

INCLUDING K–12 STUDENTS WITH DISABILITIES IN STEM EDUCATION AND PLANNING FOR INCLUSION

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ABSTRACT

This study addresses the knowledge gap on instructional practices that enable K–12 students with disabilities (SWD) to access STEM environments and develop 21st-century skills. A related purpose is to examine teachers’ planning for inclusion in elementary, middle, and high schools. STEM curriculum integrates two or more of the disciplines for approaching real-world problems. STEM lessons facilitate opportunities for students with special needs to develop their competencies and prepare for college and careers in a global economy. The primary question guiding this qualitative study was, What are teachers’ perceptions of instructional practices for STEM lessons for SWD in a suburban Virginia school division? Interviewees were 13 teachers from 12 US public schools. Drawing upon school practitioner responses, key instructional practices involving STEM lessons for SWD are reported. Access and barriers to STEM learning for SWD are also described, in addition to the PD considered desirable by participating teachers and opportunities for collaborating on STEM lessons. It was found that seven practices across the school levels enabled SWD to access STEM lessons. Three barriers for SWD’s participation in STEM projects were also identified. The need for PD targeting teacher collaboration and student disability knowledge was another outcome. The information gained should increase awareness of effective instructional practices for supporting SWD in STEM education and planning for inclusion.

This study addresses the knowledge gap on instructional practices that enable K–12 students with disabilities (SWD) to access STEM environments and develop 21st-century skills. A related purpose is to examine teachers’ planning for inclusion in elementary, middle, and high schools. Instructional practices involving students with special needs in STEM projects may not be widely known. Barriers to inclusion within STEM educational settings still exist. Teachers’ perceptions and experiences of instruction that involves SWD in STEM classrooms are central to this discussion. The most important contributors to STEM learning are educators’ content knowledge and pedagogical practices (Nite et al., 2017). Because teachers are influential, we sought to find out what they think and do.

Access and barriers to STEM education, also of interest to the current study, are reflected in the global workforce; notably, SWD remain underrepresented in STEM fields (Lee, 2011). Educators need to know what best practices in STEM enable SWD to develop 21st-century skills and, conversely, what prevents their participation and development. Education leaders may influence all these dynamics, including targeted professional development (PD) and continuing education. Utilizing teachers’ thoughts and recommendations, we offer insight into inclusion in STEM contexts, extending to targeted PD.

The question guiding this qualitative study was: What are teachers' perceptions of instructional practices for STEM lessons for SWD in a suburban Virginia school division? Secondary questions were: What do teachers think helps SWD gain access to STEM lessons? What do teachers think are barriers for SWD participating in STEM lessons? What kind of PD is needed to improve inclusivity of SWD in STEM lessons?

STEM is increasingly popular in K–12 public schools, with calls for integrative approaches to teaching the four disciplines (Estapa & Tank, 2017). Education systems worldwide are being expected to infuse STEM within various subjects (e.g., English/language arts) (Bybee, 2013; Hallinen, 2019; Klimaitis & Zakierski, 2019). STEM lessons should promote skills and content in the disciplines and be integrated into designs or projects, often with real-life application (Carmichael, 2017; Lesseig et al., 2017). STEM challenges can be as simple as building a marshmallow tower or as complicated as developing a prosthetic limb.

As a collaborating principal and professor, our mutual interest in K–12 STEM education, inclusion, and 21st-century learning inspired this study. We review literature on STEM education that merges with inclusion in classrooms and workforces. Then we move to the teacher interviews and address our methods, findings, and recommendations.

LITERATURE REVIEWED ON STEM AND INCLUSION

This section addresses what STEM and inclusion studies report about access and barriers to STEM education for K–12 SWD. It adds to the limited body of knowledge on instructional practices that involve SWD in STEM lessons and 21st-century learning.

STEM Definitions and Educational Concepts

STEM curriculum integrates two or more of the disciplines for approaching real-world problems (Hallinen, 2019). STEM lessons facilitate opportunities for students to develop 21st-century skills (e.g., citizenship, collaboration, communication, creativity, and critical thinking) in preparation for college and careers in a global economy (Mullen & Klimaitis, 2019).

No “single definition or conceptualization of what STEM integration is or should look like at the elementary level” exists (Estapa & Tank, 2017, p. 2). By *STEM*, we refer to STEM in education befitting “an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply [STEM] in contexts that [connect] school, community, work, and the global enterprise” (Hallinen, 2019, p. 6). Gerlach (2012) expounded, “Everyone knows what [STEM] means within their field,” yet meanings of STEM “all have one thing in common: It is about moving forward, solving problems, learning, and pushing innovation to the next level” (p. 3). We extend these definitions to fully include K–12 students with special needs so they too can reap the benefits of STEM education.

Viewpoints vary as to what STEM education should accentuate. As examples, Evans et al. (2014) highlighted engineering design and tackling global challenges, whereas Zollman (2012) set sights on STEM literacy for satisfying “societal, economic, and personal needs” (p. 1). STEM curriculum incorporates knowledge from diverse disciplines to propel authentic problem- and project-based learning experiences (Klimaitis & Mullen, 2020). Instruction in STEM content embeds 21st-century skills and may feature the scientific method and design processes (Basham et al., 2010).

Access to STEM ensures that widely divergent vulnerable groups (SWD and females) 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). In contrast, *barriers* to STEM lessons manifest as a lack of support, role modeling or mentoring, appropriate accommodations, advocacy, and assistive technologies (Sukhai & Mohler, 2016). *Disability* regarding children with special needs means they have at least one of the 13 conditions (e.g., specific learning disability) identified in the Individuals with Disabilities Educational Act (IDEA, n.d.). To benefit from public education, they require special education and related services.

Law and Policy Drivers of STEM Education

Regarding US education law, the Every Student Succeeds Act of 2015 (ESSA) helps fund STEM education and SWD (US Department of Education [USDOE], n.d.). This Student Support and Academic Achievement Enrichment Program has financially supported districts in increasing underrepresented students’ access to, and engagement in, STEM.

Policy can determine what is taught in the K–12 classroom and what is measured for school accountability. Accordingly, Judson (2012) compared state testing results for the 2009 National Assessment for Educational Progress and concluded that adding science as an accountability measure did not negatively impact grades 4 and 8 reading and math scores. Also, fourth-grade students scored higher in states that added science. All US states test math and science, but only a few use science for accountability purposes.

STEM education is regulated by state and local policies, initiatives, and goals (Bybee, 2013). A review of STEM definitions and materials for each of the 50 US states indicated that 58% have STEM-related postings and 82% have defined STEM in policy documents; 42% have bills, executive orders, or statutes (Carmichael, 2017).

In a US school district where elementary teachers must teach 10 STEM lessons annually, Mullen and Klimaitis (2019) studied 124 STEM lessons from 14 schools and 53 grade 5 classrooms. These lessons were examined for deeper learning and 21st-century skills in various subjects (e.g., English). SWD were included in lessons for which 91% incorporated problem solving, 90% fused critical thinking and creativity, and 54% integrated communication and 50% collaboration. STEM learning enabled SWD to develop targeted competencies.

Job Market and K–12 Education

Within a decade, STEM jobs grew at three times the rate of non-STEM jobs (US Department of Commerce, 2017). Before COVID-19, STEM jobs were expected to increase by 17%, compared with 9.8% for other occupations, with 1.9 STEM jobs for every person compared with 3.6 people for one job in another field. Besides the increased demand for STEM jobs, pay was predicted to be 26% higher than non-STEM jobs. In 2014, it was also reported that STEM wages were nearly twice that of other occupations; the 26 million STEM jobs in the US comprise 20% of all jobs (Jones, 2014). Given that the US job market influences K–12 STEM education (Bybee, 2013), instructional practices relative to equity are worth examining.

Skills and dispositions—creativity, innovation, and entrepreneurship—are expected to retain value in an uncertain future (Klimaitis & Zakierski, 2019). The preparedness of students for global economies is an investment in their future and society: “Investing to ensure a pipeline of workers skilled in STEM competencies” necessitates that these skills [are fostered] in young children” (Chesloff, 2013, p. 1). Science, technology, engineering, and math can be worked into projects that foster creativity and entrepreneurship. Student-centered approaches to instruction

allow for choices in the curriculum and ownership of learning (Brown et al., 2017). While ensuring the inclusion of SWD and females, STEM activities can propel engagement and inspire creativity, meaning-making, collaboration, connections, and global outlooks (Evans et al., 2014; Klimaitis & Mullen, 2020). Curriculum and schedules should allow for student immersion in STEM so creative capacities develop in anticipation of fulfilling careers and lives.

Children embody the fundamentals of STEM as curious beings, yet natural learning is excluded from formal education. Couros (2015) remarked, “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), adding that when students leave schools less curious, public education has failed them. Natural curiosity, independent thinking, and keen interests drive the success of STEM activities (Evans et al., 2014).

STEM Education and Student Engagement

Determining if students are immersed in a STEM activity depends on context and is somewhat subjective. However, indicators of engagement are evident (Evans et al., 2014). *Engagement* ensures student participation is beneficial, and that teachers thoughtfully prepare and plan. Engagement necessitates attention, curiosity, interest, and confidence that students demonstrate in the environment in response to “interest-driven learning” (Evans et al., 2014, p. 630). This is evidenced when students who are motivated to learn and progress seize the “opportunity to self-direct learning,” relating the “situation or problem at hand [to] their interests and experiences” (p. 630). Participation in STEM activities often involves peer interaction and tutoring and is expected to foster deep learning (Evans et al., 2014; Klimaitis & Zakierski, 2019). Engaged learning enables students to improve and experience success upon which to build (Parsons et al., 2014). In fact, engagement is “a robust predictor of student learning, grades, achievement, test scores, retention, and graduation” (Skinner & Pitzer, 2012, p. 21).

With so much emphasis on student engagement, it makes sense to prioritize learners’ interests and strengths, interaction with peers, and attraction to curricular formats with STEM-designed features (e.g., digital technologies). Based on STEM activity with middle schoolers, these focus participation, stimulate interest, and advance STEM literacy (Evans et al., 2014). Experimenting pedagogically, investing in best practices, incorporating design features, advancing creative learning, taking calculated risks, building on success, assessing progress, and learning from failure are all attributes of STEM environments (Klimaitis & Zakierski, 2019).

By monitoring their influence on participation, teachers can create dynamic STEM classrooms. Checking for student engagement, they can ask themselves if their environment is interest driven, conducive to engaging in activities, and conveys the value of effort. Such questions are especially applicable to STEM lessons, as many feature group projects. For increased engagement, learning involves student choice and is authentic, collaborative, and challenging (Parsons et al., 2014).

STEM Education and Inclusion of SWD

Three out of four SWD in K–12 public schools are instructed in the general education program. In the 2018–2019 school year, 7.1 million (14%) public school SWD ages 3 to 21 in the USA received special education services under the Individuals with Disabilities Education Act (IDEA) (National Center for Education Statistics [NCES], 2020).

The need for STEM inclusion of SWD is twofold. First, SWD are “significantly more likely to enroll in STEM majors,” and low-income SWD gravitate toward STEM majors to increase their job prospects (Lee, 2011, p. 76). Despite being in STEM majors, they are less likely to secure STEM careers. Second, SWD spend 80% of their day in the general education classroom (NCES, 2020), so teachers must ensure accessibility to STEM lessons.

Instructional practices used for including SWD in the general education classroom have been studied (Basham et al., 2010; Israel et al., 2015). The Council for Exceptional Children (CEC, 2017) identified 22 high-leverage practices for use with K–12 SWD organized around “assessment,” “instruction,” “practice collaboration,” and “social/emotional/behavioral practices.” However, research on the inclusion of SWD in STEM lessons and instructional strategies based on teachers’ feedback is limited and not all STEM disciplines (e.g., science) are included (Brown et al., 2017; Israel et al., 2013; Moorehead & Grillo, 2013). Moreover, the elementary grades are infrequently addressed.

SWD can lack exposure to the sciences, starting in elementary grades, which contributes to underrepresentation in STEM fields (Sukhai & Mohler, 2016). Although enrollment of SWD in science and engineering majors has increased, persons with disabilities remain underrepresented in the workforce.

In 2017, a new public education standard for inclusion was mandated by the US Supreme Court. *Endrew F. v. Douglas County School District* requires that an Individualized Education Plan (IEP) “enable(s) a child to make appropriate progress” (Yell & Bateman, 2017, p. 11). This calls for STEM educators to amend academic approaches to increase SWD’s participation in their lessons. Significant workload differences among staff can be a problem (Ernst & Williams, 2014). Beyond individual educators’ efforts, barriers for SWD can be reduced with accommodations and modifications guided by educational values (e.g., equity) (Sukhai & Mohler, 2016).

STEM Approaches for SWD

Supports specific to STEM for learners with special needs benefit most student populations. These include “regular movement, shorter class times, smaller classes, respectful, understanding environments, and flexible teaching styles,” the latter of which respond to problems and projects for driving inquiry (Fiore, 2014; Klimaitis & Zakierski, 2019). SWD may learn in different ways and contribute differently when working with peers on a STEM lesson or project.

Instructional strategies have been evaluated in STEM programming for middle schoolers with learning disabilities (Menzemer, 2008). Access to STEM for learners with special needs must be met with effective curriculum organized around big ideas (e.g., energy sustainability) (Basham & Marino, 2013).

Collaborative groups and station teaching for SWD are recognized in studies. STEM classes cotaught by general education and special education teachers can meet both IEP goals and learning needs (Moorehead & Grillo, 2013). Coteaching enables teacher collaboration on a big idea spanning two or more STEM disciplines (Basham et al., 2010). Heterogeneous groups for science support students with a learning disability. Small-group station rotations allow time for instruction to be differentiated and IEP gains to be measured. Accommodations and modifications can be made for small groups; working in a team allows for better communication, focused attention, and increased interaction for SWD (Basham & Marino, 2013).

Embedded STEM Supports for SWD

The Universal Design for Learning, a planning 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). Assistive technology that reads text aloud assist SWD whose reading is not at grade level (Sukhai & Mohler, 2016). Supporting multiple levels of reading ability is essential for STEM access for SWD (Basham et al., 2010). Digital models, simulations, and software assist in the comprehension of abstract concepts like space travel (Israel et al., 2015).

Barriers to Inclusive Education for SWD

At least seven barriers to inclusive education for SWD exist: (1) school personnel inadvertently thinking and acting in isolated ways rather than working together; (2) teachers and principals lacking vital knowledge and skills; (3) resistance to trying new ways to serve SWD; (4) lack of PD and training targeting inclusive STEM education practices; (5) lack of meaningful instructional, environmental, and testing accommodations; (6) low expectations for SWD; and (7) lack of mentors (Klimaitis & Mullen, 2020; Sukhai & Mohler, 2016).

Results from a schools and staffing survey found little training on the part of general education teachers in content areas outside their subject specialization that are needed for STEM projects, and special education teachers lacked specialized content knowledge (e.g., science) necessary for STEM lessons. Also, general education teachers did not have a full understanding of SWD (Williams et al., 2018). Teachers of science, technology, and math on the frontlines of STEM instruction have been known to attend fewer hours of PD than others (Li et al., 2015). PD should remedy all such deficits.

Minimal research has investigated the influence of STEM mentoring on SWD, but the need for mentors is a known obstacle (Sukhai & Mohler, 2016). Powers and colleagues (2015) examined intentional STEM mentoring for urban high school students, parents, and mentors. Some of the mentors had disabilities; coaching involved interaction with mentees and “STEM postsecondary and career exploration” (p. 27). Students and mentors participated in STEM activities. Peer mentoring sparked “STEM career development”; the SWD’s learning gains from the “successful mentoring included relationship development” and the SWD–student mentor matches reflected “personality and overall interest compatibility” (p. 30).

METHODS

Research Setting and Participants

A suburban school division in southwest Virginia, USA, was the setting, and 12 public schools served as the research sites. The division was chosen owing to its emphasis on STEM teaching from kindergarten through grade 12 and 21st-century skills. Its strategic plan required that these skills be addressed in instruction and that elementary teachers implement 10 skills-directed STEM lessons per year.

Experienced general and special education teachers were purposefully selected to share perceptions of STEM-oriented instructional practices for SWD. Eligible teachers ($N = 13$ —5 at the elementary level, 4 middle, and 4 high school; 8 females, 5 males) had at least 3 years of teaching experience; also, they had taught STEM lessons inclusive of SWD. The five elementary teachers were from five schools; the four middle school teachers were from four schools (one teacher taught

at two schools); and the four high school teachers were from three schools (two of them were from the same school). Prospective participants were based on principals' contacts.

Data Collection and Analysis

Demographic data from the 13 teachers were collected followed by their self-reports (interview data). The demographics survey (not included) was designed by the researchers. Open-ended questions on an original interview protocol (Table 1) elicited views of instructional practices that support the inclusion of SWD in STEM lessons. Interviewees were asked what they were doing to improve access and/or reduce barriers to STEM curriculum for SWD.

From May to June 2020, 45-minute interviews occurred virtually one-to-one. WebEx was used to accommodate pandemic-induced health concerns. Conversations were private, and participants and their schools remained anonymous. The audio recorded sessions were stored on a password-protected laptop and transcribed by an online service. Interview transcriptions were emailed to the participants for member checks; all verified their statements. Following qualitative procedures (Yin, 2018), deductive and inductive coding ensued. Based on the literature review and research questions, *access* and *barrier* were meta codes. Frequency counts of codes were tracked and in vivo coding was also applied; participants' actual words and surrounding phrase(s) were coded as an aid for examining nuanced expressions namely of instructional practices.

Access was linked to specific codes: *accommodation, aide, assistive technology, audio book, big idea, breaks, differentiation, digital calendar, group norms, flexible scheduling, frontloading information, graphic organizer, headphones, IEP, leadership, math ability, orthopedic impairment, paraprofessional, PD, peer helper/mentor planning, reading ability, retelling directions, scaffolding, small group(s), student input, training, and visuals.*

For *barriers*, associative codes included *advocacy, below-grade-level reading ability, collaboration time for staff, environmental trigger, executive functioning skill, lack of accommodation, lack of teaching knowledge/training, lack of support staff, low student expectation, math dyscalculia, physical disability, and planning time.*

Transcriptions, read multiple times, were coded; notes became memos. Codes were generated for each transcription, and within and across the levels (elementary, middle, and high school). In a spreadsheet, codes from the interview protocol were listed on the *x* axis, and codes from the transcriptions on the *y* axis. Eleven data summary forms were developed, one for each interview question. Three qualitative researchers each coded 20 pages of raw data. The coding was compared; searching for commonalities, we arrived at themes and intercoder reliability.

Research Design and Validation

K-12 principals carefully selected teachers based on the eligibility criteria, after we contacted 26 of them in the division. This approach is in keeping with qualitative research and open-ended (interview) questions said to work best in studies with small populations (Yin, 2018).

Our Teacher Interview Protocol (Table 1) was inspired by Hagerty's (2019) instrument that probed teacher perceptions about STEM education and Kumar's (2019) survey that explored teacher attitudes toward inclusive education in STEM classrooms. However, we did not use their questions. Besides validating the protocol, three initial interviews (with one teacher at each level) established that no procedural adjustments were needed.

Table 1

<i>Teacher Interview Protocol</i>
1. What process do you go through to become familiar with accommodations and modifications in a student’s IEP?
2. How do you prepare your STEM lesson or unit with differentiation in mind for your SWD?
3. Do your SWD have input on their areas of interest on the STEM lessons you plan for them?
4. How might your STEM lessons offer opportunities for SWD to be leaders?
5. What strategies might you be using to help a student with a math or reading disability?
6. What strategies might you be using to help a student with a physical disability?
7. What general strategies or initiatives might you be using to help SWD access STEM lessons?
8. Based on your experiences, what are some barriers to STEM lessons for SWD?
9. In your opinion, what PD/training is needed to promote the inclusion of SWD in STEM lessons?
10. If you have the assistance of support staff like special education teachers, paraprofessionals, and student mentors during inclusive STEM lessons, how do you make use of them to support SWD?
11. Is there anything else you would like to add?

DISCUSSION

Demographics were collected and nine thematic findings resulted from the teacher interviews. Seven of these are key instructional practices for including SWD in STEM lessons.

Demographically, eight females and five males, all White (one did not identify race), were distributed across the three grade levels. This sample of experienced teachers had taught anywhere from 6 to over 26 years. While some were teaching one content area only, most were handling multiple STEM and non-STEM subjects. Almost half had a master’s degree. Teachers’ license/certification areas ranged from general education to special education, to learning disabilities, and they were certified in grade levels (e.g., PK–12) and content areas (e.g., math).

Also, nine of the teachers had completed one or more special education courses in college and all but two had attended PD/training on inclusion specific to SWD. The job classification was general education for 10 of the teachers, and special education for 3. STEM was not identified as a content area or source of expertise by any participant. Engineering, notably, was missing at the elementary and middle school levels, with representation held by two high school teachers. English/language arts representation was mainly at the elementary level, where there were four such specialists, and one at the middle and high school levels. Math expertise was also mostly reflected in the lower grades, with three elementary math teachers and one in the middle and high school. Science, too, was more evident in the elementary grades, with three teaching science; two of the high school teachers taught science (with no representation at the middle school level). Technology expertise stood out at the middle school level, with three teachers of technology—one each in the middle and high schools.

Seven instructional practices (thematic findings) across the teachers and school levels enabled SWD to access STEM lessons. These best practices in inclusive STEM are elaborated

(points 1 through 7 below). Point 8 identifies barriers to SWD’s participation in STEM lessons and point 9 captures participants’ recommendations for remedying obstacles to STEM inclusion.

1. *IEP review*: Initial knowledge of SWD was achieved by these teachers through IEP document review and communication with staff members.
2. *Students’ interest*: Knowledge of a student’s disability and interests guided differentiation of instruction.
3. *Relationship building*: Teachers’ relationships with SWD and teacher knowledge helped SWD gain access to STEM lessons.
4. *Support staff*: Assistance of support staff was considered essential for managing the classroom and implementing IEP accommodations.
5. *Hands-on learning*: Learning by doing helps SWD access STEM lessons and perform roles, jobs, and tasks.
6. *Intentional grouping*: Being grouped by design supports SWD during STEM lessons and facilitates their roles, contributions, and leadership opportunities.
7. *Classroom accommodation*: Accommodations in, and modifications to, the environment and support from others enable SWD to access STEM curriculum.
8. *Participation barriers*: Student ability, lack of adult support, and time limitations with lessons were the main barriers for STEM lessons.
9. *PD recommended*. More training was called on to support teacher collaboration and extend disability knowledge.

IEP Review (Finding 1)

All 13 teachers shared the procedures they follow to get to know SWDs and find out what they need to succeed in school. Participants found it helpful to develop spreadsheets for quick reference. They also spoke with case managers and former teachers to gain insight into individuals’ needs and interests. One participant noted how after she reads the IEPs, she adapts her teaching style to SWD’s needs. All such actions qualify as best practices for inclusive classrooms: “Effective multi-tiered instruction that is personalized to students’ needs and interests depends on high-quality, comprehensive information about individual students” (p. 51); as recommended, teachers used a variety of sources to assess student strengths and needs and collaborated with stakeholders on quality programming (CEC & CEEDAR Center, 2017).

Students’ Interest (Finding 2)

Every teacher underscored the importance of understanding a student’s disability and interests to plan and adapt STEM lessons that meet their needs, which corresponds with expectations stated in research: “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” (Basham & Marino, 2013, p. 9). Being informed about students’ disabilities helps teachers balance what kind of support they provide and how much. Providing STEM learning opportunities where students can “feel the struggle” while not becoming defeated was Teacher F’s insight. Many STEM lessons are designed to be open ended, interviewees explained, so students can choose their own designs. Knowing SWD’s interests is a high-leverage practice for inclusive classrooms (CEC & CEEDAR Center, 2017). All teachers said they use knowledge of a disability and interests to allow SWD choice in demonstrating mastery. They also reported that SWD have

some of the most creative ideas in their classrooms and that they seem to like learning through STEM. Teacher C shared, “Our SWD really do enjoy STEM projects because they can be creative in an area they don’t feel frustrated in or feel like they have to perform to a certain level. There’s a bit of freedom in a STEM project.”

These teachers’ planning involving SWD accounted for the individual learner, disability type, and STEM lesson. Teacher A considered whether SWD could interpret the abstract ideas associated with STEM projects and did not hold different expectations of performance for them. An inspiring response came from Teacher G, who years earlier had a student struggling with a photography project in the STEM environment: “I quickly realized he wasn’t going to be able to manipulate the chemicals in the darkroom. So, I found things he could do well [which made him] the expert at those things.” This teacher continued to plan for alternative scenarios, making last-minute changes to benefit SWD’s learning: “I build enough flexibility into my lessons so I can make adjustments to meet the needs of a certain student or group.” Teacher L’s planning differed because her students were twice exceptional (gifted but with learning or developmental challenges), requiring extra time or added explanations. Based on IEP requirements, the teachers planned for accommodations in STEM classrooms. Some enlisted staff in planning STEM lessons and utilized aides in circumstances involving severe disabilities. The five instructional practices used to plan and differentiate STEM lessons for SWD were stipulated as disability/ability, intentional grouping, STEM dependent, plans for accommodations, and plans for support staff.

Relationship Building (Finding 3)

Becoming familiar with their SWD and building relationships with them were considered important. Teachers also reported that knowing everyone in their classes facilitates a broader support system for SWD and teacher decisions about group configuration and peer assistance. Teacher B stated, “You have to know your kids. If you know their personality and heart, you’ll know which ones are going to build up SWD and help them in a loving way.” Awareness of socioemotional needs was crucial to them; SWD were helped with developing coping skills for doing STEM projects and collaborating. Positive student–teacher relationships strengthen SWD’s sense of belonging in school (Crouch et al., 2014).

Numerous instructional practices were shared for learning SWD’s interests. Teachers allowed for choice and options within the parameters of STEM challenges. With group STEM projects, students often chose the roles, parts, jobs, or things of interest. Teachers B, F, and M described how they facilitate SWD’s problem solving, while teachers C, H, and E talked about how they encourage creativity. Participant J had students work together to mirror workforce expectations. Frequent practices used for eliciting student input on STEM activities were student interest, student design choice, group role choices, teacher facilitation, and relevance to student.

Support Staff (Finding 4)

Participants all reported utilizing support staff (when available) to help with classroom management; eight also tapped personnel to assist with implementing IEP accommodations. For STEM lessons involving a large group of students, safety was a concern, so having additional adults in the room was needed. Communication with staff was essential for being clear about what kinds of support and how much to provide for individual SWD. All adults concerned had to work together to ensure the quality and integrity of IEP accommodations (e.g., specialized instruction and services and supports like monitoring SWD’s progress). For SWD needing intensive support during STEM

projects, their lessons occurred when support staff were present. As Kumar (2019) echoed, teachers' attitude toward inclusive STEM tends to be positive when staff and resources are available.

Hands-on Learning (Finding 5)

Hands-on learning was described as an instructional practice that engages SWD in STEM lessons and increases their achievement (as confirmed by Parsons et al., 2014). At a high school, Teacher J thought that concepts make more sense for SWD when the learning is practical and project oriented. Across the high schools, many STEM lessons involved machines (e.g., laser engravers). A middle school teacher described an interactive STEM project with real-life application that had students (in a general education classroom and mainstreamed SWD) mentor SWD from a self-contained classroom. Student pairs designed storage crates for a senior citizen center. Elementary teachers' classes are presented with an open-ended STEM challenge (e.g., build a structure satisfying specifications and function requirements) for which supplies are provided.

Intentional Grouping (Finding 6)

All but one teacher indicated that intentional grouping was a key instructional practice for ensuring that SWD will thrive. Eleven teachers agreed that the mixed ability grouping of students with and without disabilities for STEM lessons affords benefits for SWD. The implication was that mixed grouping balances a student's learning challenge and compensates for disability deficits while enhancing individual strengths. These teachers also explained that they use a variety of grouping formats (mainly mixed ability grouping and cross-ability peer tutoring) to serve the needs of their SWD. These teachers used information they knew about SWD and other students to decide who would collaborate well and in what kind of format. They saw intentional grouping as a mechanism for balancing strengths and weaknesses for SWD, as well as managing behavior by avoiding personality clashes. Some of these educators rotate leadership within a group and choose the leaders, whereas others identify SWD's strengths conducive to naturally leading others. Leadership roles assumed by SWD in these classrooms include presenting on behalf of the group, making design choices, performing as a data collector, tracking of project tasks and deadlines, collecting tools/media, and overseeing equipment. Even when SWD were not group leaders, they benefitted from leadership being a norm in STEM contexts dependent on students sharing ideas, using their talents, and thinking for themselves. SWD benefit from collaborating and communicating with peers (Basham et al., 2010; Israel et al., 2015). Creating opportunities for peer leadership enables SWD to develop leadership abilities aimed at achieving a common goal and preparing for life. This process helps SWD transition from having interest in STEM to studying STEM in college and being employed in STEM careers.

Classroom Accommodation (Finding 7)

Eleven teachers asserted that room modifications gave SWD physical access to STEM lessons, and 10 reported that support from others was an access factor. They described spaces that were handicap accessible and modified for individual needs, ranging from adjusting lab tables for wheelchairs to managing constructive group collaborations. Support staff and classmates helped with SWD's access to STEM lessons, whether physical, cognitive, or socioemotional. Such modifications were in keeping with Virginia's requirement that facilities are appropriate for SWD with specialized services; sound inclusive practices extend to peer mentoring support. The teachers enlisted students as mentors of SWD on projects (e.g., brainstorming) and helpers with components of STEM projects (e.g., using manipulatives). Participant C stated, "When you find that really good

peer mentor, it can just mean the world of difference to a SWD [who] sometimes prefer the help to come from other students.”

Participation Barriers (Finding 8)

Three barriers that SWD face when trying to access STEM lessons were named: student ability (8); lack of adult support (7); and time limitation (6). Although most SWD like STEM projects, some lack confidence and may be reluctant to participate. Some SWD may have difficulty generating ideas or might need brainstorming or processing assistance to take an idea to the next level. Lack of adult support was attributed to educators and guidance counselors who do not promote SWD’s engagement in STEM tasks. Unsupportive staff, interviewees said, lacked confidence in SWD’s ability to contribute to STEM lessons or felt their time would be better spent in another subject or (math) remediation. As Sukhai and Mohler (2016) revealed, negative teacher bias is thought to be an artifact of socialization: “[SWD are] actively excluded from STEM when they are deliberately coached in a direction away from the sciences” (p. 36). This statement reinforces the concern that some staff do not support SWD’s participation in STEM. Although extended time is often an accommodation written into IEPs, interviewees viewed time as a participation barrier for SWD owing to such pressures as instructional pacing guides for curriculum that align with state standards.

PD Recommended (Finding 9)

Targeted PD is needed to improve SWD’s access to STEM curriculum. Eleven teachers asserted that PD should foster teacher collaboration and sharing of STEM pedagogical and content expertise in service of STEM learning for SWD; seven stated the need for more education around disability knowledge specific to students. Teacher collaboration, it was suggested, could be encouraged in PD sessions and within schools. A desire was expressed to work with other teachers on STEM lessons that incorporate learning strategies for SWD and observe how colleagues implement STEM curriculum and engage SWD in various subjects. Participants wanted training on each disability’s characteristics to readily modify a STEM lesson. Supportive of these statements, Williams et al. (2018) identified a need for cross-credentialing among teachers, and Nite et al. (2017) found that teacher content knowledge impacted student outcomes. Several interviewees considered their workforce knowledge to be a useful resource in the classroom but sharing it outside their program was not broached.

Conclusions and Recommendations

We have fulfilled our two purposes: to address the knowledge gap on instructional practices that enable K–12 SWD to access STEM lessons and develop contemporary competencies, and to examine teachers’ planning for inclusion in elementary, middle, and high schools. Besides reviewing studies of STEM and inclusion, we drew upon the reports of 13 teachers from 12 schools who imparted how they engage SWD in STEM activity and barriers for participating in STEM, extending to what PD could help ensure meaningful inclusivity.

Teachers and leaders play an essential role in creating cultures that favor accessibility through inclusive STEM learning for SWD. The insights conveyed could support these stakeholders with mindfully preparing for inclusion and adapting STEM curriculum. Crucial instructional practices that include SWD in STEM lessons were reported as follows:

1. Conducting an IEP document review and communicating with staff and getting to know SWD's needs and interests.
2. Gaining knowledge of a student's disability and interests guides differentiated instruction.
3. Building relationships with SWD positions teachers to help SWD with STEM learning.
4. Utilizing staff is essential for managing classrooms and implementing accommodations.
5. Intentional grouping during STEM activity supports SWD's progress and belonging.
6. Hands-on learning makes STEM accessible and the engagement can lead to achievement.
7. Modifications to settings and support help SWD access STEM projects and excel.

These findings could also help SWD in subject areas outside STEM (e.g., language arts).

A major study limitation is that the teacher data were extracted from one suburban school division, although urban and rural schools were included in the literature review. Different divisions within Virginia and other states may not have the same STEM initiatives and requirements as the context studied. Also, while we did not extend our reach to include female underrepresentation in STEM education and careers, we have investigated this area of marginalization (Klimaitis & Zakierski, 2019). Additional research could examine teacher perceptions of access to STEM for K–12 SWD to gain a broader sense of the issues at play. While participants' responses referenced a range of disabilities, emerging studies could narrow the focus by disability category (IDEA [n.d.] provides the classifications). Alternatively, follow-up research could investigate student perceptions of access to STEM or how STEM lessons address skills development and outcomes for SWD. Further, new research could examine integrative STEM activities for SWD and PD for K–12 educators. It could also focus on grades or the college level, or hybrid and virtual contexts.

Practitioners and policymakers concerned about equal opportunity and equity with respect to inclusion can benefit from four recommendations for engaging SWD in STEM lessons.

1. *Implement effective instructional practices that facilitate SWD's access to STEM curriculum.* Getting to know SWD and building relationships with them is important. Support staff play a vital role in aiding SWD's involvement in STEM and can be included in advance planning (e.g., scheduling). Pedagogically, engagement in STEM lessons is strategically leveraged by design—intentionally planned groups facilitate SWD's immersion, collaboration, group roles, and success. The accessibility of STEM lessons (including online) is a planning consideration, as is the formation of peer mentorships.
2. *Find solutions to barriers that prevent SWD from engaging in STEM lessons.* PD is advisable on disability characteristics, in effect giving teachers a firmer foundation upon which to support SWD's involvement in STEM work. Deliberate personnel planning would ensure SWD's participation in STEM learning through such means as the scheduling of paraprofessionals and/or special education teachers during STEM lessons to support SWD; establishing a common planning time between general education and special education teachers for STEM lessons; and facilitating planned collaboration and co-teaching that builds capacity for teachers and students alike.
3. *Support teacher PD to increase knowledge of disabilities, teacher and student collaboration, and STEM learning for SWD.* PD is needed to educate about issues of disability and how to make STEM accessible, inclusive, and educative. Collaboration among teachers, including teaching observations, could usefully reveal how STEM lessons are implemented in various content areas. Budgeting time for teachers' learning and actions is a crucial step toward inclusivity.

4. *Promote equitable access to STEM lessons by creating policies or operationalizing existing ones.* Education policy expectations should support STEM literacy and readiness for 21st-century jobs. Funding should align with priorities.

The unrelenting marginalization of SWD in the workforce has been called out as “occupational injustice” (Sukhai & Mohler, 2016, p. 28). Schools are expected to disrupt inequities like the lack of opportunity for SWD in STEM fields. Thus, access to STEM lessons and effective instructional practice are paramount for cultivating SWD’s 21st-century skills. The participants had some experience with supporting SWD during STEM activity and identified approaches for this purpose. However, the obstacles SWD encounter extend beyond environmental conditions. Some SWD may lack the confidence or ability to participate in STEM projects, and some adults may think are incapable. Targeted PD can address these issues and ways to help SWD cope.

Should this research sparks ideas for better serving SWD in STEM and 21st-century education, the instructional practices described offer timely information about inclusion. A desired outcome is that the teachers who made PD recommendations will positively impact school cultures. Presently, all unfolding changes are pitted against the pandemic. With the suspension of normal school operations in 2020, US public schools were challenged to reimagine how best to virtually educate students. Despite the chaos, accessibility to, and engagement within, STEM lessons that rely on hands-on learning warrant vigilance. Teachers are on the frontlines educating SWD and they need more supports. Educating SWD in the present is an investment in the future.

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