to engage in a design and redesign process for an aerospace project. Students combined science, mathematics, and engineering skills to make a 3-D model plane. One study conducted at a summer STEM institute used video recordings of students and then rated the level of student engagement by how much they participated in the design process (Nadelson et al, 2015). Over the course of 3 years of professional development, the Level of Design Rubric was used with 142 K–5 elementary school teachers. After the summer training, classroom observations were conducted using the rubric. An engagement rubric can be used by teachers without using the video recording. Engagement components are often included on rubrics used to measure the success of a STEM lesson. Examples include evidence of problem solving, collaboration with peers, presentation of results, accuracy of design, communication, and making contributions to the group (Capraro, Whitfield, & Etchells, 2016).

STEM and Problem-Based Learning

STEM and problem-based learning have some similar characteristics. Evans, Lopez, Maddow, Drape, and Duke (2014) defined problem-based learning as “the integration of the engineering design process into theories of learning and topics in STEM subjects” (p. 626). Similar tasks could be completed that would also be considered a STEM lesson. In contrast, problem-based learning may contain fewer components of STEM. Evans et al. (2014) considered the motivation of middle school students in an out-of-school design studio. Problems to be solved were chosen from engineering teaching kits. For example, a Save the Seabirds kit challenged students to create a solar-powered vehicle to carry plastic seabird eggs. Concepts such a non-renewal and renewable resources were incorporated, along with a set of challenges and scientific principles (Evans et al., 2014). Emphasis was on solving a problem. Two out of fifteen middle school students were chosen for a case study for the Seabirds kit. Results indicated that “problem solving, new media, and peer interaction as designed features of Studio STEM elicited evidence of stimulating interest in STEM for deeper learning” (Evans et al., 2014, p. 638).

Students Identified as Gifted

SWD may also be identified as gifted and are referred to as *twice exceptional*, or 2E. There are 166,632 gifted students in Virginia (VDOE, 2018e). Virginia’s policy, 8 VAC 20–40–60, requires local public school districts to “approve a comprehensive Local Plan for the Education of the Gifted that includes the components identified in the regulations” (VDOE, 2018a). Gifted regulations include the generation of products, problem solving, and problem finding, which are also skills often applied in STEM lessons (Balka, 2011; VDOE, 2018a). Virginia offers an opportunity for gifted students to attend Governor’s School. Evaluations for five STEM-focused governor’s schools in Virginia were evaluated, and it was determined that they were meeting or exceeding expectations related to STEM standards (Stith, 2017). Olszewski-Kubilius (2010) contended that rural and low-income areas do not have sufficient access to STEM schools for the gifted. Benefits of identified gifted students attending STEM schools include collaborating with “true intellectual peers,” better benchmarking with true peers for science and mathematics ability, and an increased chance of attending a top university for mathematics or science (Olszewski-Kubilius, 2010, p. 62). Olszewski-Kubilius (2010) urges policy makers to "ensure that all students, especially those whose families have limited financial and informational resources, have access and support to participate in special schools and programs" (p. 69).

STEM and SWD

SWD may learn in different ways and make different contributions when working together on a STEM lesson. SWD often lack exposure to the sciences, starting in elementary school, which eventually contributes to an underrepresentation of SWD in STEM fields (Sukhai & Mohler, 2016). The National Center for Education Statistics (NCES, 2019) reported the percentage of students who received special education services for the 2017–2018 school year leveled off to approximately 14% of total school enrollment, or 7 million students aged 3–21. From the 1990–1991 school year to the 2004–2005 school year, the percentage of students who received special education services increased by 11%, or 4.7 million students, to make a total of 13%, or 6.7 million students. The number of students served under the Individual with Disabilities Act (IDEA) declined during the school years from 2004–2005 to 2011–2012 (NCES, 2017). For the autumn of 2014, NCES reported that 95% of students ages 6–21 served under IDEA were enrolled in a regular school, and 62% were in a general education classroom for 80% of the day, an increase from 33% in 1990. The 62% of students with disabilities who spend 80% of their day in a general education classroom will most likely participate in STEM lessons. Barriers for SWD can be reduced with accommodations and modifications that make the situation fairer for SWD (Sukhai & Mohler, 2016).

Inclusivity of STEM for SWD

This section is included in the literature review because it is beneficial to include SWD in STEM lessons that take place in the general education classroom. The Virginia Department of Education *Inclusive Practices Guide* (2019a) list the following benefits of inclusive practices for SWD:

- Increased reading achievement for students with mild disabilities when given specially designed instruction in an inclusive setting.
- Less reliance on adults and greater utilization of peer supports.
- More direct instruction, improved attendance and behavior, and increased student independence after high school.
- More growth on yearly state tests in reading and mathematics in comparison to non-inclusive schools.
- No significant difference in academic performance or report card behavior ratings when compared to students without disabilities in non-inclusive general education classes.
- Opportunities for peer tutoring and support, and increased student participation. (pp. 10–11)

Three out of four SWD in K–12 public schools receive instruction in the general education program (NCES, 2017), but the number of SWD served in a general education classroom can vary. Ernst and Williams (2014) found significant service load differences of SWD among various technology teachers.

Recent legislation changed the requirements for educating students with disabilities. In 2017, a new free appropriate public education standard for SWD was mandated by the United States Supreme Court. The *Endrew F. v. Douglas County School District* case changed the acceptable standard for educating SWD. The new standard requires an IEP that is "reasonably calculated to enable a child to make appropriate progress in light of the child's circumstances" (Yell & Bateman, 2017, p. 11). Increased inclusion of SWD combined with the new standard of appropriate progress, rather than the previously held Rowley standard of minimal educational benefit, calls for STEM educators to revamp academic approaches that include SWD (Hammel, 2018; Sears, & Sears, 2018; Seligmann, 2017; Yell & Bateman, 2017).

STEM Approaches for SWD

Teachers can use various strategies to make STEM inclusive for SWD. Basham and Marino (2013) proposed that access to STEM education for students with learning difficulties involves effective curriculum design, which includes a focus on the big ideas associated with instruction. One approach for SWD is to center on a key concept or big idea. For example, if a STEM project focuses on the big idea of *living things need water*, SWD could grow a garden to incorporate a life skill, whereas general education students may choose a project on the importance of hydrating for sports (Watt et al., 2013). All students would target their projects on the same key concept of *living things need water*, but the SWD would also work on an IEP life skill goal (Watt et al., 2013). Often life skills are a part of the IEP goals and can be combined with core content curriculum using a hands-on strategy.

Collaborative Groups and Station Teaching for SWD

Cotaught STEM classes, with both a general education teacher and a special education teacher, can utilize station teaching to meet the learning needs of SWD and for implementation of IEP goals (Moorehead & Grillo, 2013). Coteaching also helps teachers work together on a big idea that covers multiple STEM disciplines (Basham et al., 2010). Station teaching breaks students into smaller groups and allows for rotations to different stations for instruction of key concepts. For example, one teacher may focus on key math concepts, another on science concepts, with a third on utilizing technology to reinforce both content areas. Station teaching can also improve content vocabulary for SWD (Moorehead & Grillo, 2013). Heterogeneous small groups for science are helpful in supporting students with a learning disability (McGrath & Hughes, 2018). SWD benefit from student collaboration and cooperative learning (Israel et al., 2015). Small-group station rotations allow more time for differentiation of instruction, including time to instruct and measure IEP goals. Accommodations and modifications can also be implemented within the small groups. In addition, working in a team or group allows for better communication and increased interactions for SWD (Basham & Marino, 2013; Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008).

Embedded STEM Supports for SWD

Universal Design for Learning (UDL) is a planning framework that is used to benefit different learners (CAST, 2018; Sukhai & Mohler, 2016). Using a UDL framework helps teachers proactively embed supports for effective instruction (Israel et al., 2015). Special education teachers may need to support "students' reading comprehension as part of active engagement in STEM literacy" (Israel et al., 2013, p 5). Reading level can be a barrier for SWD (Kennerly & Wexler, 2013; Sukhai & Mohler, 2016). Assistive technology that reads text aloud can be used for SWD who are not able to read at grade level (Sukhai & Mohler, 2016). Recognizing the importance of supporting multiple levels of reading ability is essential for STEM access for SWD (Basham et al., 2010). One helpful strategy is frontloading vocabulary to assist with texts that students need to know in order to gain an understanding of the project. A *quick write* (whereby students write what they know about an assigned topic provided by the teacher) can give the instructor insight into a student's prior knowledge. Other strategies include examining text features, paraphrasing, and making predictions. Digital models, simulations, and software can help SWD understand abstract concepts (Israel et al., 2015). For example, if the STEM topic is planets, students could participate in a simulation where they travel through space exploring the planets (Israel et al., 2013).

Embedding supports into the STEM lesson may reduce barriers for SWD. *The Inclusive Practices Guide* (VDOE, 2019a) lists the following barriers to inclusive education for SWD:

- School personnel inadvertently think and act in isolated ways rather than working together as collaborators.
- Teachers and principals lack knowledge and skills.
- Resistance to trying new ways of serving students with disabilities.
- Lack of knowledge and training related to inclusive education practices.
- Providing meaningful instructional, environmental, and testing accommodations.
- Low expectations for students with disabilities. (p. 24)

Related to lack of training, a study of the Schools and Staffing Survey (SASS) indicated that "only a small percentage of teachers had cross-credentialing even though 80 percent of all elementary and over 90 percent of all secondary STEM education and special education teachers reported having SWD on their caseloads" (Williams, Ernst, & Rossi, 2018, p. 32). Professional development may bridge the gap in this deficit. Based on a study of SASS data, Li, Ernst, and Williams (2015) contended that teachers of science, technology, and mathematics attend fewer hours of PD. Therefore, not only is PD needed, but the teachers must value the type of PD they attend.

Underrepresented Females in STEM Fields

This section is included in the literature review because females are students served under IDEA and are underrepresented in STEM fields. NCES (2019) reported that 9% of all females receive services under IDEA, compared with 17% of males. However, females make up the highest percentage of students identified as having a learning disability (44%). The learning disability category is the largest of the 13 identified disabilities (NCES, 2019). Females continue to remain underrepresented in STEM fields (Lee, 2011; MacLean, 2017; Nnachi & Okpube, 2015; Sampson, 2018). The U.S. Department of Commerce (2017b) released the *Women in STEM: 2017 Update* with the following information and statistics:

- Women filled 47% of all U.S. jobs in 2015 but held only 24% of STEM jobs. Likewise, women constitute slightly more than half of college-educated workers but make up only 25% of college-educated STEM workers.
- Women with STEM jobs earned 35% more than comparable women in non-STEM jobs—even higher than the 30% STEM premium for men. Women with STEM jobs also earned 40% more than men with non-STEM jobs.
- While nearly as many women hold undergraduate degrees as men overall, they make up only about 30% of all STEM degree holders. Women make up a disproportionately low share of degree holders in all STEM fields, particularly engineering.
- Women with STEM degrees are less likely than their male counterparts to work in a STEM occupation; they are more likely to work in education or healthcare. (p. 1)

Female Students in the K–12 STEM Classroom

With the adult STEM employment numbers and college graduate statistics, one should consider STEM education for students in K–12. Females and males participate and experience success with STEM on an equal basis in grades K–6; however, female participation in STEM classes declines in grades 7–12 (Brown et al., 2017; MacLean, 2017). Males and females have the same inherent abilities, despite typical gender stereotypes that males are *wired* more for STEM (Brown et al., 2017; Farrell & McHugh, 2017; Nnachi & Okpube, 2015). Simple teacher choices in the classroom can impact female interest in STEM. Teachers can choose to equally study famous females and males in the STEM fields, invite male and female guest speakers, and use female and male names on tests and scenarios (Brown et al., 2017).

According to Brown et al. (2017), successful engagement of females in STEM involves the following five criteria:

- Create a welcoming classroom environment that appeals to both females and males.
- Provide gender-neutral examples of technology and engineering.
- Provide students with ample choices for design-based projects.
- Offer multiple opportunities for students to engage in hands-on learning, ensuring that all students have gained experience working with different objects.
- Assess your students' aptitudes, interests, personalities, and/or skills using unbiased measures; provide students with their own test results and potential career matchups. (p. 3)

Principals can also make a difference in promoting female STEM interest (Sampson, 2018). Based on Sampson's research, principals who engaged in "transformative leadership practices by acknowledging race, and recognizing obstacles students of color face, support negating color-blinding ideologies that could impede the progress of all students" (p. 9).

Female perceptions have been linked to STEM stereotyping (MacLean, 2017). Females who see white males in STEM roles may fail to see themselves in the same role (MacLean, 2017). Heacock (2016) conducted a study of attitudes toward science, perceptions of scientists, and developing career aspirations. The study method included surveys and interviews with 40 females across three grade levels of public elementary school. Results determined that females did stereotype scientists; however, they also displayed confidence in their ability to learn about science. The females valued problem solving and experimentation. Despite the value that pre-adolescent girls placed on science, only a minority planned to include science in their career path.

The typical female stereotype for STEM is being questioned and changed. Mullen (2020) found evidence of "pushing against" typical female stereotypes during the study of a cross-global, postsecondary STEM laboratory between China and the United States. The apprentices included high school students preparing for college courses. One female "handled the equipment (e.g., boxes and cables) in the field and the transportation between countries, enabling the lab's mobility function. The female enjoyed the live science and being in the caves around thousands of bats" (p. 22). The deliberate assignment of typical *male* tasks to females can help break stereotypes. Nnachi and Okpube (2015) suggested that "if men and women in STEM are very much aware that this imbalance (bias) exists, they can work together to unbalance the unconscious thought process that led to it" (p. 190). This awareness of stereotypical roles can be one step in breaking down the barriers between females and males in STEM.

Female Longevity in STEM

Females often start out in STEM education equally with males; however, staying the course toward a STEM career continues to be a cause for concern (Brown et al., 2017; MacLean, 2017). Robnett (2013) examined how "motivation, confidence, and belongingness predicted girls' and women's identification with STEM, which in turn predicted their intent to remain in

STEM" (p. 232). In California, 134 girls with an average age of 16.52 were chosen from 3 high schools, and 125 women with an average age of 20.28 were chosen from Northern California University (Robnett, 2013). A third group of female doctoral science majors was also included in the research. Surveys were completed by all groups. The results indicated that "among high school and college students, STEM peers' influence on motivation predicted participants' STEM identification, which in turn predicted their intent to pursue a STEM career" (Robnett, 2013, p. 233). Robnett further found that "outreach programs aimed at increasing gender parity in STEM would benefit from an explicit emphasis on fostering social ties among the students they serve" (p. 247). In other words, building social connections is beneficial to females remaining on a STEM path. Notter (2010) also found that girls experienced a sense of camaraderie when they joined a collaborative STEM competition.

STEM Mentorship

One way to build beneficial social connections needed for increased female presence in STEM is through mentorship. Packard (2015) defined mentoring as

> Developmental experience or a type of support intended to advance students toward an important goal. Mentoring interactions have an impact when they communicate messages of invitation or inclusion and equip students to take on the challenges in STEM by increasing their capabilities. (p. 5)

Mentoring must be supported in order to be effective. For example, having a STEM mentor without transportation to get to the mentor becomes a barrier for females (MacLean, 2017). One empirical case study examined peer-mentoring and apprenticeship between STEM laboratories in the United States and China (Mullen, 2020). Although the study was not limited to females, relevant information can be applied to the benefits of including females in a STEM mentorship program. The apprentices in this program were "being educated on social, behavioral, familial, resourceful, and novel levels. These additional facets of self-concept were being nurtured within this mentoring-based cognitive apprenticeship" (p. 25).

STEM Mentoring and Deeper Learning

Martinez and McGrath (2014) found evidence of deeper learning when they examined eight innovative public schools immersed in 21st-century practices. The schools "hold fast to the belief that developing students into self-directed, responsible learners concerned for the learning of others is a fundamental requirement for Deeper Learning" (p. 25). Students are expected to advocate for their own learning by expressing what they desire to learn. Sukhai and Mohler (2016) considered self-advocacy an important tool for success in STEM education. Students also share the skills and talents they possess that can contribute to the learning of others. At the Science Leadership Academy in Philadelphia, Pennsylvania, explicit activities were planned to form a strong mentoring relationship among the upper class and younger or newer students. This allowed the newcomers to "become viscerally familiar with the school's core values of inquiry, research, collaboration, presentation, and reflection" (Martinez & McGrath, 2014, p. 29). At Mc^2 STEM High School in Cleveland, Ohio, the older students mentored new students by sharing the school's culture, language, and expectations. For example, students at Mc^2 were not given grades but were assigned levels of mastery on projects, and the mentors were the ones to explain this. At Casco Bay High School in Portland, Maine, ninth-grade students and teachers "camp out in yurts on a nearby island, where they kayak, hike, and cook meals together, while simultaneously embarking on a unit studying the nature of communities, from ecosystems to Masai tribes" (Martinez & McGrath, 2014, p. 30). This sense of belonging is one of the key psychological interventions that can improve STEM identity (Casad et al., 2018). A culture of collaborative and reciprocal learning between older and younger students, with a focus on real-world projects, has the potential to impact the community and result in deeper learning.

STEM Mentoring and SWD

Minimal research has been conducted on the influence of STEM mentors for students with disabilities. Sukhai and Mohler (2016) asserted that lack of a mentor for SWD is a barrier to STEM education. Although enrollment of SWD in science and engineering majors is now equal to that of students without disabilities, persons with disabilities remain underrepresented in the workforce (National Science Foundation, 2017). Powers, Schmidt, Sowers, and McCracken (2015) examined the effects of STEM mentoring for a group of 30 urban high school students, 30 parents, and 28 mentors. The SWD were enrolled in grades 9–11 and had either a 504 plan or received special education services. Some of the mentors had disabilities and some did not. "Coaching for mentors emphasized engaging in fun and informal interaction with their mentees in the context of facilitating STEM postsecondary and career exploration" (p. 27). Students and mentors participated in six activities together, such as a visit to the mentor's workplace (some STEM and college related), discussions on STEM careers, transcript and college prep work, special speakers, and strategies for STEM occupations. Results suggested that "mentoring was a catalyst for youths' STEM career development, and that key elements of successful mentoring included relationship development, encouraging guidance from mentors, and participating in experiential activities perceived as relevant by youth" (p. 30). Providing support for the mentors and the consideration of "personality and overall interest compatibility as factors in matching youth and mentors" was also considered significant (p. 30).

STEM Mentoring Assertions

Milagra Academy is an urban college preparatory school, founded in 2006 and located in San Francisco, California. The school has approximately 300 middle school students, with 97% of them participating in the federal free/reduced lunch program, 90% speaking English as a second language, and 97% being first-generation college students (Carroll, 2014). Mentors from Whitfield University were assigned to mentor 36 seventh and eighth graders during a 7-week afterschool program. The majority of the university student mentors were enrolled in engineering and science majors. Data were gathered from the journals of the university students, and the results found six assertions related to the mentoring relationships:

1. Mentors felt a responsibility to share their own inspiring STEM experiences with middle school students;
2. Mentors see themselves as role models for the students they are mentoring in diverse ways;
3. Mentors negotiated their developing relationships with students by attempting to define their roles;
4. Mentors negotiated the boundaries of authority as they built relationships and worked with middle school students;
5. Mentors found that building relationships with the students was both challenging and rewarding; and
6. Mentors became aware of the critical impact of building a team culture in working with middle school students. (Carroll, 2014, pp. 19–22)

Another important discovery was that "mentoring influence was more of a priority than the content the students were learning" (Carroll, 2014, p. 20). Also, "establishing strong personal connections is the most important part of being a STEM role model for students" (p. 29). Similarly, Notter (2010) found that adolescent girls who had female role models for an afterschool robotics program enjoyed the competition and were there to win. The girls' perceptions of feeling supported by their peers, parents, and teachers provided the motivation to pursue other STEM-related activities (Notter, 2010).

STEM Mentoring Benefits for Teachers

Benefits for students who mentor and those who receive mentoring have been well established for K–12 education. An additional benefit is what the classroom teacher receives. Lee et al. (2019) suggested that "STEM teaching can be improved once [teachers] are more confident of their class design and teaching competencies, and if they can get enough support from peers" (p. 2). Having high school student mentors in the classroom with elementary students working on a STEM project can be valuable to the lead teacher or facilitator. Lecorchick et al. (2018) suggested that mentors in the elementary environment may,

> alleviate some of the pressures associated with teaching in the K–5 arena, including planning, preparation, and other school- and district-wide initiatives, which, in turn, could give perspective on how STEM content can easily be integrated into the general classroom. (p. 20)

High school mentors are also able to provide individualized help to students. This can assist with differentiated needs in the classroom, especially for SWD or students who are considered at risk.

Similar to elementary, middle, and high school, STEM mentoring programs at the college level have been found to have psychosocial and academic benefits. Zaniewski and Reinholtz (2016) completed an analysis of 150 reports submitted by 14 mentor pairs of college science students at Arizona State University and determined that a "sense of belonging" and "positive science identities" resulted from the mentor relationships (p. 1). For college-aged students, it is suggested to allow some choice in who they would be paired with and to provide some opportunities away from the classroom, such as a discussion during a mealtime.

STEM Externships and the K–12 Classroom

Somewhat similar in benefit to mentoring is an externship. Bowen and Shume (2018) highlighted benefits to STEM instruction when teachers participate in summer externships (i.e., teachers were placed in engineering-focused businesses for four weeks). Many traditional teacher licensure programs do not include training in the engineering design process; therefore, getting the hands-on industry experience gives the teacher a better understanding of the process and its applications to the K–12 classroom (Bowen & Shume, 2018). Although many larger programs exist, this industry placement consisted of five females and four males in the upper-midwest region who taught various subject areas and grade levels within K–12. The participants followed the summer 2-credit course with a 1-credit course in the autumn. Evidence from the study suggested,

> Teachers who participated in an industry-based externship program demonstrated an increased understanding of the fundamental importance of skills for problem solving, collaboration, and communication in today's workplace environments, and expressed commitment to creating classroom opportunities for students to develop these skills through active learning in relationship to authentic "real world" contexts. (Bowen & Shume, 2018, p. 57)

The teachers were able to experience the real-life application of 21st-century skills in a STEM-based industry and then go back to the classroom where they could incorporate what they had learned and share their own *real-life* applications with the students.

Summary

STEM is an acronym used to represent an interdisciplinary approach that can be used with students in public schools. Lessons involving the four disciplines of STEM have the potential to lead to deeper learning by applying such skills as problem solving and self-directed learning (Deeper Learning Hub, 2019). STEM often involves creativity, problem solving, design, collaboration, communication, and a multitude of other 21st-century skills needed for the job market and global economy (Wan Husin et al., 2016).

Students of all learning types can participate in STEM lessons. SWD are able to tap into areas of strengths, such as creativity and collaboration, when accommodations and supports are put in place. Gifted students, including twice exceptional students, benefit from collaboration and working with other peers who can challenge them. Underrepresented groups in STEM, such as females, can be reached with purposeful teaching strategies to engage them, along with mentorship programs for a social and academic connection. Mullen and Klimaitis (2019) stated that "mentors and mentees learn together while extending the reach of what either can accomplish alone" (p. 6). SWD may be able to help their mentors just as much as their mentors are helping them, moving the relationship in a reciprocal direction.

STEM education can be implemented with federal and state funding to benefit all students in K–12 public education. Policy and governance of STEM varies among the states and individual school districts. The benefits of STEM have a far reach; the 21st-century skills and the 5 C's gained from STEM lessons are the skills desired from high school graduates in order to be college and career ready.

The findings from this literature review have prompted the consideration of a research question: What are teacher perceptions of instructional practices for SWD for STEM lessons within a Virginia suburban school division?

Chapter 3: Methodology

Purpose of the Study

The purpose of this study was to identify key instructional practices teachers use for STEM lessons for SWD. Furthermore, the study identified barriers for SWD and the professional development needed to help teachers provide inclusive STEM lessons for SWD. This chapter will explain the methodology of the proposed research study. It will cover the purpose, research design and justification, a review of the research questions, setting and participants, data collection, instrument design, data treatment and analysis.

This chapter on methodology focuses on instructional practices used for SWD to access STEM lessons, barriers, and professional development needed as perceived by teachers in a Virginia suburban school division. Insight was sought from elementary, middle, and high school teachers who teach, or have previously taught, STEM lessons that included SWD. There is research available on the inclusion of SWD in the general curriculum; however, a gap exists in the literature, specifically for helping SWD participate in STEM lessons. Another issue with the existing research is that not all grade levels are addressed. Some of the research targets elementary schools, whereas other research targets middle or high school levels. This study covered elementary, middle, and high school. Gaining knowledge regarding the instructional practices for SWD for STEM lessons has the potential to help school leaders identify strategies to address barriers and professional development needs.

The researcher's interest in STEM education came from observations of SWD during STEM lessons. The researcher served as an administrator at three elementary schools and observed increased engagement (as defined in Chapter 2) and deeper learning during STEM lessons for SWD. The researcher's initial research on STEM education increased interest in finding out what helps and hinders participation in STEM lessons for SWD. The researcher sought to discover teacher perceptions on helping SWD participate in STEM lessons and also what they continue to see as barriers.

The researcher added to the limited literature on instructional practices used during STEM lessons for SWD. Understanding current teacher perceptions from elementary, middle, and high school yielded new insights and strategies that can benefit students, teachers, and administrators. Results of this qualitative study can also aid scholars with additional findings for incorporation of STEM lessons in the classroom for SWD.

Research Design

This research was a basic qualitative study designed to investigate the experiences of teachers' STEM lessons that include SWD. It informs scholars and practitioners on teacher perceptions of instructional practices for SWD for STEM lessons. Interviews with teachers allowed for personal experiences and perspectives to be shared. Interview questions were used to find out what teachers have done to help improve access and/or reduce barriers to STEM lessons for SWD.

Qualitative research is a method that can be used to determine the *why* and *how* related to a phenomenon in a natural setting. The why and how of STEM lesson instructional practices for SWD was examined. This qualitative approach to inquiry is sensitive to people and places; it used "inductive and deductive analysis" and launched "patterns and themes" (Creswell, 2013, p. 44). This study added to the limited research available for improving access and reducing barriers to STEM lessons for SWD.

The researcher served as the primary instrument of data collection for this study and selected the setting and participants, conducted all interviews, and completed the data analysis.

Each contributor participated in a single, one-on-one interview. Due to COVID-19, contributors participated via electronic platform—Webex—and were provided the link in advance of the interview. Interviews were audio recorded. No video recording took place. Interviews were recorded on a password-protected computer. The Webex interviews allowed for the conversation to remain private and for the person being interviewed to remain anonymous.

Interview transcriptions provided the data for this study. The researcher uploaded the recordings to GMR, an online transcription service. Single interviews were sent to the transcription service as they were completed. Transcriptions were emailed to the participants for member checks. Once verified, the researcher read the transcriptions multiple times and took notes before starting the coding process. Codes and themes were generated for each interview transcription. Codes are "labels that assign symbolic meaning to descriptive or inferential information compiled during a study" (Miles, Huberman, & Saldana, 2020, p. 62). Codes can be simple or complex. Based on the literature review and research questions, codes relative to this study (for access) included accommodations, assistive technology, audio books, big ideas, breaks, differentiation, digital calendar, explicit teaching of group norms, flexible scheduling, front-loading information, graphic organizers, headphones, IEP process, math ability, orthopedic impairment, paraprofessionals (instructional/teacher assistants), peer helpers/mentors planning, reading ability, retelling directions, scaffolding, small groups, student input, universal design for learning, leadership, and visuals. Codes for barriers included below-grade level reading ability, collaboration time for staff, environmental triggers, executive functioning skills, lack of accommodations, lack of teaching knowledge/training, lack of support staff, low student expectations, math dyscalculia, physical disabilities, planning time, and self-advocacy.

When appropriate, in vivo coding was used. This type of coding "uses words or short phrases from the participant's own language in the data record as codes" (Miles et al., 2020, p. 65). Codes were entered into a Microsoft Excel spreadsheet. Key words from the interview questions were listed on the *x* axis, and codes from each interview were added on the *y* axis.

Themes are an "extended phrase or sentence that identifies what a unit of data is about and/or what it means" (Miles et al., 2020, p. 73). The researcher reviewed the codes to look for commonalities and identified themes from the most frequently occurring codes. Based on the literature review, themes for this study included differentiation strategies used by the teachers, common accommodations and modifications to the STEM lessons, mentorship, training/PD needs, and lack of disability knowledge.

For reliability purposes, codes and themes were reviewed by three experienced qualitative researchers with doctoral degrees. The researchers derived codes and themes from 10–20 pages of data. Marshall and Rossman (2016) suggested that intercoder reliability can be used to determine if an instrument measures what it is designed to measure. Through the process of data collection, the researcher gained insights into what helps SWD participate, and thrive, in STEM lessons. In addition, the researcher identified barriers to STEM lessons for SWD and desired PD based on teacher perceptions. The information can be used to inform leaders on instructional practices related to STEM lessons for SWD.

Research Design Justification

Qualitative research was chosen as the methodology for this study because it generated a rich understanding of the lived experiences of teachers who work with SWD during STEM lessons. This method also allowed for in-depth analysis of the data. There is currently limited research available on what helps SWD access STEM lessons and what barriers impede their participation within the general education setting. To gain insight into these phenomena, the approach must explore the issue to gain a "complex, detailed understanding which can only be established by talking directly with people" (Creswell, 2013, p. 48).

Research Questions

The primary question guiding this study was, What are teacher perceptions of instructional practices for students with disabilities (SWD) for science, technology, engineering, and mathematics (STEM) lessons within a suburban Virginia school division? Secondary questions were:

1. What do teachers think helps SWD gain access to STEM lessons?
2. What do teachers think are barriers for SWD participating in STEM lessons?
3. What kind of professional development is needed to improve inclusivity of SWD in STEM lessons?

Study Setting

The study setting was a suburban school division in southwest Virginia. The selection was purposeful and convenient. The school division incorporated STEM instruction from elementary school through high school. Components of STEM lessons overlap with the 2015 Profile of a Virginia Graduate's expectations of citizenship, collaboration, communication, creativity, and critical thinking, also known as the 5 C's (VDOE, 2019a). The division's strategic plan for all schools required the incorporation of the 5 C's into instructional practices. All elementary teachers are expected to implement 10 STEM lessons per school year that cover components of the 5 C's and the Virginia Standards of Learning. High school students in the division have the opportunity to attend a STEM academy at the Career and Technology Center. Students also have access to STEM programs at the Governor's School.

Selection of Participants

Purposeful sampling was used for participant selection because “their nature and substance will illuminate the inquiry question being investigated” (Patton, 2015, p. 265). This type of sampling will show “different perspectives on the problem” (Creswell, 2013, p. 100). Participants were chosen from a variety of schools and grade levels.

Following IRB approval, the Application for Approval to Conduct Research was completed and submitted to the division assistant superintendent (see Appendix B). The researcher scheduled a meeting with the assistant superintendent to request permission to conduct the study and followed up with a letter (see Appendix C). The researcher received approval to conduct the study from the division assistant superintendent on behalf of the division superintendent and research committee members. The researcher contacted the principals to obtain a list of potential participants (see Appendix D). The request was for names of general education or special education teachers who teach STEM lessons that included SWD or did in the past. An additional stipulation of teachers having a minimum of 3 years of experience was requested. Based on the criteria, the principals emailed or called the researcher with the names of teachers for potential participants. Recruitment letters were emailed to 20 teachers, and 13 were chosen and consented to participate. Five elementary, four middle school, and four high school teachers from 12 schools participated in the study. One additional elementary teacher agreed to participate; however, the maximum number of elementary teachers was already reached based on IRB study approval. Teachers represented 12 schools from the 26 schools in the division.

A demographic questionnaire with a brief explanation of the study was emailed to potential participants. To the extent possible, a diverse group of teachers was included based on the demographic questionnaire. This questionnaire included questions about ethnicity, gender, grade level, years of teaching experience, and subject area of instruction (see Appendix E). The questions assisted the researcher with selection of a diverse group of teachers. After identifying prospective participants, a letter was emailed to request their participation in the study (see Appendix F).

Data Collection Procedures

The researcher completed a course on social and behavioral research through the Collaborative Institutional Training Initiative (CITI), (see Appendix G). Prior to data collection, approval was granted from the Virginia Tech Institutional Review Board (IRB), (see Appendix H). Data were strictly self-reports from interviews based on teacher perceptions. Division principals were contacted to request the names of teachers who met the initial criteria of (1) general education teacher or special education teacher; (2) teaches STEM lessons that currently included, or previously included SWD; and (3) minimum of 3 years of teaching under contract. Demographic data on potential participants were collected via email and used for participant selection. Once selections were made, consent for participating was obtained (see Appendix I) and interviews were conducted one-on-one via Webex in a single session. Each interview lasted up to 45 minutes, was audio-recorded, and followed interview protocol (see Appendix J). Interviews were conducted May 19 – June 8, 2020. The researcher endeavored to listen carefully to the participant and provided assistance when needed by using question probes. The interviews were considered a success, as the participants did most of the talking and provided salient information.

Once each interview was completed, the recorded file was uploaded to the online GMR transcription service. Once transcribed, the researcher emailed a copy of the transcription to the participant for a member check. Once verified by the participant, the researcher started analysis by reviewing each transcribed interview (see sample in Appendix K). Specific directions for analysis are discussed in the "Data Analysis" section.

Instrument Design and Validation

For qualitative research, the researcher serves as the instrument. Interviewing teachers who work with SWD in STEM lessons provides other teachers and administrators with practical ideas to use in the classroom. Open-ended questions were chosen to allow the "person being interviewed to select from among that person's full repertoire of possible responses those that are most salient" (Patton, 2015, p. 447). The questions selected for the interview were grounded in the literature review and research questions. "The credibility of qualitative methods, therefore, hinges to a great extent on the skill, competence, and rigor of the person doing the fieldwork" (Patton, 2015, p. 22). The researcher followed interview protocol suggestions made by Creswell and Poth (2018):

- Determine the research questions that will be answered by the interviews.
- Identify interviewees who can best address these questions based on a purposeful sampling procedure.
- Distinguish the type of interview by determining what mode is practical and what interactions will net the most useful information to address research questions.
- Collect data using adequate recording procedures when conducting one-on-one or focus group interviews.
- Design and use an interview protocol or interview guide.
- Refine the interview questions and the procedures through pilot testing.
- Locate a distraction-free place for conducting the interview.

- Obtain consent from the interviewee to participate in the study by completing a consent form approved by the human relations review board.
- Following appropriate interview procedures.
- Decide transcription logistics ahead of time. (p. 165)

In addition to the interview protocol, the researcher reviewed current research on STEM education (see Appendix L). Topics from two recent studies were used for three of the questions. Although the questions for this study are different, they are based on the same topic. Hagerty (2019) used a mixed methods approach, open-ended questions, and a survey instrument to examine teacher perceptions about STEM education. Kumar (2019) examined teacher attitudes, concerns and self-efficacy toward inclusive education in STEM classrooms using a survey developed by Sharma and Jacobs, the Attitude toward Inclusion Scale. The survey included questions relating to STEM access (infrastructure) and support staff. Like the current study, these STEM studies used teacher perceptions for the data. Input from the school division was provided for three of the questions.

When a draft of the questions was completed, the researcher's advisor assisted in narrowing and sharpening the focus of each question. Table 1 provides a list of interview questions and the source for each; however, the questions were devised by the researcher in consultation with the researcher's doctoral chair, Dr. Carol Mullen, and in some cases, the researcher's school division.

Table 1
Questions for Interview Protocol and Verifying Sources

Interview Question	Source
What process do you go through to become familiar with accommodations and modifications contained in a student's IEP?	McLeskey et al. (2019); Watt et al. (2013)
Explain how you prepare your STEM lesson or unit with differentiation in mind for your students with disabilities.	School division director of special education (personal communication, 2020)
How do your SWD have input on their areas of interest on the STEM lessons you plan for them?	School division director of special education (personal communication, 2020)
How do your STEM lessons offer opportunities for SWD to be leaders?	School division director of special education (personal communication, 2020)
What strategies do you use to help a student with a math or reading disability?	Fisher (2019); Sukhai & Mohler (2016)
What strategies do you use to help a student with a physical disability?	Lee (2011); Sharma & Jacobs (2016)
What general strategies or initiatives do you use to help SWD access STEM lessons?	Fisher (2019); Lam et al. (2008
Based on your experience, what are some barriers to STEM lessons for SWD?	Sukhai & Mohler (2016)
What kind of professional development/training is needed to promote inclusivity of SWD in STEM lessons?	Bowen & Shume (2018); Nite et al. (2017)
If you have support staff during inclusive STEM lessons such as a special education teacher, paraprofessional, or student mentor, how do you use them to support SWD?	Lecorchick et al. (2018); Sharma & Jacobs (2016)
Is there anything else you would like to add?	Standard interview question

In addition to the validation of the interview questions from the literature review and research questions, after three interviews the researcher evaluated if the wording needed to be refined. Interviews were conducted with one teacher at each level to "refine the interview questions and the procedures further" (Creswell, 2013, p. 165). Based on participant responses, the interview questions did not need to be refined. Alignment of the interview questions to the primary research question and secondary questions are listed in Table 2.

Table 2
Alignment of Interview Questions to Research Questions

Research Question	Corresponding Interview Question for Instructional Practices	Corresponding Interview Question for Barriers	Professional Development
Primary RQ 1	1, 2, 3, 4, 7, 10, 11		
Secondary RQ A	1, 2, 3, 4, 7, 10, 11		
Secondary RQ B		5, 6, 8, 11	
Secondary RQ C			9, 11

Confidentiality and Ethical Treatment of the Data

Participants were offered the opportunity to choose a pseudonym to maintain anonymity. No participants chose a pseudonym, therefore the researcher assigned letters of the alphabet to each participant. All audio recordings were stored on the researcher's password-protected computer. All transcriptions were uploaded to a password-protected shared folder with the researcher's advisor, Dr. Carol Mullen. Consent forms and data analysis sheets were also uploaded to the shared file. Federal regulations require study documents to be maintained for 2 years following completion of the study.

Data Analysis Techniques

The first part of the data analysis was an organization of the demographic information. Data were entered into a Microsoft Excel spreadsheet by the participant letter. To the extent possible, participants were chosen to represent a diverse group of teachers. Part II of the data analysis was constructed from the codes and themes developed from the transcribed interviews. The researcher used the data analysis steps as suggested by Creswell (2018) as a guide as follows: managing the data, taking notes on initial ideas, and arranging codes into themes.

The researcher used a deductive coding method to analyze the data. Some access and barriers to STEM lessons for SWD have been identified in the literature review (see Chapter 2). A predetermined start list of codes and themes (listed in the "Research Design" section of this chapter) was used. Miles, Huberman, and Saldana (2020) stated, "The list comes from the literature review, conceptual framework, list of research questions, hypotheses, problem areas, and/or key variables that the researcher brings to the study" (p. 74). The researcher sought to extrapolate explicit and implicit meaning contained in the interview excerpts. Comparing and contrasting each code with other codes helped maintain a meaning-based analysis. This took place during coding and memoing. Codes were clustered based on shared meanings that aided in theme development and findings. During analysis, the researcher maintained a focus on the original aim of the study but also remained open to patterns that deviate from the focus. Some inductive coding egressed during data collection and analysis. This allowed the researcher to remain open to interviewee responses rather than trying to make all answers fit into predefined codes. Patton (2015) suggested that qualitative inquiry is oriented toward "exploration, discovery, and inductive logic" (p. 64). The sequence for data analysis was as follows:

1. Managed and organized the data in Microsoft Excel by developing a data summary form sheet for each interview question. This form helped to organize and classify information. See "Data Collection" section of this chapter.
2. Read each transcribed interview multiple times and made notes in the margin to help identify key points.
3. Listed the initial codes and memoed developing themes. Compared codes and themes with those developed by the three experienced researchers.

4. Finished the coding and looked for commonalities among the responses in order to finalize themes and findings.
5. Interpreted, summarized, and represented the data.

Creswell (2013) asserted that "qualitative research involves abstracting out beyond the codes and themes to the larger meaning of the data" (p. 187). For this study, the larger meaning of the data served to answer the research questions.

Summary

Chapter 3 provided an overview of methodology for the research study. Components included in the chapter are purpose of the study, research design and justification, research questions, proposed study setting, participant selection, data collection procedures, study approval process, instrument design and validation, data treatment, and data analysis. The primary source of data is individual interviews conducted with teachers.

Answers to the research questions should help other teachers to identify access and barriers to STEM lessons for SWD. The open-ended interview questions gave voice to teachers, which allowed them to share instructional practices to help SWD participate in STEM lessons. This methodology enabled the researcher to gain insight into barriers and suggested professional development to aid SWD with access to STEM lessons.

Chapter 4: Data Analysis

Introduction

The purpose of this study was to identify key instructional practices teachers use for STEM lessons for SWD. Furthermore, the study identified barriers for SWD and the professional development needed to help teachers provide inclusive STEM lessons for SWD. The following findings were identified based on responses to the interview questions:

1. Participants gained initial knowledge of SWD through IEP document review and communication with other staff members.
2. Participants indicated that knowledge of a student's disability and interests guided differentiation of instruction.
3. Participants noted that building student relationships and teacher knowledge of SWD helps SWD gain access to STEM lessons.
4. Participants believed that support staff was essential for assistance with classroom management and implementation of IEP accommodations.
5. Participants shared that intentional grouping supported SWD during STEM lessons and roles within the group provided leadership opportunities.
6. Participants declared that hands-on learning helped SWD gain access to STEM lessons.
7. Participants indicated that modifications to the classroom setting and support from others helped SWD gain access to STEM lessons.
8. Participants identified student ability, lack of adult support, and time limitations with lessons as the main barriers for STEM lessons.

9. Participants mentioned that more PD was needed in the areas of collaboration among teachers and student disability knowledge.

Further explanation of the findings is discussed in chapter 5.

Each participant completed a demographic questionnaire. Eight females and five males participated in the study. All teachers had a minimum of six years of experience and ten of the participants had between 11 and 26+ years of experience. All but one identified as Caucasian. One participant shared that she preferred not to identify. Over half of the participants had graduate degrees including one participant with a doctorate. Nine participants had a college course on special education and all except two had attended professional development on inclusivity for SWD. One special education teacher at each level (elementary, middle, and high school) participated in the study. The results of the demographic questionnaires are displayed in Tables 3 and 4.

Table 3
Participant Information Based on Completed Demographic Questionnaires

Participant	Gender	Ethnicity	Years of Experience	Teaching Areas	Highest Degree	License Certification Area
A	Female	Caucasian	21–25	Science	Bachelor	Early education NK–4, middle education 4–8
B	Female	Caucasian	11–15	English/ Language Arts	Bachelor	Early education NK–4
C	Female	Caucasian	6–10	Mathematics English/ Language Arts Special Education	Master	Special education general curriculum K–12
D	Female	Caucasian	11–15	Science Mathematics English/ Language Arts Social Studies	Bachelor	preK–8
E	Male	Caucasian	21–25	Science, Technology, Mathematics, English/Language Arts	Master	Elementary education K–5, administration and supervision preK–12
F	Female	Caucasian	6–10	Mathematics English/ language arts	Bachelor	General education K–8, special education K–12
G	Male	Caucasian	16–20	Technology	Master	Technology education 6–12
H	Male	Caucasian	26 or more	Technology	Master	Technology education
I	Female	Caucasian	6–10	Technology	Bachelor	Technology education, library media preK–12

Table 3 (continued)
Participant Information Based on Completed Demographic Questionnaires

Participant	Gender	Ethnicity	Years of Experience	Teaching Areas	Highest Degree	License Certification Area
J	Male	Caucasian	11–15	Technology, engineering	Bachelor	Technology education, gifted education, trade and industry
K	Male	Caucasian	11–15	Science	Master	Earth and space science
L	Female	Prefer not to Identify	11–15	Engineering, mathematics	Ph.D.	Technology education, mathematics
M	Female	Caucasian	16–20	Science, English/ language arts, world geography	Master	Specific learning disabilities K–12, emotional disturbance K–12, special education general curriculum K–12

Table 4
Additional Demographic Information

Participant	College-Level Special Education Courses	Attended In-service Training on Inclusivity for SWD	Type of Teacher
A	1–2	Yes	General
B	1–2	Yes	General
C	3 or more	Yes	Special education
D	1–2	No	General
E	3 or more	Yes	General
F	3 or more	Yes	Special education
G	None	Yes	General
H	3 or more	Yes	General
I	None	No	General
J	3 or more	Yes	General
K	None	Yes	General
L	None	Yes	General
M	3 or more	Yes	Special education

Participants responded to the primary research question: What are teacher perceptions of instructional practices for SWD for STEM lessons within a Virginia suburban school division? Secondary questions included:

1. What do teachers think helps SWD gain access to STEM lessons?
2. What do teachers think are barriers for SWD participating in STEM lessons?
3. What kind of professional development is needed to improve inclusivity of SWD in STEM lessons?

Due to COVID-19, all interviews were conducted using an online platform, Webex. After the interviews were conducted, the researcher uploaded each audio-recorded interview to GMR transcription service. The researcher emailed the transcribed document to the participants for verification, after which the researcher started data analysis by organizing the data into an Excel spreadsheet. Separate sheets for each interview question were created within one Excel file for data summary. The researcher read through the transcripts multiple times, took notes, and then used deductive coding to identify meanings. All codes were entered into the Excel file. Common themes and codes were identified based on participant responses. To ensure coder reliability, 10–20 pages of one interview were independently coded by three doctoral researchers before the current researcher's analysis was completed, and these researchers identified the same or similar codes. Table 5 contains sample codes compared to the researcher's codes.

Table 5
Sample Inter-rater Coding

Researcher	Inter-rater 1	Inter-rater 2	Inter-rater 3
Accommodation Summary Chart	Accommodations	Get chart of accommodations from sped teacher	Develop a chart of accommodations
Build Relationships Knowledge of SWD	Relationships Know the child	Relationships Know personalities	Relationships matter Know your students
Visuals – teacher Visuals - student	Visuals	Use visuals Have students draw pictures as reminders	Use visuals
Working in groups may be a barrier for some students.	Working in groups (barrier)	Preference for individual work over group work	Student may lack confidence in a group
Preferential seating Proximity	Preferential Seating Proximity	Proximity Preferential seating	Preferential seating Utilize proximity
Believe in SWD so they will believe in themselves.	Give students opportunities	Belief in student is important to student success.	Believe in the students
Collaborate with other teachers	Meet as a team.	Collaborate	Collaborate with math teacher

Consent forms, transcribed interviews, and the Excel data summary sheets were uploaded to a shared file available to the researcher's advisor, Dr. Carol Mullen. None of the teachers elected to choose pseudonyms, so the researcher assigned letters of the alphabet to each as follows: A–E for elementary teachers, F–I for middle school teachers, and J–M for high school teachers. This chapter exhibits the findings for each interview question as it relates to the research questions (RQs) and secondary research questions (SRQs). Some participants' quotes have been edited to reduce repeated words, reduce filler words such as *um*, *ahh*, and *you know*, slang words such as *gonna*, and words that do not impact context.

Analysis of Interview Questions

Interview Question 1 (RQ 1). *What process do you go through to become familiar with accommodations and modifications contained in a student's Individualized Education Plan?*

Each of the 13 participants shared their experience about what they do at the beginning of the school year to become familiar with the student's IEP. Common themes included read/review IEP (13), create summaries for quick reference (8), and communicate with case manager and/or former teachers (8). All participants shared that they reviewed the IEP either in a printed format or through the division online software program, Synergy. In this division, homeroom teachers are required to verify they have accessed and reviewed the IEP in Synergy. Participant G stated that while reading through the IEP, he liked to "get to the bottom line of what accommodations I need to make for that particular student." Participant L used the initial IEP review as a way to get to know the specific areas of difficulty for each student and adapted her "teaching style for that student." Participant H took notes during the IEP review to keep track of testing accommodations. Middle school and high school participants valued the quick reference/summary charts due to the number of students they taught and because their roster may change each semester. Participant H noted that student rotations resulted in a new group of seventh graders, "up to 30 kids" every 7 weeks. Participant B thought the quick reference/summary charts helped with the "wordiness" of the IEP and provided a quick list of accommodations and modifications. Participant A stated, "It's on a spreadsheet and chart so you can see all the different children at one time and what their different needs are and what the different accommodations are for them." Participant K created his own summary chart and then compared it with the coteacher's chart to ensure nothing was missed.

Participant M prepared a binder as a quick reference for the general education teachers. She included the spreadsheet of accommodations, copy of the IEP, and data sheets for what teachers need to collect. Participant D discussed communicating with other teachers after the review of the IEP and stated that "for the most part, in our school, we know all the kids even if they're not in our grade level." Participants used the collaboration time with case managers and other teachers to ask questions, clarify information in the IEP, and inquire about student backgrounds. Participant E stated, "When we are doing their STEM projects I always like to check with [the case manager] to make sure that I'm doing what they need accommodation-wise to better assist." Participants C and F (special education teachers) noted that they checked in with the general education teachers to verify understanding of the IEP accommodations and ensure that accommodations were working for the student.

Interview Question 2 (RQ 1, SRQ 1). *Explain how you prepare your STEM lessons or units with differentiation in mind for your SWD.*

Although the participants varied from elementary school to high school, commonalities of planning for students' participation in STEM lessons was evident. The three most common areas were considering a student's individual disability/ability (13), intentional grouping (12), and planning that depended on the type of STEM lesson (9). Participants C, F, and K considered the student's disability in relation to emotional needs. Participant C questioned, "Are they going to be able to emotionally handle it if they start to get frustrated during the project?" Similarly, Participant F stated that she was "looking primarily more at their social, emotional, and coping abilities." Participant K went beyond required accommodations by planning deadline extensions for SWD who may be dealing with non-school issues. He reported that he told students, "If you didn't make it, talk to me about it." Participants shared various ways they were intentional when planning which group SWD would participate in. Participant D placed SWD with a group of students who were patient and more accommodating than other students, while Participants F and G helped SWD build their confidence by becoming experts in a portion of the STEM project. Participant H believed that SWD were creative and "adept at problem solving" because they have been "problem solving their whole life when you think about it." Participant H also reported that these strengths helped to balance out SWD's weaknesses when working in groups. Similarly, Participant B spoke about the superior creativity efforts SWD added to groups: "I have found that my children with special needs and IEPs are usually the ones that are the most creative with their STEM projects and oftentimes put the most effort into them versus some of your higher learners" who put less time into a STEM project and just want to get it done.

Participants planned for SWD based on the type of STEM project. Participant A considered the abstractness of the STEM project and if the SWD could conceptualize it. She adjusted expectations based on the student's ability but would not lower effort expectations just because the student had a disability. When working with chemicals, Participant G planned an alternative role for a SWD who had difficulty manipulating the chemicals: "I had enough flexibility in my lessons if I needed to make accommodations or make adjustments to meet the needs of a certain student or a group of students, I would make those adjustments during the lessons." Participant L's planning was slightly different because the SWD in her program were considered twice exceptional and usually only required some extra time or additional explanations. A summary of abbreviated responses is displayed in Table 6.

Table 6
Planning for Differentiated STEM Lessons

Instructional Practice	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Considered student's disability/ability	X	X	X	X	X	X	X	X	X	X	X	X	X
Intentional grouping	X	X	X	X	X	X	X	X	X	X	X		X
STEM dependent	X	X		X	X		X	X	X	X		X	
Plan for accommodations	X	X	X		X		X	X		X		X	
Plan for support staff			X	X	X					X	X		X

Participants planned for accommodations based on IEP requirements and also noted which would be applicable to the STEM project. In some cases, participants included coteachers in the planning and utilized one-on-on instructional assistants for students with more severe disabilities.

Interview Question 3 (RQ 1, SRQ 1). *How do your SWD have input on their areas of interest on the STEM lessons you plan for them?*

A summary of the most frequently used instructional practices for student input is listed in Table 7, which also includes examples of participant responses. In order to avoid repetition, the in vivo codes are not exhaustive.

Table 7

Instructional Practices Used for Student Input on STEM Lessons

Instructional Practice	Participants	Sample Participant Responses
Find out student interest	12	“keep in mind what their interest are” “technology has made it easier for the kids to find something to interest them” “we did something with the robot dogs because I knew that would be interesting to him” “encourage and spark that interest” “I usually do some sort of poll in the beginning” “the Freenet form gives me all that data about what they like” “I use Edmodo, I could ask survey questions” “They break it up based on what their interests are” “we journal it” “they are very willing to tell us what they like and what they don’t like”
Student design choice	10	“their input is basically what is their final product is going to look like” “sketch out what they are going to do . . . what they are interested in” “make the video look however they want” “you just play around with the materials, test things out” “I would give them a list of alternatives or options” “I give them a battery and LED lights and wires, and then pretty much say here’s some other stuff that’s available” “If they want to collect materials to build, they can do that” “We are learning about space, how would you teach this to an elementary student?”
Group role choices	10	“try the different types of jobs within a STEM project” “I let them pick the jobs they like to do” “don’t put them in with a personality that’s going to overpower them to where they won’t speak” “breakout boxes . . . my primary focus was just getting them to be able to cope when they have no idea where to start” “When they work in groups, I usually have them break up what part they want to focus on”
Teacher as facilitator	6	“pushing them to pull out their best” “my job is to teach you to be creative and become good problem solvers”

		"I can give them some open-ended type questions to kind of get their brains going" "I adapt to what they need" "If they come up with an idea that might be a better way to do it, then I'm going to let them do it"
Relevant to student	6	"going to make an effort to make this relevant and interesting to them" "we talked about where robots are used in jobs" "I always like to take it back to the workforce" "tie in that real world" "pick what is suitable for them" "what they are comfortable doing"

Participants shared a variety of methods for how they got to know students and what they are interested in. They also allowed a wide range of design choices within the parameters of the STEM lessons. With group projects, students were frequently given the choice for the roles they took in the groups and could change those roles based on their interests in the STEM lesson. Participants B, F, and M facilitated problem-solving skills, while Participants C, H, and E encouraged student creativity. Student input was also correlated with what was relevant to the student. Participant J encouraged students to work together as would be expected in the workforce.

Interview Question 4 (RQ 1, SRQ 1). *How do your STEM lessons offer opportunities for SWD to be leaders?*

The most frequent practices for leadership opportunities were building relationships with students (12), leadership roles within STEM groups (11), ideas for STEM projects (7), and student voice (7). Participants B and F shared that it was important to know students to determine their comfort level stepping into leadership roles. Participant G expanded, "Usually you have students with IEPs that are really good at something. If you can find out what that something is . . . you put them in charge of it." Participant H shared that leadership among SWD can be personality driven. Participants B and K acknowledged that some SWD may not want to lead. When Participant D assigned SWD as leaders in a group, she also provided explicit instructions to the entire group to establish roles for members. Participant M offered opportunities for SWD to teach peers: “They can feel like a leader if they’re teaching someone else how to do it.” Participants A, E, and M recognized that STEM lessons provided opportunities for SWD to lead with their ideas. Participant E stated, “I think it automatically encourages them to think outside the box.” Participant A encouraged students in the group to claim their original ideas. Participant M expressed that hands-on STEM lessons offered more opportunities for SWD to “shine” compared with traditional learning. Participant L emphasized student voice by encouraging her twice exceptional students to advocate for themselves. Likewise, Participant C shared that one of her students had an IEP goal related to advocating for himself by establishing his role in groups.

Participants shared examples of how SWD take on leadership roles during STEM lessons. To build confidence with the math portion of STEM, Participant F set up an opportunity for SWD to mentor students in a lower grade level at a different school. A weekly math problem was posted via video and the SWD would answer questions and model how to solve the problems. Similarly, Participant H put his SWD in a leadership role by having the students mentor students from a self-contained special education classroom where students were identified with an intellectual disability. The two groups worked together on a STEM project that involved designing and building a product for senior citizens. Participant G focused on the strengths of SWD. He allowed one SWD to step into a teacher role by running the computer numerical control (CNC) router for all the students who needed it for their STEM project. Another SWD who had a reading disability as a weakness, but speaking as a strength was given the lead for the group on an oral presentation overview of the finished STEM project. Other examples of leadership roles include design choice in the engineering process, designated data collector, keeping track of deadlines during the stages of a STEM project, tool collector, machine inspector, and taking charge of fixing broken equipment/machines. Table 8 summarizes the instructional practices that support leadership among SWD during STEM lessons.

Table 8
Leadership Opportunities for SWD in STEM Lessons

Instructional Practices	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Relationships	X	X	X	X	X	X	X	X	X	X	X	X	X
Group leadership roles	X	X	X	X		X	X	X	X	X	X		X
Ideas for STEM projects	X				X		X		X	X		X	X
Student voice	X	X	X			X	X					X	X

Interview Question 5 (RQ 1, SRQ 1). *What strategies do you use to help a student with a math or reading disability?*

Participants reported that they often applied the same strategies from other content areas to STEM lessons. Participant B shared that her team used similar strategies for consistency and to reduce the amount of change for the student: "What are you doing in your daily small group math or small group reading that can be carried over into the STEM?" Participants reported that STEM lessons provided an opportunity to apply other content area knowledge and strategies. Participant G shared how hands-on learning helped SWD:

> The nice thing about Tech Ed is I would talk even to the middle school students. I would talk about the Pythagorean Theorem and then I would ask them, without any teaching, where would we apply that information? Usually, they couldn't answer that question, so then, you would take out a square piece of wood, draw some lines, and show them how to apply Pythagorean Theorem.

Similarly, Participant H shared how he helped students go from concrete to abstract: "They take a solid object that they can literally see and touch in their hands, and then they design that in SketchUp. The ultimate outcome is they get to build that as well." Participants B and D listed examples of math visuals such as hundreds charts, number lines, rulers, and multiplication charts. Participant A stated, "I do a lot of manipulatives, a lot of pictures with math because some kids just need that to understand the concepts." Teacher read-aloud was used by six of the participants; however, participants also discussed being mindful of not asking students to read aloud if it would make them feel uncomfortable, especially those with a reading disability. Participant M stated, "We never do popcorn reading because there are kids that have such severe anxiety they can't read out loud in front of everybody or there are kids that just flat out can't read—I mean they just can't read very well."

Participant E used multiple methods for teaching SWD to solve problems, while Participant F found it helpful to avoid giving too much information to SWD and instead taught "tricks" for solving certain problems by implementing specific steps without having to fully understand the process. Participant D stated, "Everything starts with the vocabulary before we do anything." Table 9 displays a list of instructional strategies identified by four or more participants to assist SWD, which include hands-on learning (13), visuals/graphic organizers (7), read-aloud (6), multiple ways to solve a problem (5), and frontloading information (5).

Table 9
Instructional Practices to Help a Student With a Math or Reading Disability

Strategy	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Hands-on activities	X	X	X	X	X	X	X	X	X	X	X	X	X
Visuals or graphic organizers	X	X		X	X			X			X		X
Read-aloud	X	X	X			X			X				X
Multiple ways to solve problem	X				X	X	X				X		
Frontload information		X	X	X							X		X

Following is a list of additional strategies and the number of participants who shared each: consult other teachers/experts (3), one-on-one support (3), math manipulatives (3), reword or summarize (3), notes/study guide (3), drawing (2), teaching advocacy (2), asking questions (2), extra directions (2), student check-in (1), reduced amount of math problems (1), scaffolding (1), high-interest materials (1), activate prior knowledge (1), chunk text (1), and oral presentations (1).

Interview Question 6 (RQ 1, SRQ 1 & 2). *What strategies do you use to help a student with a physical disability?*

The most commonly used strategies were classroom accommodations (11); support from teachers, aides, and other students (10); lesson modifications (5); and technology assistance (4). Participants did not report concerns for SWD's participation in STEM lessons when they had a physical disability. All participants were able to accommodate SWD or modify the lesson to allow for participation. Physical disabilities that participants discussed included students who used wheelchairs, students who were blind or hearing impaired, students who had cerebral palsy, students with an amputation, and students who had fine motor difficulties. A summary of reported strategy frequency for physical disabilities is exhibited in Table 10.

Table 10

Strategies Used to Help Students With Physical Disabilities

Strategy	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Classroom accommodations (environmental)	X	X	X	X	X	X	X	X			X	X	X
Support from other people	X	X	X		X	X	X	X	X	X			X
Modification to lesson		X					X		X	X	X		
Technology assistance	X							X	X		X		

Participants reported a variety of classroom accommodations. Examples include making space for wheelchairs, adjusting lab table heights, planning for where students would sit on the carpet for circle time, and arranging classrooms so students could move freely rather than staying in one spot. Participant L's warehouse-type classroom allowed students to roam freely, and "instructions are not at standing eye-level; they are at mid-level, so anybody in a wheelchair would be able to see." Participants A, B, and H reported how minimal help from adults made a big difference for the students. Participant A stated, "I'll be right alongside them helping them cut so that they can keep pace with the rest of the class." Participant J reported that other students volunteered to help:

> What was really nice was the way the other students acted because they realize, you know, when it came to making his project, the students were volunteering "I'll do this part for you" and whatnot. He was there involved but not standing at the machines and actually running it. But his design was what was being made so he got the satisfaction from that standpoint. And, like I said, I was very impressed how the students stepped up and wanted to interact and be helpful.

Participants E and K used a UDL approach. The STEM lessons were planned ahead of time with disabilities in mind so everyone could access the lesson. The UDL approach also allowed for student flexibility to demonstrate mastery of a concept. Participants A, H, I, and K used technology as an accommodation. Examples included use of an iPad to enlarge text, audio systems, sound reductions, stylus, and using larger robots rather than smaller ones.

Interview Question 7 (RQ 1, SRQ 1). *What general strategies do you use to help SWD access STEM lessons?*

Two of the most frequently used general strategies for helping SWD access STEM lessons are listed in Table 11. Examples of participant responses are included.

Table 11
General Strategies for Helping SWD Access STEM

Strategy	Participants	Examples
Know your student	12	"If it's a child who really struggles" "Explaining to them on their level" "I've got a student that significantly struggles with written work, allow that student to give it verbally" "I know they may not be good for that person" "They have a little bit of self-confidence" "Sometimes I just know it's not going to work due to frustrations levels"
Plan/prepare	9	"I make packets for them and condense the information" "Guess what we are going to do today and the kids don't even know about this yet" "Change in their schedule may be something you need to give a heads up on" "STEM lessons are available on Blackboard" "I'm completely open about modified assignments"
Graphic organizers, visuals	7	"same poster or anchor chart" "if it's something they need to draw, then it might have a picture of a pencil" "those reminders and visuals allowed the kids to work better in groups and become more independent" "a checklist that's something they can keep nearby so they know they're staying on track" "I do more visual type math questions"

Participants discussed the importance of knowing each SWD and his or her unique needs. They explained that because they knew their students, they were able to look at STEM lessons ahead of time and consider what they needed to do to prepare SWD for success. Participant B applied what she knew about her SWD to write a STEM lesson plan that could be done independently:

> With special needs, when they have to keep coming to you and asking you to re-read, that is embarrassing to them, if they feel like they're coming and asking more than others. So sometimes having them draw a little picture that will remind them, "Oh, I know that's what I am supposed to do on this step," and it makes it more independent for them if I kind of do that with them on the front end.

Participants L and H posted their lessons on an electronic platform, Blackboard, which is available to students outside of class. Participant L stated, “I post a lot on Blackboard; everything I teach goes up there. So students who need reinforcement in other ways, if they miss a lesson, whatever the situation might be.” Additional strategies discussed by participants included graphic organizers (7), restating in student’s own words (3), visuals (2), study packets (2), adult collaboration (2), preferential seating (1), avoiding too much teacher talk (1), re-reading (1), and explicit instruction on computer use (1).

Interview Question 8 (RQ, 1, SRQ 2). *Based on your experience, what are some barriers to STEM lessons for SWD?*

The five most identified barriers are student ability (8), lack of adult support (7), time limitations (6), student emotions (4), and resources (4). An additional barrier was SWD who had a difficult time working with other students (3). Table 12 contains a summary of barriers to STEM lessons for SWD based on the frequency of participant identification.

Table 12
Barriers to STEM Lessons for SWD

Barrier	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Student ability	X	X	X	X	X	X					X	X	
Lack of adult support		X					X	X	X	X	X		X
Time limitations	X			X	X	X		X			X		
Student emotions	X				X				X	X			
Resources		X					X				X	X	

Participants shared that student ability sometimes hindered participation in STEM lessons. Participants B and C said that some of the STEM lessons were written on a level that their SWD found difficult to understand. Participant C also had concerns that some SWD lacked recall of information and the ability to use math steps in the problem-solving process. Participants E and F thought that some of their SWD found the open-ended and exploratory nature of STEM too challenging. Likewise, Participant E felt that some SWD lacked the thinking skills needed for STEM lessons but that explicit instruction in this area would be helpful. Participant K expressed concern for SWD due to the lack of previous experience with STEM lessons. Participants G, H, and M expressed concern for the adults in the school system that held SWD back from STEM opportunities. Participant H stated,

> I'm going to say the biggest barrier isn't coming from the student necessarily. It comes from the expectations that others have placed on them prior to their being asked to do certain things. And so in that sense the biggest barrier is probably the adults that they've interacted with prior to, or even during, that time.

Participant M concurred, "A lot of kids with disabilities have been trapped in the general education process the whole time, so they don't have a chance to participate in as many STEM initiatives as they should." Participants F and H thought that budgeting time in the schedule for SWD to complete STEM lessons was a challenge and that students needed more time to explore. Participant E stated, "You've got to stay on task in order to get it completed in the timeframe allotted." For students with attention issues, staying on task can be a barrier. Some participants considered student emotion a barrier. Participants A and I shared that SWD may get frustrated easily and shut down during a STEM lesson. Participant B voiced concern for lack of self-confidence, which affected group participation. Participants K and L expressed concern over their "shoestring" budget. Participant K stated, "If I broke my budget down per student for labs for the year, it's $2.50. What kind of specialized services can I provide with $2.50?" Participants K and L shared that they find other ways to fund materials for their students.

Interview Question 9 (RQ 1, SRQ 3). *What kind of professional development/training is needed to promote inclusivity of SWD in STEM lessons?*

Collaboration among teachers (11), student and disability knowledge (7), modification of STEM lessons (6), and hands-on training (5) were requested the most. Other types of PD desired included content knowledge (4), classroom management during STEM lessons (3), training new teachers (1), and follow-up application of professional development (1). Table 13 displays the most frequently recommended types of PD for promoting inclusivity of SWD in STEM lessons.

Table 13

Professional Development for STEM Inclusivity of SWD

Professional Development	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Collaboration among teachers	X	X	X	X	X	X	X	X		X		X	X
Student and disability knowledge			X	X	X	X	X	X	X				
Modified STEM lessons		X	X		X	X		X				X	
Hands-on training	X					X		X			X	X	

Participants expressed interest in PD being more collaborative among general education content area teachers, coteachers, and special education teachers. Participants A and J favored peer observations to gain a better understanding of what other teachers were teaching and how they were presenting material. Participant M felt it was important for special education teachers to attend STEM training alongside general education teachers. Participant C advocated for PD for general education teachers to learn more about a student's disability and how to modify STEM lessons to meet their needs:

> When it really comes down to our kids with disabilities, when they are working these STEM projects, is that they can be easily frustrated. And, you know, sometimes our general education teachers aren't sure how to handle that or aren't sure how to step in and help modify something on the spot for the students.

Participant B proposed PD for teachers to make STEM lessons on a student's reading level and with a student's specific disability in mind. Participant A expressed concern about teachers gaining deeper knowledge in content areas: "I think what I find is many teachers are afraid of science. They don't feel comfortable with it. It's a little bit scary to them." Participant L expressed a desire for more hands-on professional development: "I would think that somebody with the skills to create those accommodations for students with different abilities would need to actually work with teachers in a small workshop setting."

Interview Question 10 (RQ 1, SRQ 1). *If you have support staff during inclusive STEM lessons such as a special education teacher, paraprofessional, or student mentor, how do you use them to support SWD?*

Participants identified the following as most significant: support with classroom management (13), relationships (11), assisting with accommodations (8), and student mentors (8). Other uses for support assistance included planning (3), grading (2), and lab setup (2). Table 14 exhibits the most frequent participant responses.

Table 14
Use of Support During Inclusive STEM Lessons

Support	Participant												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Support with classroom management	X	X	X	X	X	X	X	X	X	X	X	X	X
Relationships (know your students)	X	X	X	X	X	X	X		X	X	X		X
Assist with accommodations or modifications	X	X	X			X		X	X	X	X		
Student mentors		X	X	X		X	X	X		X			X

Support for classroom management was significant. Participant D stated, "It's important to monitor what's going on, and if there's a disruption the special education teacher or instructional assistant could assist or redirect with a positive statement such as, 'Oh! I really liked so-and-so's ideas.'" Participant E referred to having extra support in the classroom as a "double dip" for SWD because they received assistance from more than one person. Participants G, H, and L noted that extra support helped with safety. Participant G stated, "Let's face it, you've got 25 students and you're using tools where they could lose an arm or leg. Well, maybe not a leg, an eye." Knowing student needs and building relationships were also identified as significant areas for using support in the classroom. Participant A noted, "Every child's different. There's no cookie-cutter answer. So you're going to do whatever is necessary." Participant B concurred, "We've looked at STEM, and we've said, 'Okay, well, we feel like this child's going to be okay and isn't really going to need the special education teacher.'" Participant M mentioned an instructional assistant: "She knows which kids to make sure they're on task. And we have to continuously move around, so there are three people in there instead of two."

Support staff to assist with accommodations and modifications was helpful. As a special education teacher, Participant F emphasized the importance of accommodations: "I feel like it's my responsibility to make sure that those accommodations are met no matter what we're doing." Participants H and I stressed the importance of balancing accommodations and assistance for SWD with allowing them to find solutions on their own.

Mentorship was a fourth area of significance. Participants B and C gave examples of how student mentors helped SWD. Participant B stated, "[The student mentor] was really, really good about asking [SWD] questions and listening to them and wanting to know what their ideas were." Participant C stated, "They did such an amazing job helping this student make a bulleted list of easy words that he could read, and then when he read those words, he recalls what he wants to say." Participant J gave examples of student's strengths with 3D printing and design concepts and using those talents to mentor others: "I try to put a lot of the leadership and the ownership and the teaching side of it to the students." In addition, Participant J shared that SWD could also serve as mentors and included an example of how a student with autism was detail oriented, did not skip steps, and did everything in a particular fashion: "They're passionate about it, and they do become good teachers."

Interview Question 11 (RQ 1, SRQ 1-3). *Is there anything else you would like to add?*

All 13 participants valued giving SWD opportunities to participate in STEM lessons. Furthermore, most found that SWD tended to thrive with this type of instruction. Several participants communicated that there were some barriers in STEM lessons that SWD faced and that PD was needed to help with inclusivity of SWD in STEM lessons.

Participant F recognized the value of participation in STEM lessons for SWD: "I think that a variety of options for engagement that are provided with STEM are beneficial and allow students who likely do not have the same level of consistent success in traditional formats." Participants C, D, and G echoed the importance of including SWD in STEM lessons. Participant E stated, "I think we need to definitely make sure that they have an equal opportunity and experience in STEM lessons and make every accommodation that is necessary to include them."

Participants A, B, and M shared examples of how SWD excelled in STEM lessons. Participant B stated, "Some of the most creative projects, and I see this year after year, the most creative and neatest, the most detailed that have been put into them, are oftentimes my kids with special needs." Participant H further stated, "We underestimate all of our students with disabilities to reach logical conclusions, the problems that we present them with because we expect them to do it within their own boundaries." Participant I valued the persistence and stamina of SWD: "They're the ones that really grab onto the assignments, and you can tell they're trying harder than some of the others usually because it's different. And they want to keep trying."

Several participants identified barriers that remain for SWD in STEM lessons. Participants D, F, H, and K thought time for STEM lessons remained a barrier and that it was difficult to coordinate schedules among teachers. Participant D advocated for educators to avoid choosing STEM lessons as an optional time for SWD to be pulled out for related services, such as speech or occupational therapy. Participant H was concerned that students are not given enough time to explore due to having "one semester to cover an entire curriculum. How much time can you give a student to explore?"

Participant J emphasized the importance of teachers working together rather than solo: "The kids are kind of caught in the middle too because it's like we're all on our own little islands doing our own little thing." Similarly, Participant K advocated for PD and time to form relationships among teachers, including coteachers and special education teachers.

Findings for the Research Question

The primary research question was, What are teacher perceptions of instructional practices for SWD for STEM lessons within a Virginia suburban school division? Secondary questions were:

1. What do teachers think helps SWD gain access to STEM lessons?
2. What do teachers think are barriers for SWD participating in STEM lessons?
3. What kind of professional development is needed to improve inclusivity of SWD in STEM lessons?

From the data analysis, seven findings were identified as instructional practices used for SWD for STEM lessons. In addition, two findings were determined for the secondary research questions about barriers and professional development. Further discussion of each finding appears in Chapter 5. Figure 1 summarizes the key instructional practices identified by participants that enable SWD to gain access to STEM lessons. Barriers to STEM access and needed professional development are represented in Figure 2.

Figure 1

Key Instructional Practices in STEM Lessons for SWD

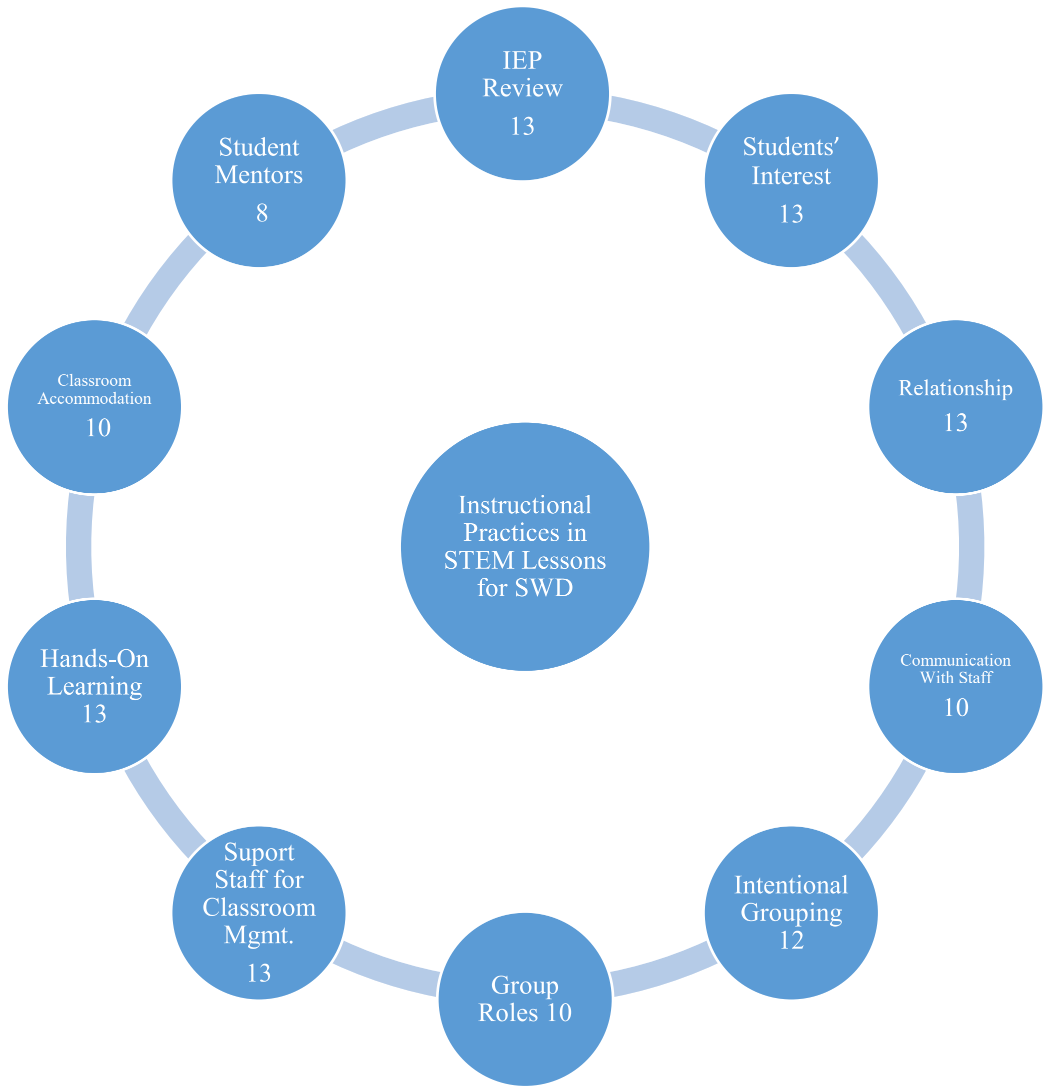
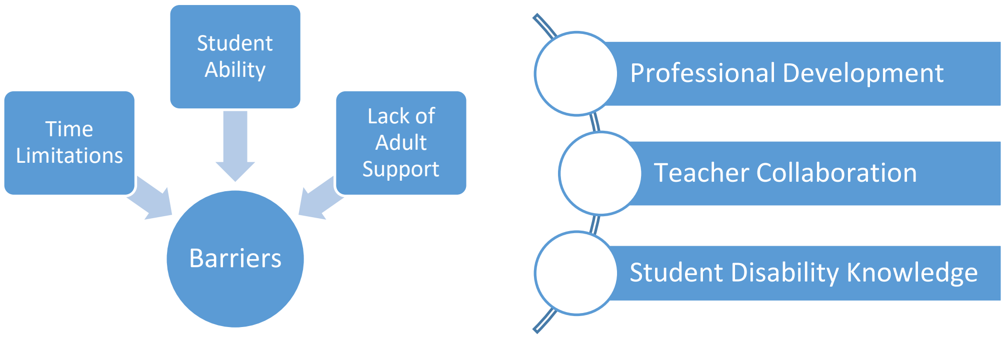


Figure 2

Barriers to STEM Lessons for SWD and Recommended Professional Development



The data analysis yielded 10 themes for instructional practices to support SWD access to STEM lessons. Word counts on instructional practices were completed on each interview. In addition, text from the interview was reviewed for context. Table 15 displays the instructional practices with level of frequency as discussed by the participants. The most frequently identified are highlighted in gray. A word count frequency is included. Word counts were derived from a combination of statements by the participants and inferences by the researcher. The table also includes examples of supporting data.

Table 15
Instructional Practices for SWD to Gain Access to STEM Lessons

Instructional Practice	Participants	Word count	Examples
IEP review/gain knowledge of student's plan	13	68	"Understanding the data that is in the IEP and the testing"
Students' interest	13	42	"Break it up into groups based on interest area"
Relationship/know your students	13	54	"It all goes back to that relationship that you have to have with each student, and you have to know if there's a trigger"
Use of support staff	13	46	"Usually I have communicated with those adults ahead of time saying, Here's what I'd like you to do"
Hands-on learning	13	29	"It has to be hands on. Kids have to touch it, feel it, talk about it, demonstrate"
Intentional grouping	12	41	"Break into smaller groups, and doing that with intention"
Communication with staff	10	34	"Make sure that you have open and direct communication; if that child has an aide, that aide should know what to expect"
Group roles	10	30	"When they work in groups, I usually have them break up what part they want to focus on"
Accommodations/ modifications to classroom	10	30	"We have one child in a wheelchair, and they went around and raised up the tables for him in several of the classrooms"
Support from others (student mentors)	8	21	"We find something that each kid can do really well, and then we'll have them help somebody else"
Visuals/graphic organizers	7	19	"The same poster or anchor chart that we use in reading was used across the grade level, so we try to make sure that we're incorporating what we're doing in our everyday lessons into our STEM"
STEM-dependent planning	6	7	"I look at each STEM individually. Some STEMs, the children are expected to do one-on-one, while others are more cooperative"
Frontload information	5	11	"It's helpful to frontload with them on what they're expected to do"
Extended time	5	5	"Limited timeframe"
Technology	4	15	"Use a stylus to outline the car project that [the blind student] was working on so he could go ahead and get a sense of what the shape was"

Table 15 (cont.)

Instructional Practices for SWD to Gain Access to STEM Lessons

Instructional Practice	Participants	Word count	Examples
Read-aloud	4	8	"A lot of the time they either need it read to them"
Multiple ways for problem solving	4	4	"Show 4–5 ways until they get it"
Preferential seating	4	3	"Because he wasn't as mobile as everyone else, he got the preferential seating so that he was right by the store [STEM supply store]"
Reword/summarize	3	6	"I would want them to read, and then, I would ask them to summarize what they've read"
Study guide/notes	3	4	"Have the outline ready for that individual"
Manipulatives	3	5	"I use a lot of manipulatives"
Asking questions	2	2	"Ask questions because sometimes students say they get it and they do not"
Extra directions	2	2	"Try to give further explanation"
Drawing	2	2	"There will be a lot of drawing"
Teaching advocacy	2	2	"Establish your role right from the beginning"
High-interest materials	1	3	"Use *National Geographic*, something that happened in the last month or so, sites on Twitter"
Oral presentation	1	2	"We try to incorporate an oral presentation into every STEM project"
Reduce amount of work	1	1	"Give fewer problems"
Scaffolding	1	1	"Stretch it out, and then they'll be given less and less information and will be working it out on their own"
Packets	1	1	"I make packets and condense all the information"
Chunking text	1	1	"They can focus on a little bit at a time"
Activate prior knowledge	1	1	"I'll have a chart at the beginning, "what do I think I know"

Instructional practices were identified as key if eight or more participants identified the practice more than 21 times. The participants' responses throughout each interview placed value on SWD's participation in STEM lessons. Overall, participants believed that SWD thrived with the challenges of a STEM project. Participant findings resonated the importance of building a relationship with students by getting to know them, using the village of people available to assist, and implementing modifications/accommodations for equitable access.

The 13 participants' responses to the 11 interview questions yielded emerging themes that are discussed in Chapter 5. In addition, the following chapter will identify practical actions for educators that will assist in the equity of STEM lessons for student with disabilities.

Chapter 5: Findings, Implications, and Conclusions

Introduction

This research focused on the perceptions of K–12 teachers in a Virginia suburban school division. The study addresses a gap in the literature by finding out what teachers are doing to help students with disabilities (SWD) access science, technology, engineering, and mathematics (STEM). The purpose of this study was to identify key instructional practices teachers use for STEM lessons for SWD. Furthermore, the study identified barriers for SWD and the professional development needed to help teachers provide inclusive STEM lessons for SWD. This chapter contains an introduction, overview of the findings, and discussion of the findings; conceptual, practitioner, and policy implications; conclusions; recommendations for further research; and researcher reflections.

Overview of the Findings

Participants were teachers from 12 schools (5 elementary, 4 middle, and 4 high). There are nine findings based on the analysis of participant responses to interview questions.

10. Participants gained initial knowledge of SWD through IEP document review and communication with other staff members.
11. Participants indicated that knowledge of a student's disability and interests guided differentiation of instruction.
12. Participants noted that building student relationships and teacher knowledge of SWD helps SWD gain access to STEM lessons.
13. Participants believed that support staff was essential for assistance with classroom management and implementation of IEP accommodations.

14. Participants shared that intentional grouping supported SWD during STEM lessons and roles within the group provided leadership opportunities.
15. Participants declared that hands-on learning helped SWD gain access to STEM lessons.
16. Participants indicated that modifications to the classroom setting and support from others helped SWD gain access to STEM lessons.
17. Participants identified student ability, lack of adult support, and time limitations with lessons as the main barriers for STEM lessons.
18. Participants mentioned that more PD was needed in the areas of collaboration among teachers and student disability knowledge.

Discussion of Findings

Finding 1. *Participants gained initial knowledge of SWD through IEP document review and communication with other staff members.* All 13 participants shared their experiences and procedures they followed to get to know their SWD and what each student needed in order to be successful in school. In *High Leverage Practices for Inclusive Classroom*, McLeskey et al. (2019) suggested, "Effective multi-tiered instruction that is personalized to students' needs and interests depends on high-quality, comprehensive information about individual students" (p. 51). High-leverage practice number 4 is "Use multiple sources of information to develop a comprehensive understanding of a student's strengths and needs," and number 5 is "Interpret and communicate assessment information with stakeholders to collaboratively design and implement educational programs" (p. xi). The participants found it helpful to develop spreadsheets for quick reference, especially when they had a lot of students to keep up with. Participants also spoke with case managers and former teachers to gain student insight. After reading the IEPs, one participant noted how she adapts her teaching style to match SWD's needs.

Finding 2. *Participants indicated that knowledge of a student's disability and interests guided differentiation of instruction.* All 13 participants shared the importance of understanding a student's disability and interests in order to plan and adapt STEM lessons to meet their needs. Based on Marino's (2010) research, Basham and Marino (2013) stated, "The success of SWD who participate in general education STEM classes is directly linked to teachers' abilities to understand students' unique learning needs and problem-solving abilities" (p. 9). Knowing information about students' disabilities helps teachers balance how much support they provide. Participant F expressed the importance of learning opportunities where students could "feel the struggle" during a STEM lesson but not to the point of feeling defeated. Many STEM lessons are open ended to allow students to choose their own designs based on their interest areas. Knowing SWD's interests is considered a high-leverage practice for inclusive classrooms (McLeskey et al., 2019). Participants also used knowledge of the disability and interest areas to allow SWD choice in demonstrating final mastery. Participants reported that SWD have some of the greatest creativity and outside-the-box design ideas.

Finding 3. *Participants noted that building student relationships and teacher knowledge of SWD helps SWD gain access to STEM lessons.* All 13 participants referenced getting to know their SWD and how this helped to build relationships with them. Research by Crouch, Keys, and McMahon (2014) supported the importance of student–teacher relationships. They found that SWD had a higher sense of belonging to the school when they had positive interactions with the staff. Participants also reported that knowing students is key when deciding on groups and enlisting student support. Participant B stated, "You have to know your kids. If you know their personality and you know their heart, then you will know which ones are going to build up SWD and help them in a loving way." Participants also thought it was important to get to know the social/emotional needs of SWD to help them with coping skills during STEM lessons.

Finding 4. *Participants believed that support staff was essential for classroom management and assistance with implementation of IEP accommodations*. All 13 participants used support staff (when available) to assist with classroom management, and 8 used support staff to assist with implementation of IEP accommodations. Kumar (2019) suggested that teachers had a positive attitude toward inclusive STEM when they had support staff and resources. For some STEM lessons, safety was a concern with a large number of students, so additional adults in the room made a difference. Communication with staff members was essential for sharing clear directions on how much support to provide for SWD. Participants voiced that all adults had to work together to ensure integrity of the IEP accommodations. For SWD who needed a lot of support during STEM lessons, participants scheduled the lessons for a time when they had support staff in the classroom.

Finding 5. *Participants shared that intentional grouping supported SWD during STEM lessons and roles within the group provided leadership opportunities*. Twelve out of 13 participants indicated that intentional grouping was a key instructional practice, and 11 agreed that grouping students during STEM lessons provided leadership opportunities for SWD. Research suggests that SWD benefit from collaborative groups (Israel et al., 2015). Basham and Marino (2013) and Lam et al. (2008) reported that SWD benefit from team and/or group work because it provides an opportunity for communication and increased interactions with others. Participants used information they knew about SWD and the other students in their class to choose who would collaborate well in a group. They reported that intentional grouping helped to balance out strengths and weaknesses for SWD. Intentional grouping also helped with behavioral issues by avoiding personality clashes with SWD. Some participants rotated leadership within a group and chose the leader; others identified talent areas for SWD and used that strength to naturally lead others. Even if the SWD was not appointed as the leader, participants thought leadership was a norm during STEM lessons because students were encouraged to think for themselves and share their ideas. Leadership provides an opportunity for SWD to develop soft skills for the job market. This should continue to be nurtured to enable SWD to transition from being interested in STEM careers to being employed in STEM careers.

Finding 6. *Participants declared that hands-on learning helped SWD gain access to STEM lessons*. All 13 participants identified hands-on learning as an instructional practice to help SWD gain access to STEM lessons. They expressed that hands-on learning increased student engagement, which is linked with student achievement (Parsons et al., 2014). Participant J suggested that concepts made more sense for SWD when they participated in a hands-on project. In high school, many of the STEM lessons involved hands-on learning with machines like laser engravers, 3D printers, and CNC routers. A middle school participant shared a hands-on project with real-life application. The STEM lesson involved students in a general education classroom mentoring SWD from a self-contained classroom. Mainstreamed SWD also served as mentors. Students worked in pairs to design unique storage crates for a local senior citizen center. Elementary participants shared that students are often given an open-ended STEM challenge and a container of supplies to build a structure with certain specifications and function requirements.

Finding 7. *Participants indicated that modifications to the classroom setting and support from others helped SWD gain access to STEM lessons*. Eleven participants agreed that classroom modifications helped SWD gain physical access to STEM lessons, and 10 reported that support from others was also an access factor. The Virginia Quality Standards require facilities "that are not stigmatizing with regard to location, appearance or design" when used by SWD for specialized services (VDOE, 2019a, p. 15). Participants reported that their classrooms were handicap accessible and that in cases where they were not, modifications were made, such as changing the location or adjusting lab tables for wheelchairs. Participants shared that they made modifications to the classroom environment based on individual needs of students. They also reported that support staff and other students helped SWD gain access to STEM lessons.

The Virginia Department of Education's *Inclusive Practices Guide* lists use of peer supports for less reliance on adults (VDOE, 2019a). Participants reported enlisting other students as mentors and helpers. Participant C stated, "When you find that really good peer mentor, I mean, it can just mean the world of difference to a SWD. Sometimes SWD prefer help with other students rather than adults." Other students would assist with a STEM lesson if SWD had difficulty with a particular component of the project.

Finding 8. *Participants identified student ability, lack of adult support, and time limitations with lessons as the main barriers for STEM lessons*. Participants identified three main barriers that SWD face when trying to access STEM lessons. Students' ability was identified by 8 out of 13 participants, lack of adult support was identified by 7, and time limitations was identified by 6. Sukhai and Mohler (2016) reported, "Students are also actively excluded from STEM when they are deliberately coached in a direction away from the sciences because the educators believe STEM is not a viable option" (p. 36). In addition, "social interpretations of individuals' functional limitations due to disability may contribute to attitudinal barriers on the part of educators" (p. 37). Participants reported that although most students enjoy STEM lessons, some lack self-confidence and may be reluctant to participate. Participants thought that some SWD may lack the ability to come up with an idea or might need assistance with brainstorming/processing to take an idea to the next level. The seven participants who identified lack of adult support as a barrier related it to some teachers and guidance counselors who do not promote participation in STEM lessons for SWD. According to participant responses, the adults who are not supportive tended to lack confidence in SWD's ability to participate in STEM lessons or felt SWD's time was better spent in another subject area, such as math remediation. Although SWD often have extended time written in their IEP, participants reported that time remained a barrier due to the pressures of required curriculum pacing.

Finding 9. *Participants mentioned that more PD was needed in the areas of collaboration among teachers and student disability knowledge*. All participants agreed that more PD was needed to improve access to STEM lessons for SWD. Eleven participants recommended more teacher collaboration, and 7 expressed a desire for more specific disability knowledge. They suggested that collaboration among teachers could occur at a PD session or within the building. Several participants expressed the desire to work on STEM lessons together that would include strategies for SWD. They also expressed interest in observing other teachers to gain knowledge in specific content areas and learn how other teachers are implementing STEM lessons. Williams et al. (2018) identified a need for cross-credentialing among teachers. Similarly, Nite et al. (2017) found that teacher content knowledge had a significant impact on student outcomes. Several participants were career switchers and were able to share current practical knowledge from the workforce. Participant L stated,

> The other engineering teacher in my program also is a mechanical engineer, and she also has her own company that she runs. So, we both have that kind of practical knowledge, and that really translates statically to the kinds of things that we teach in class.

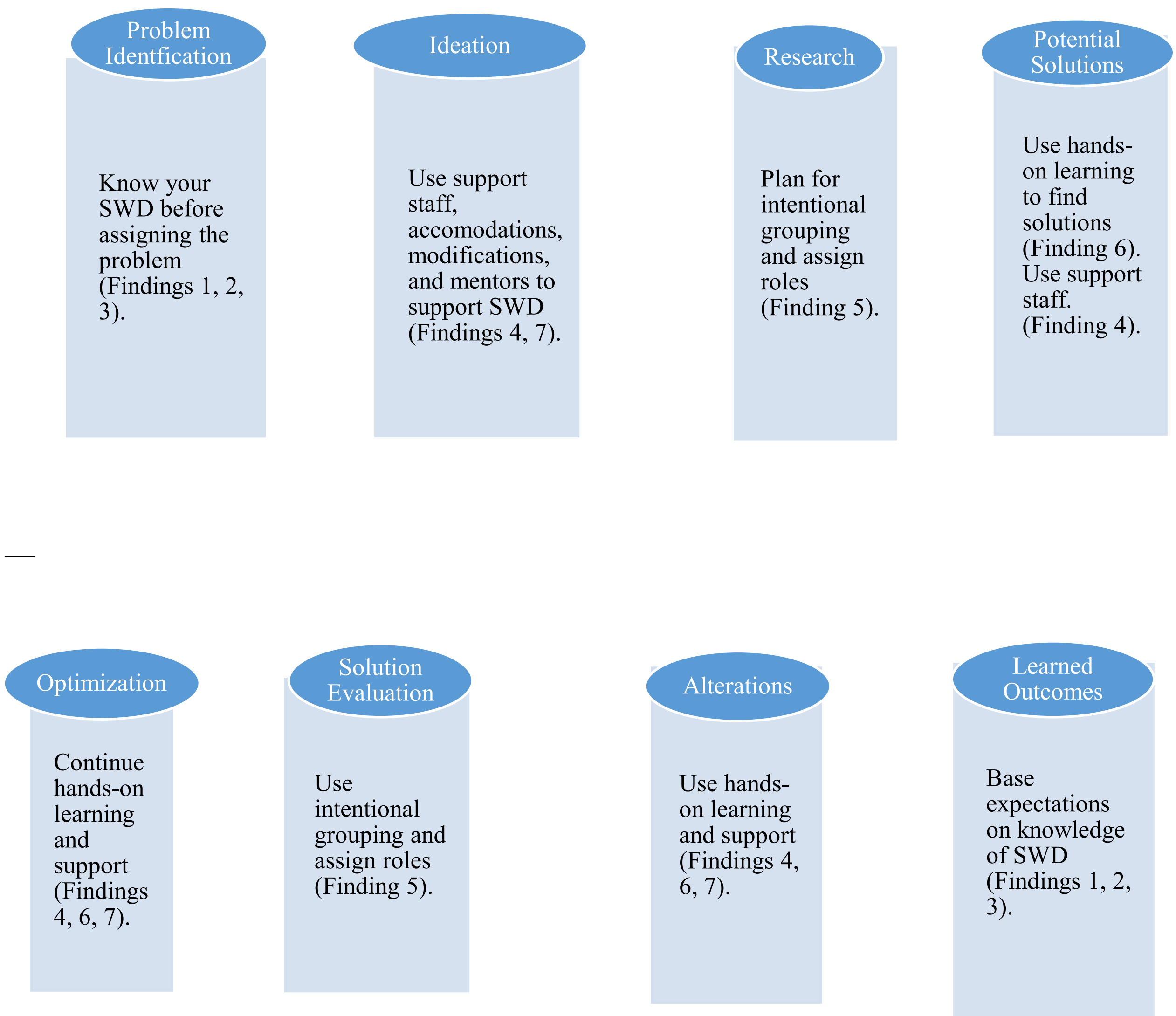
Participants reported that they needed more PD on characteristics for each disability to gain strategies and skills in order to readily modify a STEM lesson.

Pedagogical Framework Implications

Research from this study can be applied to the PIRPOSAL pedagogical framework (Wells, 2016). Participants acknowledged that graphic organizers are helpful for SWD and also identified hands-on learning as an important practice. PIRPOSAL could be used as a graphic organizer for students and as a checklist for teachers. The acronym, PIRPOSAL, outlines the process students may go through during the stages of a STEM design: P = problem identification, I = ideation, R = research, P = potential solutions, O = optimization, S = solution evaluation, A = alterations, and L = learned outcomes. Figure 3 applies the results from this study to suggested steps in the PIRPOSAL pedagogical framework. PIRPOSAL concepts are represented in the ovals, and the instructional practices identified in this study are represented in the rectangles.

Figure 3

PIRPOSAL Pedagogical Framework Connected to STEM Lessons Instructional Practices for SWD



Practitioner Implications

School division leaders, principals, and teachers concerned about the inclusivity of SWD in STEM lessons should consider the findings of this study.

1. *Teachers and principals should consider instructional practices used to help SWD gain access to STEM lessons.* This recommendation is associated with Findings 1–7. Data analysis shows the importance of getting to know SWD and building relationships with them. Principals should consider the importance of support staff for STEM lessons and, if possible, use this information during master schedule planning. Teachers should consider that hands-on STEM lessons improve engagement. Additionally, intentionally planned groups help SWD collaborate with other students and offer opportunities for leadership roles. Principals and teachers should ensure that the location of STEM lessons is accessible to all students. Finally, consideration should be given to student mentor programs that assist SWD in accessing and engaging in STEM lessons.
2. *School division leaders, principals, and teachers should consider identified barriers to STEM lessons for SWD.* This recommendation is associated with Finding 8. PD could be provided on disability characteristics so teachers would have greater insight into how to support SWD during STEM lessons. Guidance departments should consider if or why more SWD are not being tracked into STEM programs at the high school level and come up with a plan to be more inclusive if needed.
3. *School division leaders and principals should consider providing PD for teachers to improve access to STEM lessons for SWD.* This recommendation is associated with Finding 9. Participants identified the kind of PD needed to help teachers improve access to STEM lessons for SWD. Collaboration among teachers, including teacher observations, would provide an opportunity to learn how STEM lessons are implemented in other disciplines. In addition, budgeting time for teachers to gain deeper knowledge about disabilities and plan for specific disabilities is an important step toward inclusivity.

Policy Implications

The VDOE expects students educated in K–12 public schools to be STEM literate and ready for 21st-century jobs (VDOE, 2018c). Findings 8 and 9 should be considered by the VDOE when developing educational policy. SWD continue to experience barriers to STEM literacy, which may have an impact on the workforce. Sukhai and Mohler (2016) reported this as an “occupational injustice” and continued marginalization of SWD (p. 28). Policies promoting equal access to STEM lessons for SWD are needed at the state and local levels. Funding at the local level should be allocated for professional development to improve SWD success in STEM.

Conclusions

This study aspired to address a gap in the literature on access to STEM lessons for SWD by seeking teacher perceptions about what helps SWD in the classroom. Furthermore, this study aimed to find out what barriers continue to exist and what kind of professional development is needed to improve access to STEM lessons for SWD. Teachers from 12 schools (elementary through high school) from one suburban school division in Virginia participated in the study. They identified instructional practices they used with SWD and demonstrated value for STEM lessons for SWD.

Effective instructional practices are paramount for the inclusivity of SWD in STEM lessons. The participants in this study had experience with effective practices for supporting SWD during STEM lessons. Getting to know the student through document review, communicating with others, and building relationships helped teachers plan differentiated instruction and set reasonable expectations. Teachers considered students’ strengths and interests and were mindful about choosing groups for SWD. The intentional groups provided balance for SWD’s strengths and weaknesses and opportunities for leadership. Participants found that hands-on learning during STEM lessons increased access for SWD. For some SWD, physical modification to the classroom was important, while other SWD required support from others, including student mentors.

Data analysis suggested that even with implementation of effective instructional practices, barriers still exist for SWD. Often, students are barriers to themselves. They may lack the self-confidence or ability to participate in STEM lessons. In some cases, not only do students lack self-confidence, but also adults may lack confidence in SWD's ability to effectively participate in STEM lessons. PD may rectify this by providing time for teachers to collaborate and learn from one another while also learning more about each disability category.

Recommendations for Further Research

Results of this study provided information for the gap in the literature on teacher perceptions for helping SWD gain access to STEM lessons. The study also provided information about barriers to STEM lessons for SWD and PD needed to improve access. Based on the study findings, the researcher has identified five areas for further research.

1. The population sample for this study included K–12 teachers from one school division. Additional research could expand the study to other districts and states to gain a broader sense of teacher perceptions about STEM lessons and SWD.
2. The participant responses in this study were based on a wide range of disabilities. Further research could narrow the focus by disability category.
3. Further research on this topic could be conducted based on student perceptions of access to STEM lessons.
4. STEM lessons have components of the 5 C's. Further research could be conducted on which C's are incorporated into STEM lessons for SWD in middle and high school.

5. This study included elementary, middle, and high school teachers. Further research could be expanded to the college level.

Researcher Reflections

As an elementary school principal, I have personally witnessed how my SWD thrived during STEM lessons. They were the inspiration for my interest in this topic. During the research I discovered that teachers from elementary, middle, and high school witnessed the same phenomenon. As a former special education teacher, I constantly looked for strategies to help SWD succeed and to level the playing field for equal access to the curriculum. Although accommodations are needed to make STEM lessons accessible, it is my opinion that it is the right and equitable thing to do for SWD. Participant C shared,

> Our SWD really do enjoy STEM projects because they can be creative in an area they don't feel frustrated or feel like they have to perform to a certain level. There's a little bit of freedom in a STEM project.

During the interviews, the participants shared how they had gone above IEP requirements to help SWD feel comfortable with STEM lessons. Teachers are truly amazing—they do so much when they are given so little.

I hope this research gives teachers, principals, and district leaders ideas to better serve SWD. The instructional practices will provide a starting point for those new to teaching STEM lessons and some alternative methods for experienced STEM teachers. It is my hope that the teachers' ideas for professional development will be implemented and professional development will reduce barriers to STEM lessons for SWD.

Presently, the world is in the midst of a coronavirus pandemic. Public school systems in the United States are trying to figure out how to educate students. Some are shifting from total

shutdowns with only distance learning to hybrid learning models where students come to school a couple days a week in socially distanced classrooms. As a principal, I am very concerned about all my students during this pandemic, especially my SWD. The results of this study show the important role of teachers and support staff in helping SWD gain access to curriculum. Teachers have been and will continue to be groundbreakers when it comes to educating their students through whatever mode they have available. Fortunately, all students in my school system have access to a division-provided computer and internet hotspots for those who need it.
Unfortunately, I know this is not the case across the nation. Through this pandemic, we have learned how much we value and need human interaction. I am confident we will get through this and our teachers and students will press forward to overcome the obstacles we currently face.

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Appendix A: Poster Presentation: STEM Lessons

An Analysis of a STEM Program: The Impact of Deeper Learning and 21st Century Skills

Cindy Klimaitis, Ph.D. Candidate, Virginia Tech School of Education
Marlene Zakierski, Ph.D., Associate Professor, The Sage Colleges

Background

Science, Technology, Engineering, and Mathematics (STEM) education provides opportunities for students to engage in real-life problem solving using embedded 21st Century skills and elements of deeper learning.

STEM has many definitions depending on the field it is applied to. Hallinen (2019) defines STEM as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (p. 6).

Funded by the Hewlett Foundation, the Deeper Learning Hub (2019) proposes six competencies for deeper learning: **content mastery, effective communication, collaboration, critical thinking and problem solving, self-directed learning, and an academic mindset** (sense of belonging and motivation) (p.1). STEM and deeper learning share similar elements of 21st Century Skills such as collaboration, communication, critical thinking and creativity (Brannen-Sarrategui, 2015).

Research Questions

1. What percentage of 21st century skills are included in grade 5 STEM projects?
2. What percentage of deeper learning components are included in grade 5 STEM projects?
3. What percentage of core subjects are included in grade 5 STEM projects?

Theoretical Framework

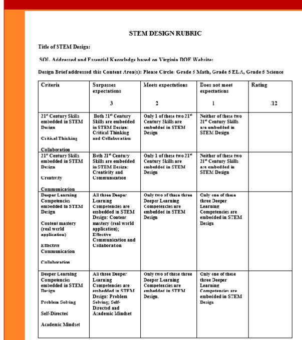
STEM education in K-12 public schools is often the result of policy which is driven by economics and workforce needs. Carmichael (2017) reviewed STEM definitions and published materials related to STEM education for each of the 50 states in the United States. Results show 58% of states have published STEM materials on their website and 82% have a STEM definition in policy materials. Approximately 42% of the states have written bills, executive orders or statutes. Given these statistics and driving forces in STEM education, equity of instructional practices is worth examining. Based on the U.S. Department of Commerce, STEM jobs have grown at three times the rate compared to non-STEM jobs over the past 10 years (2017). Tienken (2017) proposes that "one could conjecture that skills and dispositions that are difficult to offshore – creativity, innovation, and entrepreneurship – will retain value in 2035 and beyond" (p. 46).

Methods

Rubric used to assess embedded opportunities for 21st Century Skills and Deeper Learning. Projects were also examined for inclusion of core subject areas.

- 124 STEM project samples
- 53 Grade 5 Classroom Teachers
- 14 Elementary Schools

Rubric



STEM DESIGN RUBRIC

Title of STEM Design:

SOL Addressed and Essential Knowledge based on Virginia DOE Website:

Design Brief addressed this Content Area(s): Please Circle: Grade 5 Math, Grade 5 ELA, Grade 5 Science

Criteria	Surpasses expectations 3	Meets expectations 2	Does not meet expectations 1	Rating /12
21st Century Skills embedded in STEM Design Critical Thinking Collaboration	Both 21st Century Skills are embedded in STEM Design: Critical Thinking and Collaboration	Only 1 of these two 21st Century Skills are embedded in STEM Design	Neither of these two 21st Century Skills are embedded in STEM Design	
21st Century Skills embedded in STEM Design Creativity Communication	Both 21st Century Skills are embedded in STEM Design: Creativity and Communication	Only 1 of these two 21st Century Skills are embedded in STEM Design	Neither of these two 21st Century Skills are embedded in STEM Design	
Deeper Learning Competencies embedded in STEM Design Content mastery (real world application) Effective Communication Collaboration	All three Deeper Learning Competencies are embedded in STEM Design: Content mastery (real world application); Effective Communication and Collaboration	Only two of these three Deeper Learning Competencies are embedded in STEM Design	Only one of these three Deeper Learning Competencies are embedded in STEM Design	
Deeper Learning Competencies embedded in STEM Design Problem Solving Self-Directed Academic Mindset	All three Deeper Learning Competencies are embedded in STEM Design: Problem Solving; Self-Directed and Academic Mindset	Only two of these three Deeper Learning Competencies are embedded in STEM Design.	Only one of these three Deeper Learning Competencies are embedded in STEM Design	

Results

- Average rubric score: 9.5 out of 12
- 21st Century Skills: Critical Thinking & Collaboration = 2.4 out of 3
- 21st Century Skills: Creativity & Communication = 2.5 out of 3
- Deeper Learning: Content Mastery, Communication & Collaboration = 1.8 out of 3
- Deeper Learning: Problem Solving, Self-Directed, Academic Mindset = 2.7 out of 3
- At least one core subject was included in all STEM projects. 34% of the STEM projects included two or more core subjects.

Findings

% of Opportunity for 21st Century Skills in STEM Projects

Critical Thinking	90%
Collaboration	50%

% of Opportunity for 21st Century Skills in STEM Projects

Creativity	90%
Communication	54%

% of Opportunity for Deeper Learning Components

Content Mastery (Real-World Application)	69%
Communication	54%
Collaboration	50%

% of Opportunity for Deeper Learning Components

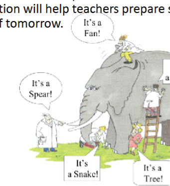
Problem Solving	91%
Self-Directed	93%
Academic Mindset	67%

Core Subjects included in STEM Projects

Mathematics	31%
Science	45%
English	42%

Implications

STEM projects provide increased opportunities for students to use 21st Century Skills and also experience components of Deeper Learning. Both provide a foundation of skills needed in the workforce. The percentage of each subject area can guide teachers to make decisions on future STEM projects. Increased group work can provide additional opportunities for collaboration and communication. STEM projects can be used to increase literacy skills when writing and oral presentations are included. Continued professional development in the area of STEM education will help teachers prepare students for the jobs of tomorrow.



Limitations

Sample size is limited and should not be generalized. Core subject material is based on the Virginia Standards of Learning. STEM projects are from a high-performing suburban school district.

Mentoring

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ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

ORIGINAL ARTICLE

Defining mentoring: a literature review of issues, types, and applications

Carol A. Mullen and Cindy C. Klimaitis

This literature review of contemporary mentoring delineates mentoring definitions and anchors these with explanatory discourse. Select empirical studies spanning 1983–2019 were analyzed, with a focus on education across grade levels. Alternative mentoring issues, types, and applications, also located, are integral to this discussion. While researchers describe what mentoring is, it is also important to clarify what it is not. Traditional definitions of mentoring have been losing traction, with mentoring alternatives forging new possibilities within changing learning and work environments. Contexts of mentoring include a personal professional relationship to an educational process; an organizational, cultural, and global context; and a systemic reform strategy that builds human capacity. This complex definitional terrain is situated within theoretical mentoring frameworks. Mentoring as deep, equitable learning with social transformative value is illustrated. Science, technology, engineering, and mathematics and other educational examples serve this purpose. Challenges to the field from alternative mentoring theory are discussed for transparency around meanings of mentoring and contributions that advance socially just relationships, organizations, and cultures. The article provides a timely and needed framework to discriminate and differentiate mentoring from other developmental relationships.

Mullen, C. A., & Klimaitis, C. (2019). Defining mentoring: A literature review of issues, types, and applications. *Annals of the New York Academy of Sciences*, 1-17. (Online First)

Contact

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Dr. Marlene Zakierski: zakiem@sage.edu

Appendix B: Permission to Conduct Research

Title of the Research Study: Instructional Practices for Science, Technology, Engineering, and Mathematics (STEM) Lessons for K–12 Students With Disabilities: Perceptions of Teachers from a Virginia Suburban School Division

Research Question: What are teacher perceptions of instructional practices for SWD for STEM lessons within a Virginia suburban school division?

Secondary Questions:

A. What do teachers think helps SWD gain access to STEM lessons?

B. What do teachers think are barriers for SWD participating in STEM lessons?

C. What kind of professional development is needed to improve inclusivity of SWD in STEM lessons?

A statement of the research problem and rationale, including definitions of key terms
The need for STEM education for SWD is two-fold. First, SWD are "significantly more likely to enroll in STEM majors," and low-income SWD are "more likely to select STEM majors, possibly to increase their chances of securing employment" (Lee, 2011, p. 1). Although SWD are enrolling in STEM majors, they are less likely to have a career in STEM (Basham, 2018). Second, as SWD spend approximately 80% of their day in the general education classroom (NCES, 2017), they need to have access to STEM lessons alongside their non-disabled peers. Science, technology, engineering, and mathematics (STEM) is defined as:

> An interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. (Hallinen, 2019, p. 6)

An explanation of the importance of the study, including the theoretical framework and implications for K–12 school settings
Expectations that SWD will be included in the general education classroom and will be a part of the global workforce gives cause to study how teachers can help SWD gain access to STEM lessons. This study will provide practical suggestions for helping SWD gain access to STEM lessons while removing some of the barriers. Other schools may use this study to compare their school division's ability to include SWD in STEM lessons. Administrators may be able to gain ideas on how to be more inclusive of SWD in STEM lessons. Potential needs for professional development may be identified to increase access or reduce barriers to STEM lessons.
An explanation of the research design and proposed methodology
This will be a simple qualitative study using teacher responses to interview questions as the data source. Interviews will be conducted at the elementary, middle, and high school level. Approximately 3–5 interviews will be conducted with participants at each level within the school division.

A description of data collection instruments (a copy of the instrument is a required part of the application)

To the extent possible, a demographic questionnaire will be used to obtain a diverse group of participants. Principals will submit the names of teachers who meet the criteria for the study (general or special education teachers who teach STEM lessons that include students with disabilities and who have a minimum of 3 years of teaching experience under contract). The interview protocol is attached to this application.

An explanation of how and to whom the results will be reported

Results of the study will be shared with the superintendent, assistant superintendent, director of special education, executive director of elementary instruction, and the executive director of secondary instruction. The information will be shared in a way that is preferred by each person (email/meeting/conference call).

A timeline for completing the research

April 1–August 31, 2020

An explanation of steps that will be taken to safeguard the privacy and confidentiality of RCPS employees, students, and parents; the explanation should include information regarding how and when collected data will be destroyed

All information will be kept anonymous. No schools will be identified. No students or parents are involved in this project.

Pseudonyms will be assigned for all potentially identifying information. Any information collected about schools from publicly available websites will be assigned pseudonyms. The file that matches pseudonyms to the original identifying information will be kept in a separate electronic file.

After data have been collected and analyzed, the files will be put into an electronic file on a password-protected computer. Once analysis is completed, any personally identifying information will be destroyed.

Any and all identifiable data will be disposed of upon the completion of the study. Any non-identifiable data will be disposed of after the completion of the research study.

An explanation of the setting in which the proposed research will be conducted; if research activities will take place during school hours, an explanation of how instructional time will be impacted must be included

Research will not take place during instructional time. Interviews will be conducted one-on-one in a private setting and through an electronic platform (Zoom, Skype, or phone) due to the coronavirus pandemic. Each interview will last no longer than 45 minutes.

Appendix C: Letter to Superintendent, Requesting Permission to Conduct Study

March 26, 2020

Dear Dr. Nicely and Dr. Eastwood,

Thank you for your continued support of my doctoral work in the Educational Leadership and Policy Studies program at Virginia Polytechnic Institute and State University. I am working under the direction of my advisor, Dr. Carol Mullen. I have proposed a research study that, once completed, will become my doctoral dissertation. The purpose of this letter is to provide an overview of my study and to request your permission to conduct the research study in County Public Schools. I am interested in gaining information to promote equal access during STEM lessons for students with disabilities. I have also completed and attached the required form for RCPS, Permission to Conduct Research, and have included the required IRB approval.

The topic for my dissertation focuses on instructional practices for STEM lessons for students with disabilities. The study will inform teachers, administrators, and key central office staff members about what teachers are doing in the classroom to help students with disabilities access STEM lessons and what barriers they think continue to exist. STEM lessons can offer opportunities for students to engage in our RCPS Strategic Plan goals for deeper learning and the 5 C's: collaboration, communication, creativity, critical thinking, and citizenship. The information obtained for this study may help to inform future professional development for the teachers and administrators in the school division. It may also provide strategies for teachers who endeavor to provide inclusive STEM lessons.

The study will be a basic qualitative study that will include one 45-minute interview with each participant, conducted by me. I would like to interview 9–15 teachers, which would include 3–5 interviews from each level: elementary, middle, and high school. At no time will their involvement disrupt their daily teaching responsibilities. The research study will conform to the requirements set forth by the Virginia Tech IRB. A written report of the study will be provided to you upon completion of the study.

Thank you for your consideration. I look forward to receiving your permission to conduct the study. Please feel free to contact me if you have any questions and I will set up a time to personally meet with you.

Yours sincerely,

Cindy C. Klimaitis
Principal, Oak Grove Elementary
PhD Candidate, VT School of Education
cklimaitis@rcps.us & cklimait@vt.edu

Appendix D: Letter to Principals

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
IRB# 20–303

Email Subject Line: Recruitment for Participation in STEM Education Research

Dear __________,

I am a doctoral candidate in the Educational Leadership and Policy Studies program at Virginia Tech, working under the direction of Dr. Carol Mullen. The topic of my dissertation study focuses on instructional practices for participation in STEM lessons for students with disabilities (SWD) based on teacher perceptions. I also hope to gain teacher input on what types of professional development are needed to help SWD participate in STEM lessons. Criteria for participating in this study include (1) general education or special education teachers who teach STEM lessons that include or previously included SWD and (2) must have 3 years of teaching experience under contract.

I have attached the research approval letter from ___Public Schools. I have also attached the teacher recruitment letter for your review. Will you send me a list of teachers who meet the criteria listed above? Thank you for your time.

Please email me at cklimait@vt.edu if you have any questions.

Yours sincerely,
Cindy C. Klimaitis, Principal
Doctoral Candidate, Virginia Tech
cklimait@vt.edu

Appendix E: Demographic Questionnaire

Demographic Questions:

1. Select your gender.
   a. Female
   b. Male
2. Select your ethnicity.
   a. American Indian or Alaska Native
   b. Asian or Asian American
   c. Black or African American
   d. Hispanic or Latino
   e. White or Caucasian
   f. Other
3. Select the number of years of teaching experience under contract, including the current school year.
   a. 3–5 years
   b. 6–10 years
   c. 11–15 years
   d. 16–20 years
   e. 21–25 years
   f. 26 years or more
4. Select the subject(s) you teach.
   a. Science
   b. Technology
   c. Engineering
   d. Mathematics
   e. English/Language Arts
   f. Other ______
5. Select the highest level of education you have completed.
   a. Bachelor's Degree
   b. Master's Degree
   c. Education Specialist Degree
   d. Ed.D/Ph.D.
6. Please list your areas of teaching license certification.
   ____
7. How many college-level courses have you completed in special education?
   a. 1 or 2
   b. 3 or more
   c. None
8. Have you attended an in-service training on inclusivity for students with disabilities?
   a. Yes
   b. No
9. Select the one of the following that best describes you.
   a. General Education Teacher
   b. Special Education Teacher
   c. Other

Appendix F: Letter to Prospective Interview Participants

Dear: _______________,

I am a doctoral candidate in the Educational Leadership and Policy Studies program at Virginia Tech, working under the direction of Dr. Carol Mullen. The topic of my dissertation study focuses on instructional practices for participation in STEM lessons for students with disabilities (SWD) based on teacher perceptions. I also hope to gain teacher input on what types of professional development are needed to help SWD participate in STEM lessons. Criteria for participating in this study include general education and special education teachers who teach STEM lessons that include or previously included SWD and have 3 years of teaching experience under contract. Your principal has identified you as a teacher who meets the criteria for this research study. Your participation in this study will not affect, in any manner, your position as a teacher in the division. Your responses during the interview will be kept anonymous. Any identifying factors will be kept confidential.

Your participation in this study is requested. I am interested in your experiences as a teacher of STEM lessons that include or previously included students with disabilities. The research study will conform to the requirements set forth by the Virginia Tech IRB. Thank you for your consideration in participating in this study. Please email me at cklimait@vt.edu if you are willing to participate or have any questions.

Yours sincerely,
Cindy C. Klimaitis, Principal
Doctoral Candidate, Virginia Tech
cklimait@vt.edu

Appendix G: CITI Certificate

CITI PROGRAM

Completion Date 20-Feb-2019
Expiration Date 19-Feb-2022
Record ID 30659937

This is to certify that:

Cindy Klimaitis

Has completed the following CITI Program course:

Social & Behavioral Research (Curriculum Group)
Social & Behavioral Research (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Virginia Polytechnic Institute & State University (Virginia Tech)

CITI Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wdf048092-0be5-4d04-99f8-7e270432104d-30659937

Appendix H: IRB Approval Letter

VIRGINIA TECH.

Division of Scholarly Integrity and Research Compliance
Institutional Review Board
North End Center, Suite 4120 (MC 0497)
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732
irb@vt.edu
http://www.research.vt.edu/sirc/hrpp

MEMORANDUM

DATE:	April 21, 2020
TO:	Carol Ann Mullen, Cindy Carter Klimaitis
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires October 29, 2024)
PROTOCOL TITLE:	Instructional Practices for Science, Technology, Engineering, and Mathematics (STEM) lessons for K-12 Students with Disabilities: Perceptions of Teachers from a Virginia Suburban School Division.
IRB NUMBER:	20-303

Effective April 21, 2020, the Virginia Tech Human Research Protection Program (HRPP) and Institutional Review Board (IRB) determined that this protocol meets the criteria for exemption from IRB review under 45 CFR 46.104(d) category(ies) 2(ii).

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit a new request to the IRB for a determination.

This exempt determination does not apply to any collaborating institution(s). The Virginia Tech HRPP and IRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

https://secure.research.vt.edu/external/irb/responsibilities.htm

(Please review responsibilities before beginning your research.)

PROTOCOL INFORMATION:

Determined As:	**Exempt, under 45 CFR 46.104(d) category(ies) 2(ii)**
Protocol Determination Date:	**April 21, 2020**

ASSOCIATED FUNDING:

The table on the following page indicates whether grant proposals are related to this protocol, and which of the listed proposals, if any, have been compared to this protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Appendix I: Informed Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
In Research Involving Human Participants

Title of Project: Instructional Practices for Science, Technology, Engineering, and Mathematics (STEM) lessons for K–12 Students With Disabilities (SWD): Perceptions of Teachers from a Virginia Suburban School Division

Investigator (s): Cindy Klimaitis: cklimait@vt.edu, phone (540)339–0045)
Dr. Carol A. Mullen: camullen@vt.edu, phone (540) 231–5494

I. Purpose of this Research Project

The purpose of this study is to identify instructional practices for science, technology, engineering, and mathematics (STEM) lessons for students with disabilities (SWD) based on the perceptions of teachers. The researcher also hopes to gain teacher input on what types of professional development are needed to help SWD participate in STEM lessons. Criteria for participating in this study include general education and special education teachers who teach STEM lessons that include or previously included SWD and have a minimum of three years of teaching experience under contract. Information gathered through this study will be used in the researcher's dissertation. Participants will be provided with a copy of the completed dissertation upon successful defense.

II. Procedures

One-on-one interviews will take place via an electronic platform (Zoom, Skype, or phone) by me (investigator), Cindy Klimaitis, in a private environment. Interviews will last no longer than 45 minutes. Interviews will be audio recorded and transcribed. The topic of my dissertation focuses on instructional practices for STEM lessons for SWD based on the perceptions of teachers. In addition, information will be sought on what types of professional development is needed to improve STEM inclusivity for SWD. I will meet with you at an agreed-upon date and time.

III. Risk

Your participation in this study will not affect, in any manner, your position as a teacher in the school division. Your responses to one interview conducted by a Mrs. Cindy Klimaitis will be kept anonymous.

IV. Benefits

Your participation in this study is voluntary. It is the researcher's hope that the findings will add to the literature surrounding instructional practices for STEM education for students with disabilities as well as support current and future leaders in the inclusive practices of STEM lessons. No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

The data that are collected from you during the above-mentioned interview will be kept confidential at all times and will be known only to Cindy Klimaitis. The audio recording of the above-mentioned interview will be transcribed by GMR Transcription Services. Member checks will be used with the interviewees by sharing the transcribed interviews with the participants to

ensure their perspectives have been recorded accurately. The audio recording of the interview, all paper and electronic copies of the interview transcript, and all paper and electronic copies of the data analysis will be stored securely in a on a password protected computer. Only Cindy Klimaitis will have access to the above-mentioned data and the signed consent form. Also, at no time will Cindy Klimaitis reveal identifying data or any other identifying study-related information to anyone. The audio recording of the interview will be erased, and the signed consent form will be destroyed upon the successful completion of the dissertation defense.
The Virginia Tech (VT) IRB may review this study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

Participation in the study is voluntary and no compensation will be offered.

VII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free to not answer any questions that you choose or not respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue as a subject.

VIII. Questions or Concerns

If you have any questions or concerns about this study, you can contact Cindy Klimaitis, whose contact information is included at the beginning of this document.
Should you have any questions or concerns about how this study is conducted or your rights as a research subject, or need to report a research-related injury or event, you may contact the Virginia Tech Institutional Review Board at irb@vt.edu or (540) 231–3732.

IX. Subject's Consent

I have read the consent form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________
Subject signature

____
Subject printed name

Note: Each subject must be provided a copy of this form. In addition, the IRB office may stamp its approval on the consent document(s) you submit and return the stamped version to you for use in consenting subjects; therefore, ensure each consent document you submit is ready to be read and signed by subjects.

Appendix J: Interview Questions and Protocol

STEM Interview Questions

The following interview questions will be used in each interview, conducted by the researcher. Each interview will be digitally recorded by the interviewer and later transcribed to aid in the anonymity of the participants.

Interviewer: Thank you for agreeing to participate in this interview to help me collect information about instructional practices for participation in STEM lessons for SWD. For the purpose of this study, STEM is defined as an interdisciplinary teaching approach that combines two or more of the disciplines (science, technology, engineering, mathematics) on a problem-solving project or a lesson that has real-life application. I will ask each as stated. Based on your responses, follow-up probes may be asked.

1. What process do you go through to become familiar with accommodations and modifications contained in a student's Individualized Education Plan?
2. Explain how you prepare your STEM lesson or unit with differentiation in mind for your students with disabilities?
3. How do your students with disabilities have input on their areas of interest on the STEM lessons you plan for them?
4. How do your STEM lessons offer opportunities for students with disabilities to be leaders?
5. What strategies do you use to help a student with a math or reading disability?
6. What strategies do you use to help a student with a physical disability? Prompt: such as a student using a wheelchair?
7. What general strategies or initiatives do you use to help students with disabilities access STEM lessons?
8. Based on your experience, what are some barriers to STEM lessons for students with disabilities?
9. What kind of professional development/training is needed to promote inclusivity of students with disabilities in STEM lessons?
10. If you have support staff during inclusive STEM lessons such as a special education teacher, paraprofessional, or student mentor, how do you use them to support students with disabilities?
11. Is there anything else you would like to add?

Interviewer: Thank you for participating in the interview to help me collect information about instructional practices for participation in STEM lessons for SWD. A record of the transcribed interview will be sent to you for verification.

Appendix K: Sample Data Summary Sheet

		w Question 1 - IEP process for Accom &										
Interview 3 - Elementary		Read & Review			Case Manager			ask questions when needed				
Participant A					creates notebook			communicates with case		manager/managers		
					spreadsheet &			clarifiy when needed				
					charts for accom.			quick reference				
					see all needs for multiple							
					children at a glance							
Interview 5 - Elementary		Read & Review			Some sped teachers							
Participant B					provide summary charts with							
					all accom.	helps with wordiness of IEP						
					If she does not get a chart, she makes her own							
					for a reference							
Interview 7 - Elementary		Read & Review			Collaborate with gen ed.			Meet & review IEP with gen ed teachers			Teacher students	
Participant C					to see if accom & mod are working			Discuss student background			about their accom.	
					could change throughout the year			Review Accom.			(advocate for themselves)	
					amend iep if needed						explicit instruction on accom	
					spend time with student - check to see if accom. Is working						with students	
Interview 8 - Elementary		Read/file review						Communicate with past teachers				
Participant D								For the most part, teachers know all students in the school				
								even if not in your grade level				
Interview 10 - Elementary		Read/review			Check for Accom.			Communicate with case manager				
Participant E								Ask to come in during STEM to observe				
								Observe student in action to see if goals need to be tweaked				
Interview 1 Middle School		Read & Review	print Accom.		Create chart		sep. caseload		checklist		Verify A & Mod.	
Participant F			print Svcs.		for quick ref.		from others				are implemented	
									Daily check-in			
Interview 2 - Middle School		Read & Review	Summarize		Made his own					had a Read. Dis.	Accom. Examples	
Participant G					"codes" for a			Students		relates	Proximity seating	
					quick ref. by			as Advocates		to students	Extra bathroom breaks	
								for needs				
Interview 9 - Middle School		Read & Review	skim background		Make Notes			Meet with		large turnover		
Participant H					for modifications			sped				
					Ex. Testing			teachers				
					small groups			communication		Beg. Of year		
								(1st group)		gets more infor		
								lacks this later on		compared to middle and end of year		
Interview 11 - Middle School		Read & Review	Synergy					Communication				
Participant I								with case managers				
								asks questions				
Interview 4 - High School		Read/Review			Coord. Provides a list of students			Communicate with sped coordinator				
Participant J		Download from			(SWD) per course			Ask questions when needed				
		Synergy										
Interview 6 - High School		Read/Review			Creates a summary chart of accom.			Co-teacher also creates a chart & then				
Participant K		in Synergy program			for each student			they compare notes				
								Serves to check one another, ensures nothing is missed				
					Keeps information in 3 ring binder			Ex. Add to small group				
					Other teachers can access					Co-teacher tracks student use of accom.		
					Uses as a reference					offer everytime, but students may say they		
					more in the beg. Of year					do not need it, track data on usage		
										Ex. Use of read aloud accom.		
Interview 12 - High School		Read/Review										
Participant L		reread			try to understand the problems the student may have							
					consider how to adapt teaching style to meet needs of student							
Interview 13 - High School		Read/Review			Creates charts/spreadsheet					Already know students		
Participant M					with accom. And other notes					Know IEP Accom. Because he wrote the IEP		
					prints out and places in a binder for gen ed. teachers							
					also prints out a copy of IEP							
					Binder also has data sheet for collection							

Appendix L: Sources Reviewed on the Topic of STEM Education

Themes: STEM Policy/Governance STEM Engagement/Pedagogy/Deeper Learning STEM Inclusion/SWD Females in STEM Mentoring
Methodology: Empirical Surveys/Rating Scales Legislation/Government Documents Summary of Existing Research

Table 16
Sources Reviewed on the Topic of STEM Education

Source	Method/Data Source	Central Themes	Findings
Kennerly & Wexler, (2013)	Observations	How STEM is taught in secondary versus cognitive needs of students with learning disabilities. Reading level can be a barrier. Students sometimes lack content vocabulary and math facts.	Supports help content acquisition SWD. Podcasts (CAPs) support student cognition.
Moorehead & Grillo, (2013)	Journal article, observations	Inclusive STEM, coteaching, undefined teacher roles, lack of student vocabulary	SWD benefit from station teaching (Flip-Flop-Fish) Tier I instruction benefits students. Response to intervention benefits.
Watt, Therrien Kaidenbert, & Taylor, (2018)	Journal article, observations	Inclusive practices Inquiry-based science classes, memorization issues	SWD need scaffold and structured approach, Universal Design for Learning (UDL)

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Basham & Marino, (2013)	Journal article, observations	Lack of students with disabilities entering the STEM workforce. SWD lack of understanding of STEM concepts.	SWD need explicit teaching, guided inquiry, use of technology (iPads, software), UDL
Isaacson, Michaels, Supalo, & Roth, (2016)	Journal article, observations	Access impedes desire to choose STEM careers. Students who are blind or have limited visions lack accessible hands-on science experiments.	SWD need frequent accessible activities.
Stith, (2018)	Interviews, Governor's School evaluations	Effectiveness of STEM delivery in five Governor Schools in Virginia	Five governor schools in VA met or exceeded evaluation standards. The schools also promote STEM capable citizens through scientific research and civic service.
Delp, (2017)	Surveys	Process and alignment of components and approaches for STEM education implementation. Thirty out of 137 approached school districts participated.	STEM approaches and implementation are not aligned with the literature findings for comprehensive STEM programs. Districts want to influence student interest in STEM related careers.
Simmons, (2017)	Interviews, field notes, surveys	Experiential learning through STEM education Identification of fundamental principles for experiential learning.	Fundamental principles hands on, real-world, student ownership, scheduled teacher time to plan, manage, and deliver said instruction, among others.
Brannen-Sarrategui, (2015)	Interviews, surveys, observations	Mandated decree for Science Fair participation, Globalization, economy driven	Students saw themselves as capable of STEM jobs in the future, increased 21st century skills (problem solving).

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Carmichael, (2017)	State documents, legislature, state web sites,	State-by-state policy analysis, for four STEM models, disciplinary by subject, integrated disciplinary, and integrated disciplinary and integrated, and undefined	The majority of the states have clear STEM programs defined by policy.
Zollman, (2012)	Journal article, summary of definitions, findings of others	Learning for STEM Literacy How to develop, apply, and support STEM education Literacy definitions of professional organizations Use of STEM to "Satisfy societal, economic, and personal needs"	STEM cannot be independent silos Content and pedagogy should be blended. Students' attitudes, beliefs, self-esteem, confidence, and motivation should be considered.
English & King, (2015)	Journal article, observations	Aerospace engineering design process Study identified five comprehensive engineering processes for fourth grade students.	Fourth graders have the potential for engineering. Balanced scaffolding by teacher needed. Mathematics and science learning applied to designs.
Marzano, (2013)	Journal article, observations	Teacher tools for identification of concepts for student engagement	Four teacher checks for student engagement: Examples: Demonstrate why the content is important. Make things interesting.
STEM Coalition, (2018)	Website	Legislative Update STEM Business partners	Updates on STEM job in the United States. Links to current state STEM initiatives.
Educate to Innovate, (2009)	Website: White House Initiatives	President Obama's STEM Initiative Business partnerships STEM careers Women and girls in STEM	$700 million in public-private partnerships for STEM education Federal investment in STEM 2010 Initiative: Change the Equation

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Skinner & Pitzer, (2012)	Interviews, questionnaires, 1020 students self-reported	Student engagement related to achievement Increased engagement leads to less maladaptive coping strategies	Engagement predicts achievement Appropriate coping strategies are used more by engaged students.
Bowers & Ernst, (2018)	STEM-centric lesson plan rubric, Test of hypothetical value, Wilcoxon-signed-rank test, normative approximating method, interrater reliability	Sixteen elementary teachers enrolled in a STEM cohort program through McDaniel College in Maryland submitted lessons plans for review. Plans were rated based on STEM-centric components using a rubric with a ratings range from 1 – 4. One = Unsatisfactory, two = Developing, three = Proficient, and four = Exemplary	Study failed to reject the research hypothesis questions. Lesson plans were rated as proficient or exemplary based on four questions. To what extent are teachers within the McDaniel College pilot cohort proficient in developing lessons that: • Integrate Science, Technology, Engineering, and Math disciplines • Engage students in inquiry • Support student collaboration as a STEM team • Support students' strategic application of technology Questions derived from the Maryland STEM Standards of Practice. Four out of the seven standards were chosen as a focus for the lesson plan study.

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Bowen & Shume, (2018)	Grounded theory, teacher interviews, Educators in Industry Program	Nine out of 11 K–5 teachers enrolled in a summer 4–week industry program participated in the research study. Five themes emerged: • Value of problem solving • Importance of collaboration • Importance of communication • Using "real world" connections • Casting students as employees	Teachers valued problem-solving for industry classroom environment. Practices shifted to include more problem-solving approaches. Communication identified as most important 21st Century learning skills valued by industry. Provided more opportunities for students to communicate their thinking with other students. Industry experience exposed teachers to awareness of how employees collaborated together, Multiple teams work on a single project. Secondary teachers found the industry experience helpful with "real world" connections to classroom content. One teacher designed a math lesson based on what she had learned at a civil engineering firm working on a road construction project. Elementary teachers "hire" their students on inquiry projects such as designing storm resistant buildings. Industry experience influenced classroom practice in two ways: • Increased student opportunities to develop skills for industry-related workplace environment • Teachers utilized more "real world" authenticity in the classroom.
Ernst, Williams, Clark, Kelly, and Sutton, (2017)	SASS-TQ from the National Center for Education Statistics, Section VII School Climates and Teacher Attitudes	Other studies have looked at how teacher job satisfaction is positively influenced by teacher autonomy in the classroom and a perception of having influence over school policy. This study looks at subject-specific areas of math, science, and technology	Subject-specific differences exist. Technology teachers were found to have increased influence over school policy compared to math teachers. Technology teachers also had the highest level of classroom control. Science teachers had the second highest level of control and math had the least control of the three subject areas. Standards and high-stakes testing were possible influences for science and math teachers having less autonomy in the classroom and a perceived view of decreased influence over school policy. Technology can also be an elective course in some districts.

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Gupta, Hill, Valenzuela, & Johnson (2017)	Grade six student workshop on chemical reactions	Conducting workshops to gain student interest in STEM careers. Low cost STEM designs to increase availability for economically disadvantaged students.	The food science project was chosen because of the students' familiarity with the daily life experience of the subject, safety, and upstate New York's food and agricultural workforce needs.
Mitzell & Brown (2016)	Review of 104 published articles from 2013–2015 on the status of STEM education research	Trends and innovations in STEM education research. The study is a follow-up to the one conducted by Josh Brown in 2012. The study addressed the same research questions as the former study: • Has there been continued development within STEM education research? • What is the scope of the research being conducted in STEM education? • Where is STEM research being conducted? • Who are the participants in STEM research?	Larger number of qualifying articles in the current study. In 2012, 60 qualified articles were found in a 45–month period compared to 104 in a 33–month period for the current study. The scope of the research includes: • Standards development • Program implementation • Science education • Technology education • Engineering education • Integrative STEM • Mathematics education (added for current study only) STEM research is being conducted at more universities compared to only a cluster of 13 universities in 2012. The current study shows 19 universities publishing 90 articles and over 30 universities publishing one article each. The majority of the research continues to focus on K–12 education.

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Farrell & McHugh (2017)	IRAP compared to IAT—College students categorized target words, rate on 11-point scale whether men or women are more suited to the arts and STEM subjects	Gender STEM BIAS Implicit Cognition Females in STEM	Students demonstrated a significant implicit pro-male-STEM bias Pro-female STEM bias, significant only among female STEM students. Repeat of a 2015 study by this researcher
Brown, Ernst, Clark, DeLuca, & Kelly (2017)	Journal article (expanded on findings from other studies)	Gender stereotypes and false beliefs persist despite actual abilities of males and females. Teachers can make a difference by the *tactics* they use.	Females may be more engaged if: • Classroom appeals to females and males • Equal representation (i.e. male and female guest speakers) • Choices on projects and hands-on opportunities • Roles in groups are mixed (i.e. mixed gender or gender specific) • Career testing and other measures to show females have the same STEM abilities as males.
Nickels & Gartner (2018)	Journal article, blended learning/STEM classroom application	Blended Learning supports personalized learning Increased Mathematical Understanding Deeper engagement with STEM Integrated approach	Blended Learning allows for: • Digital differentiation & adaptive learning • Deepen content via Small group & face-to-face with teacher • Increase problem solving via collaborative project-based learning

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Robnett, (2013)	Dissertation, survey, path analysis, mediational model, high school girls, college	STEM Identification STEM Peer Climate Intent of females to remain in STEM	"Confidence and motivation statistically outweigh belongingness when all three are simultaneously tested as predictors of STEM identification" "Belongingness predicted undergraduates' intent to pursue an advanced degree in STEM, which indicates that it is still an important peer climate affordance."
Sampson, (2018)	Dissertation, case study, two schools, two principals	Support of African-American Girls in STEM How do principals support African-American girls in their STEM programs? What practices engage underrepresented students in STEM? CRT	"It takes a village" mindset School Culture Community partnerships Study Groups Internships
Heacock, (2016)	Dissertation, interviews, surveys, mDAST, CIS	Self-efficacy, stereotype threat, and career choice theory of females in grades 3, 4, & 5 related to Science and Scientists How do these attitudes affect STEM career interest?	Did not experience gender bias (inferred) Did stereotype scientist Thought science was important, enjoyed scientific experimentation Valued problem solving
Lesseig, Slavit, & Nelson (2017)	Journal article, TESI case study	Interdisciplinary approach Connections across curriculum Middle School	"Sometimes your lowest students, your least engaged students in the classroom, will excel the most in STEM projects…. Like all of a sudden they come alive in these STEM projects."
Jensen & Nickelsen (2008)	Book	Defines and distinguishes between simple and deeper learning.	n/a – not a study – relates to pedagogy Specific definitions given with graphics for comparisons

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Hewlett Foundation (2019)	Website	Provides 6 competencies for deeper learning.	n/a not a study – relates to pedagogy
Jaquith, Zielezinski (2017)	Research brief (used a coding scheme for the documents examined)	Examined 71 files related to deeper learning between 2012 and 2017. Conducted by the Stanford Center for Opportunity Policy in Education as requested by the Hewlett Foundation.	For deeper learning, build on "tools and descriptions already in place, focus on learning as an outcome, and use research as a strategy for further knowledge development."
Warkentien Charles, Knapp, & Silver (2017)	Article, Research Triangle Institute, surveys	Studied effects of 5 years of Deeper Learning Networked high schools.	Results show students had increased opportunities to develop the six competencies of deeper learning, an overall increase in academic achievement, and higher college enrollment. Students also had more opportunities for project-based learning and collaboration with other students.
Rodriquez, Bellanca, & Esparza (2017)	Book	Pedagogy foundation	Connects deeper learning with 21st Century Skills of collaboration, communication, critical and creative thinking, problem solving, and self-directed learning.
Mullen (2018)	Empirical case study	Examined peer-mentoring and apprenticeship between STEM labs in the U.S. and China	Self-concept nurtured.

Table 16 *(cont.)*

Author & Year	Method/Data Source	Central Themes	Findings
Martinez & McGrath (2014)	Case study	Examined 8 innovative public schools immersed in 21st Century Skills. Students mentor one another and teachers also mentor.	Common threads of deeper learning: collaboration, problem solving, real world projects. Students were self-directed and responsible learners. Students learned from one another.
Powers, Schmidt, Sowers, & McCraken (2015)	Case study	Examined STEM mentoring for a group of 30 urban high school students, 30 parents, and 28 mentors	Results suggest "mentoring was a catalyst for youths' STEM career development". Key elements of successful mentoring include relationship development, encouraging guidance from mentors, and participating in experiential activities perceived as relevant by youth"
Carroll (2014)	Case study	Examined mentoring during a 7 week after-school STEM program for 7th and 8th graders. Mentors were mainly Science majors at a local university.	Results suggest "mentoring influence" was more of a priority than the content the students were learning" Establishing strong personal connections is the most important part of being a STEM role model for students.
Zaniewski & Reinholtz, (2016)	Case study	Analysis of 150 reports submitted by 14 mentor pairs of college science students	Found that a "sense of belonging" and "positive science identities" result from mentorship.
Nite, Capraro, Capraro, Peterson, & Metoyer (2017)	Meta-synthesis	Promising practices in STEM Teaching and Learning.	Examined STEM teaching and learning in middle and high school. Used 61 artifacts out of 509 compiled which were classified into 5 categories: reformed based teaching and learning, informal education, teacher factors, technology, and school factors. Findings: Most promising practice – Improvement of teacher content knowledge and pedagogy is the most important for effective STEM instruction. Support systems, such as mentors, are also effective. Inquiry is the most studied practice and may also be the most important.
Williams, Ernst, &	Empirical Survey (SASS)	Teaching Credentials in the Inclusive STEM Classroom	Increase of SWD in STEM Classrooms.

Rossi (2018)			Examined teaching credentials of STEM educators and special education teachers. Used secondary analysis of 2011–2012 Schools and Staffing Survey Teacher Questionnaire. Findings: only a small % of teachers had cross-credentialing. 80% of elementary and 90% of secondary had SWD on their caseloads.
Ernst (2014)	Empirical, ex post facto, survey (SASS)	SWD & LEP Service Loads of teachers	Used the SASS data set from the NCES to find out service loads of teachers. Discusses some accommodations for SWD & LEP Examples: note takers, readers, recording devices, sign language interpreters, screen-readers, voice recognition, adaptive software Findings: significant differences in service loads for technology teachers (communication & construction teacher)
Wells (2016)	Pedagogical framework	PIRPOSAL Model for STEM	This conceptual/pedagogical framework could be useful for SWD (my opinion due to my research findings that SWD benefit from graphic organizers and organizational tools). The acronym meaning is as follows: P=problem identification, I = ideation, R=research, P=potential solutions, O = optimization, S=solution evaluation, A = alterations, L = learned outcomes.
Fisher (2019)	Journal article	ESSA & SWD, robotics	References funding from the Every Student Succeeds Act and how it can be used for STEM. References how SWD lack procedural skills due to executive functioning deficits (Marino, 2010). List supports based on FIRST (For Inspiration and Recognition of Science and Technology) after-school STEM club using robotics. Supports are listed for SWD in STEM in the following areas: reading, executive functioning, attention, dyscalculia, autism, loud environments, unstructured environments, expectations, and behavior.

Marino (2010)	Literature review (71) from 1997–2009	SWD in inclusive science classrooms Technology research agenda for Elem. & Secondary	Technology can be used to help SWD. Identified 5 issues: 1–Clear disconnect between general education and special education technology-enhanced research. 2–Lack of access to curricular materials. 3–Students' attitudes about science. 4– Limited experiences with STEM careers. 5– General education teacher perceptions of SWD.
Li, Ernst, & Williams (2015)	Empirical, survey (SASS)	Supporting SWD & LEP STEM Educator Professional Development	2011–2012 School and Staffing Survey (SASS) Teacher Questionnaire. Examined STEM teacher participation in PD for science, technology, and mathematics (STM) compared to others. Findings: STM teachers tended to engage in fewer PD hours
Crouch, Keys, & McMahon (2014)	Empirical, teacher ratings	Student-Teacher Relationships Matter for School Inclusion	Examined the relationships of 133 students who transitioned from a school with mostly students with disabilities to 23 regular (urban Midwest) schools. Based on 111 teaching ratings, the study found that SWD who experience more positive or fewer negative social interactions with school staff have a higher sense of school belonging.

Legend

STEM	Science, Technology, Engineering, Math
CAPs	Content Acquisition Podcasts
UDL	Universal Design for Learning
SWD	Students With Disabilities
SASS-TQ	Schools and Staffing Survey—Teacher Questionnaire
IRAP	Implicit Relational Assessment Procedure
IAT	Implicit Association Test
CRT	Critical Race Theory
TDSAS	Three-Dimensions of Student Attitude Towards Science
mDAST	Draw-a-Scientist Test
CIS	STEM-Career Interest Survey
TESI	Teachers Exploring STEM Integration
DLN	Deeper Learning Network