FOR STUDENTS WITH DISABILITIES
Journal of Science Education

RESEARCH ARTICLE

STEM and high school students with disabilities: A qualitative review of the research literature

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Abstract

We conducted a qualitative review of the research literature on STEM (science, technology, engineering, mathematics) related to high school students with disabilities (SWD). We selected and analyzed 53 articles to answer two questions: (1) How are high-school SWD prepared for careers in STEM? (2) How are educators prepared to support high-school SWD for opportunities in STEM? In answering the first question, four qualitative themes emerged: (a) barriers to STEM, (b) increasing STEM opportunities, (c) STEM readiness in college and career, and (d) STEM identity. In answering the second question, three qualitative themes emerged: (a) individualizing learning and supports for SWD, (b) using technology and collaboration among educators, and (c) professional development for educators. Limitations of this review related to search terms and inclusion criteria. Implications of this review related to the need for more research on STEM enrichment programs, STEM identity, and long-term outcomes.

Keywords: high school students with disabilities, STEM and special education, STEM careers

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Submitted October 03, 2021
Accepted July 09, 2022
Published online November 21, 2022
DOI: 10.14448/jsesd.14.0006

Introduction

The National Science Foundation (NSF) began using an acronym 'SMET' in the 1990s, combining science, mathematics, engineering and technology (McComas, 2014; Sanders, 2009). As the Assistant Director for Education and Human Resources Division at the National Science Foundation (NSF) in 2001, Dr. Judith Ramaley rearranged the letters to 'STEM'. In an interview several years later she explained the acronym change, stating that 'STEM' emphasized the connection between the four individual subject areas, rather than implying that any one or two were more important than the others (Christenson, 2011; Chute, 2009).

While some have viewed STEM as eluding a single straightforward definition (Gerlach, 2012), others have posited that one is unnecessary (Holmlund et al., 2018). Regardless of whether such a definition will ever be established, the last twenty years has seen STEM grow from classrooms and research centers to mainstream culture. That growth, however, has not occurred evenly nor experienced similarly across different groups of people. Young adults and students with disabilities (SWD), especially, have encountered more barriers to STEM opportunities and their benefits than their peers without disabilities (National Science Foundation, 2021). Thus, we conducted a qualitative review of the research literature over the last twenty years in order to understand what that growth in STEM has meant in terms of the educational and career goals and opportunities for high school SWD.

Rationale of Current Study

The Bureau of Labor Statistics (2017) reported that in 2015, there were nearly 9 million jobs in science, technology, engineering, and mathematics (STEM) fields with an average annual wage of $87,570 in STEM occupations and $45,700 in non-STEM occupations. In April 2020, the Bureau of Labor Statistics (2020) projected 8.8 % growth in STEM occupations in the U.S. from 2018 to 2028, with a median wage of $86,890, and 5.0 % growth in non-STEM occupations with a median wage of $38,160. These government reports focus on STEM occupations requiring at least a bachelor's degree and clustering in metropolitan areas, such as San Francisco and New York. That focus, however, limits the consideration of and access to STEM careers for millions of people who do not fit into either category. In response, the Brookings Institution analyzed STEM occupations by coding the "O*NET Knowledge Statements" used to define occupations in the labor market based on the amount of STEM knowledge required (Rothwell, 2013). That process resulted in expanding the STEM designation to include occupations requiring less than a bachelor's degree and existing outside of metropolitan areas. This expanded designation comprises what is now generally known as the 'hidden' STEM economy.

Major initiatives by the National Science and the U.S. Department of Education, among others, have placed greater emphasis the preparation of all youth for college and careers STEM fields. Despite these efforts, however, data continue to show that SWD in early grades are falling behind their peers without disabilities in science achievement (National Center for Education Statistics, 2015). Thus, we intended this qualitative literature review to inform the field, particularly high-school educators and transition specialists. Aside from reporting our findings, we also had practical goals of increasing awareness of the different pathways to a STEM career. We specifically focused this review on high-school SWD and educators as they are at the core of the special-education transition pro-

DOI: 10.14448/jsesd.14.0006

cess (i.e., IDEA Indicator 13) that prepare SWD for post-high school education/training or employment (i.e., IDEA Indicator 14). Thus we framed our review around two main questions and corresponding sub-questions:

1. How are high-school SWD prepared for careers in STEM?
   (a) What barriers do SWD identify relative to STEM coursework or careers?
   (b) What supports do SWD need in order to engage in STEM opportunities?
   (c) What contributes to SWD developing a STEM identity?
2. How are educators prepared to support high-school SWD for opportunities in STEM?
   (a) How do educators individualize instruction for SWD in STEM?
   (b) What contributes to educators' confidence in teaching SWD in STEM?
   (c) What professional development do educators need to support SWD in STEM?

Method

We chose to conduct a qualitative review of the research literature related to STEM and high school SWD. Although a common criticism of the type of literature review is that it limits the generalization of cumulative knowledge (Paré et al., 2015), we chose it for two reasons. One, we believed the field (i.e., both researchers and practitioners in education) would benefit from a broad coverage of articles that provide the scope of the current knowledge regarding STEM and high school SWD and how that knowledge has been derived. Two, we recognized that the extant literature in special education and related fields would contain a variety of articles and different methods (e.g., Snyder, 2019). Being able to compare across these different articles (e.g., research reports, position papers) and methods (e.g., quantitative, qualitative) to discover common themes with well-established research methodology, rather than only assessing measured quantitative effects, was essential (Onwuegbuzie et al., 2012). We next detail how we conducted the review.

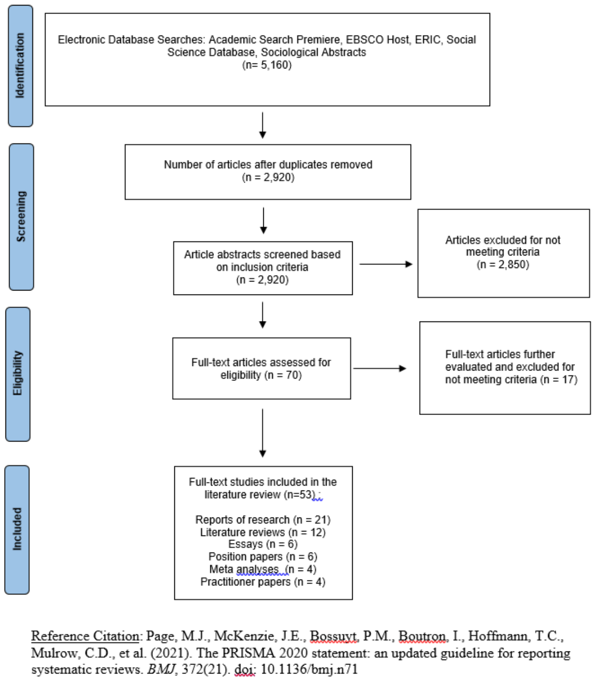

Figure 1: PRISMA Diagram for the Search of Research Literature and Selection of Articles

PRISMA

We utilized the PRISMA (Preferred Reporting Items for Systematic reviews and Meta- Analyses) method utilizing best-practices depicted with a flow diagram (see Figure 1) to "prepare a transparent, complete, and accurate account" (Page et al., 2021, p.1) of why we conducted this literature review, what we did, and what we found. The specific PRISMA process that was followed in our review consisted of three steps in order: (1) Identification: Records were identified through database searching; (2) Screening: Records were screened for eligible, records sought for retrieval, and full-text articles assessed for eligibility; (3) Included: Total number of studies that were included in the review. Each step is separately detailed below.

Identification

We started with a broad definition of STEM as referring to any one of the four fields – science, technology, engineering, and mathematics – as well as the integration of two or more fields (Honey et al., 2014). We conducted a search of electronic research databases, including EBSCO Host, Academic Search Premiere, ERIC, Social Science Database, and Sociological Abstracts, by applying combinations of 'high school students with disabilities' and the STEM terms. We enabled the search engine to use related words and terms. In this step, we applied these filters: peer-reviewed articles, in English, and published in the year 2000 or later. This process yielded a total of 5,160 articles. We then searched through this set of articles and deleted duplicates, which yielded a total of 2,920. The next step in the PRISMA process, screening, further reduced the total number of articles for this review based on the inclusion criteria.

Screening

We downloaded articles from the databases and sorted them into two categories, relevant and not relevant. Relevant articles included any one of these criteria: (a) addressed high-school SWD preparing for or engagement in STEM careers, (b) high-school educator professional development for STEM, or (c) high school-level STEM program or curriculum. This process yielded 70 full-text articles deemed relevant by a consensus of all the authors. We independently read these articles applying the inclusion criteria. Then we met, and together we further scrutinized these articles. Based on the meeting and discussion, we excluded an additional 17 full-text articles and selected a final set of 53 full-text articles to review.

Included

These 53 selected articles are marked with an asterisk in the References section. The first and second authors took these articles and imported the PDF files into NVivo 12 (QSR, 2019), a software commonly used for qualitative data analyses. Because we utilized qualitative methodology for conducting this literature review, we followed best practices in qualitative research in education for ensuring trustworthiness and credibility, which included (a) reaching data saturation to include different perspectives and enhance richness of information, (b) triangulating different sources of data, (c) acknowledging how researcher perspectives, beliefs, and biases influence data collection and findings (i.e., reflexivity), (d) coding independently for initial review and then conducting consensus coding to develop final codes, and (e) minimizing reactivity through neutral stances and questions (Brantlinger et al., 2005).

The first and second authors read and reviewed each article independently and applied start codes (Miles et al., 2014) on all 53 articles in the NVivo software. To ensure thorough and consistent coding, they defined the codes using examples and non-examples (Rossman & Rallis, 1998) culled from the articles. Next, the authors extracted 'node reports' from the NVivo software (a feature of the software) in order to inspect and identify main codes and sub-code extensions. The authors then selected 30 articles at random to conduct interrater agreement for coding using Cohen's Kappa (Cohen, 1960), and produced a coefficient of .73. This value

DOI: 10.14448/jsesd.14.0006

represented the proportion of coders' agreement across the 30 articles taking into account coders' chance agreement (McHugh, 2012). The authors completed consensus coding, and derived the themes to answer the two questions that framed this literature review.

Findings

A summary of the 53 articles included this literature review is provided in Table 1; (see end of document) they are also indicated with an asterisk for the corresponding citation in the Reference section. These articles were published between 2000 and 2020 in 36 peer-reviewed journals, and a plurality (n=21) were research reports using qualitative, quantitative, or mixed methods. The remaining included articles were literature reviews (n=12), essays (n=6), position papers (n=6), meta-analysis (n=4), and practitioner papers (n=4). Our analyses of the 53 articles produced findings in the form of qualitative themes, which also constituted answers to the two questions and sub-questions (described earlier in the introduction) that framed this review.

First Question: Preparing High-School SWD for STEM Careers

For the first review question, our analysis of selected literature resulted in four emergent themes: (a) barriers to STEM, (b) increasing STEM opportunities, (c) STEM readiness in college and career, and (d) STEM identity. Our analyses of the selected literature also produced subthemes for two of these themes, barriers to STEM and increasing STEM opportunities.

Theme 1: barriers to STEM

This theme emerged as the area of the relevant literature receiving the most research attention. Three specific types of barriers (i.e., sub-themes) were prominent: (a) lack of STEM experiences, (b) inaccessible classroom or school environments, and (c) lack of access to STEM curriculum. Examples of these sub-themes included traditional approaches to STEM that rely on substantial memorization (Scruggs et al., 2008; Villanueva & Hand, 2011), complex and dense STEM content that places significant demands on working memory and attention (Basham et al., 2010; Boyle, 2012; Isaacson & Michaels, 2015; Mason & Hedin, 2011), limited STEM access due to negative stereotypes and expectations (Basham & Marino, 2013; Dunn et al., 2012), and inadequate accommodations (Rule & Stefanich, 2012). Barriers to STEM also involved the intersectionality of student disability with socioeconomic status (SES), gender, and race/ethnicity (Mau & Li, 2018; Wang & Degol, 2017), which presents implications for STEM education and career pathways, as diverse SWD become an increasingly larger share of the postsecondary education population and the workforce in STEM occupations (Byars-Winston, 2014).

Theme 2: increasing STEM opportunities

For this theme, two specific opportunities for increasing STEM opportunities (i.e., sub-themes) were prominent: (a) expanding STEM programs by program and setting, and (b) recruiting and supporting SWD in STEM. Examples of these sub-themes included summer science camp for those with visual impairment (Supalo et al., 2011; Supalo et al., 2014); financial supports and off-campus internships in STEM (Leddy, 2010; Shoffner et al., 2015); STEM learning communities (Izzo et al., 2011; Peters-Burton et al., 2014) and use of different spaces at school for STEM learning (Subramaniam et al., 2012); supports and mentorships in STEM (Dunn et al., 2012), and increasing institutional commitment to recruiting, retaining, and graduating

DOI: 10.14448/jsesd.14.0006

SWD into STEM fields (Marino & Beecher, 2010).

Theme 3: STEM readiness in college and career

This theme appeared to be more sparse and emerging than the other areas (i.e., themes) of the relevant literature (above). Research suggests that high-school SWD need rigorous curriculum to prepare for STEM in career or college, but that alone is insufficient (Gottfried et al., 2016). They also need work-based experiences (Cease-Cook et al., 2015), which would involve partnerships with organizations in the community to provide those experiences, as well as career-technical education (CTE) (Sublett & Plasman, 2017) or other applied STEM courses while in high school (Plasman & Gottfried, 2018), and other STEM learning opportunities such as in-school field-trips and or out-of-school tutoring (Rakich & Tran, 2016).

Theme 4: STEM identity

This theme represents the newest area of the relevant literature. Thus, we found the fewest number of studies in our search. STEM identity and its often-associated area of social-emotional learning (SEL) have historically received the least research attention in special education, perhaps, due in part to construct and data complexity, with interconnected and contextualized variables such as identity, self-efficacy, and self-confidence. Gregg et al. (2017) studied the effects of virtual mentoring, using devices and platforms such as email, smartphones, and social media, on persistence in STEM for high-school SWD. The authors found that the largest improvements were in their perceptions of self-advocacy and self-determination, although these outcomes differed by student disability type and ethnicity. Likewise, analyzing nationally representative data of high school students, Sublett and Plasman (2017) reported that applied STEM coursework was predictive of self-efficacy increases in science and math for males without disabilities, but not for females or for SWD.

Second Question: Preparing Educators to Support SWD in STEM

For the second review question, our analysis of selected literature resulted in three emergent themes: (a) individualizing learning and supports for SWD, (b) using technology and collaboration among educators, and (c) professional development. Our analyses of the literature did not produce any sub-themes for these three themes.

Theme 1: individualizing learning and supports for SWD

This theme was the most prominent among the themes relating to educators supporting high-school SWD in STEM. Project or inquiry-based learning and instruction are increasingly being recommended as significant elements of support for SWD (Kaldenberg et al., 2015; Seifert & Espin, 2012; Therrien et al., 2011; Therrien et al., 2014). One example of this approach, the Science Writing Heuristic, involves designing learning templates for SWD and teachers (e.g., Villanueva & Hand, 2011). Other approaches include the use of graphic organizers (Carnahan et al., 2016; Dexter et al., 2011). King et al. (2016) suggest that any of these approaches utilize, at a minimum, explicit instruction with prompts and positive reinforcement.

Other researchers, such as Hwang and Taylor (2016) and Brigham et al. (2011), advocate individualizing of supports for SWD in STEM by (a) taking an interdisciplinary approach to supporting SWD in STEM, (b) collaborating across each STEM area, and (c) making direct

DOI: 10.14448/jsesd.14.0006

connections to other disciplines, such as literature. An example of an interdisciplinary approach gaining favor among educators is called "STEAM" first developed at the Rhode Island School of Design. The argument is that incorporating the arts strengthens the curriculum for SWD by (a) motivating students especially when accessing the difficult aspects of STEM; (b) providing opportunities for self-expression, an important element in learning; and (c) serving as scaffolding for SWD to learn abstract and theoretical concepts in STEM.

Other research suggests co-teaching model could be an effective way to support and accommodate SWD in general education STEM (Moorehead & Grillo, 2013). Such a model would allow each teacher to focus on their respective strengths – the general educator as content knowledge specialist and the special educator as differentiation specialist. Mastropieri and Scruggs (2001), Mastropieri et al., (2005), and Scruggs et al. (2007) found that while teachers favorably viewed co-teaching, it also presented challenges relating to the classroom, students, and school administration: (1) Special educators too often served more of a subordinate function rather than a true "co-" teacher; and (2) Research based effective practices for supporting SWD, such as mnemonics, self-monitoring, peer mentoring, were often not being utilized.

Theme 2: using technology and collaboration among educators

Technology has often been utilized by educators to enhance access to STEM fields for SWD (Williams et al., 2015). For example, computing and computational thinking have been used to tailor STEM instruction (Israel et al., 2013; Israel et al., 2015). Benefits of this approach include improvements in (a) collaborative problem solving, (b) attitude about computer science, (c) higher-order thinking skills, and (d) creation of applied, real-world contexts for teaching algorithmic problem solving. Universal design for learning (UDL) could also play a key role through multiple means of representation, expression and action, and student engagement. Isaacson and Michaels (2015) evaluated Math Speak, a system for speaking mathematical expressions in a non-ambiguous manner, for teaching math to SWD, was generally effective in communicating math and chemistry concepts to students with blindness and visual impairments. Marino and Beecher (2010) analyzed a Response-to-Intervention (RTI) approach incorporating video games to support STEM for students with learning disabilities. They found video games aided teachers in progress monitoring; video-game interface provided a way for teachers to collect assessment data in real time. Hart and Whalon (2012) analysis of self-management and technology strategies in science comprehension produced mixed results.

Theme 3: professional development

This theme represents an increasingly important area of the research literature. Yore and Treagust (2006) placed a greater focus and emphasis on teachers' understanding the importance of students' vocabulary acquisition in science learning and literacy. Along those lines, Taylor et al. (2020) recommended inquiry-based instruction for SWD in STEM be an integral part of teachers' pre-service training and PD. This included explicit instruction in science vocabulary acquisition and retention, and the use of direct instruction, and mnemonics, as these elements have accumulated evidence in the research literature for their effectiveness in instructional supports for SWD. Kahn et al. (2017) reported that teacher candidates tended to primarily rely on SWD seeking help from other students before and after instruction, rather than

DOI: 10.14448/jsesd.14.0006

being directly involved in designing environments and developing supports for SWD that would more likely foster student autonomy. In addition, there are other supplemental programs outside of the school environment that can offer PD opportunities in STEM for special education teachers, for example, the "Sci Train", a project funded by the NSF designed to provide high-school science and math teachers effective methods of instruction, including the understanding and application of modifications and accommodations, and developing a resource library of these methods (Moon et al., 2012). Others have argued that the traditional classroom approach have ignored or hindered the essential element of innovative teaching, the ability of teachers to utilize their experiences, knowledge, and other unique personal factors to teach STEM (Fore et al., 2015).

Discussion

Our analyses of 53 selected articles from the relevant literature produced several themes and sub-themes to answer two specific questions. Now, we turn to a discussion of how those findings provide meaningful contributions to the literature, while also pointing to knowledge gaps that remain. We then conclude this review with its limitations, and the implications in the field of education and special education for both research and practice.

Qualitative Themes and Research Gaps

Significant changes have occurred in U.S. education related to STEM and high-school SWD, particularly since the passage of two landmark national laws, 'No Child Left Behind' in 2001 and 'Individuals with Disabilities Education Improvement Act' in 2004. Those changes are reflected in the peer-reviewed research; and thus, our present literature review was an attempt to capture the breadth and scope of that research over the last two decades. Taken together, the four themes that answered the first review question and the three themes that answered the second review question form an interesting – albeit preliminary – narrative regarding high-school SWD and STEM, and the role of educators, and leaving other questions to answer in the future.

First review question and themes

The first review question was "How are high-school SWD prepared for careers in STEM?", and our analyses of the selected literature yielded four emergent themes: (a) barriers to STEM, (b) increasing STEM opportunities, (c) STEM readiness in college and career, and (d) STEM identity. Based on our analyses, the focus of the literature appears to be on barriers and increasing opportunities in STEM for high-school SWD, but there are differences. For example, a female tenth-grade student of color with a learning disability might experience some similar but also some different barriers in STEM than a male eleventh-grade student with autism. Also, increasing STEM opportunities through summer science-camp or active recruitment and retention into STEM programs, may be impactful for some but not others based on disability conditions. In reviewing a decade of NSF-funded research aimed at broadening participation of SWD in STEM, Thurston et al. (2017) found that barriers have become entrenched over decades. These include discrimination, lowered expectations, lack of access to facilities and adaptive technologies, and lack of resources and knowledge/skills by teachers. These barriers are connected to wider, systemic socioeconomic disparities (Falkenheim et al., 2017). For example, SWD are (a) less likely to graduate from college or university in a STEM major (National Science Foundation, 2019), (b) more likely to be

DOI: 10.14448/jsesd.14.0006

unemployed or under-employed, and (c) more likely to live in poverty (Semega et al., 2019). Even adults with disabilities who have earned STEM degrees have experienced (a) fewer opportunities in internships and research assistantships, (b) less funding from scholarships and grants, and (c) higher unemployment rates in STEM fields than their peers without disabilities (National Science Foundation, 2021).

While the problem of barriers in STEM for SWD and the interventions to address them (e.g., project-based learning and universal design) (e.g., Bargerhuff, 2013) have been well-studied (see Scruggs & Mastropieri, 2007), there remain gaps in knowledge. For example, there is still not a good understanding of how these approaches and others, such as summer STEM programs, produce large scale (i.e., across different student-disability groups and settings) or long-term positive effects (i.e., from grade school through post-high school). Part of this gap could be due, at least in part, to the complex multilevel interactions of many variables (e.g., Austin & Merlo, 2017) involved in STEM success for SWD, including but not limited to disability, demographics, family dynamics, school and district factors, and the contextualized nature of how IEPs are developed and implemented by educators for SWD.

In addition, while STEM identity for high-school SWD is an important emerging area of research, there is still very little understanding of how it develops in the early years of schooling, from primary to middle grades (see Wang & Degol, 2017) affecting the trajectory in later years. Moreover, while there is increased understanding of the connection between STEM identity and social-emotional learning for students in general education, this research is lacking in special education. Finally, there is very little empirical understanding of the developmental pathways through which STEM identity of SWD translates to STEM success, and how this process differs among their peers without disabilities, from high-school to college, or from high school to STEM workforce in traditional and 'hidden' STEM fields (see Rothwell, 2013).

Second review question and themes

The second review question was, "How are educators prepared to support high school SWD for opportunities in STEM?"; and our analyses produced three emergent themes: (a) individualizing learning and supports for SWD, (b) using technology and collaboration among educators, and (c) professional development. Based on our analyses, the focus of the literature in this specific area of research appears to be individualizing the learning experience and supports for high-school SWD in STEM, and utilizing more regular professional development of educators to keep up with the changes in STEM areas (e.g., new technologies, new scientific applications). The narrative focuses on educators and their pivotal role in the high-school STEM success for SWD, and in their post-high school transition to STEM career pathways.

What stood out in particular in this area of the literature was the emphasis, at a classroom level, of the utilization of project based or inquiry based learning, coupled with the emphasis on direct instruction (see Rizzo & Taylor, 2016). Much of this research focus is weighed toward reading (i.e., vocabulary, comprehension) STEM texts for high-school students with a specific learning disability (SLD) and autism spectrum disorder (ASD). Some of this focus can be explained by the fact that the largest group of SWD served in special education in the U.S. are those with SLD, and the fastest growing group of SWD are those with ASD (National Center for Education Statistics, 2022). What is still a significant gap in this research,

DOI: 10.14448/jsesd.14.0006

however, is that there are 11 other categories of disabilities under IDEA for which SWD can be served in special education. Clearly much more research is needed regarding high-school students with these other disabilities, about how well (or different) project/inquiry-based learning and direct instruction affect their STEM learning and outcomes, and whether those approaches differ in effectiveness across the STEM areas – science, technology, engineering, and mathematics.

The literature also pointed to a more emerging area of research, involving specialized, STEM-specific professional development of educators. This could include active collaboration of teachers in general education and special education in both STEM instruction and supports for high-school SWD (see Moon et al., 2012). Perhaps this push for collaboration reflects the sheer complexity of STEM instruction and supporting high-school SWD, something that requires more than what special educators can reasonably endeavor all on their own. For example, content knowledge in the four STEM areas – science, technology, engineering, and mathematics – also covers subject matter that includes biology, chemistry, geology, physics, astronomy, computer science, and material science. The issue here, however, is that given the resources challenges that many schools and districts have across the country, specialized professional development for both general educators (e.g., direct instruction to support high-school SWD learning in STEM) and special educators (e.g., computer programming in Java) may be difficult or very limited.

Limitations of This Qualitative Review

There were three main limitations in this literature review. First, although we used search terms in various combinations and searched multiple databases, it is still possible that our search was too narrow. Second, while we followed an inclusion criteria driven by specific questions, it is likely that additional and or different patterns could be identified by others who reviewed the same literature. Third, the studies that were research reports varied in rigor; only a few of these are likely to meet the strict "What Works Clearinghouse" criteria (https://ies.ed.gov/ncee/wwc/) for establishing evidence-based practices in education. This puts a limitation on how educators could use information from this review – or the individual results of each of those research reports directly – in whatever program, practice, or policy at their school or in their district.

Finally, we acknowledge that the inclusion of different types of articles in our literature review reflects not only the diversity of thoughts and writings in the field, but also the challenges of conducting research specific to STEM and high-school SWD. While very few of these studies have been assessed as having sufficient methodological rigor to meet the standards of the "What Works Clearinghouse", the inclusion of these 'other' types of articles – essays, literature reviews, meta-analyses, position papers, and practitioner papers – and the development of qualitative themes across these articles were meant to portray or represent the current state (i.e., focus areas, emerging areas) of the peer-reviewed literature regarding high-school SWD and STEM.

Implications for Research and Practice

Implications for practice

Research from the past twenty years has indicated that high-school SWD can achieve in STEM. Nevertheless, there remain disparities between students with and without disabilities as well as gaps in research knowledge. One

DOI: 10.14448/jsesd.14.0006

clear implication of our review for educators, in both general and special education, is that the utilization of technology and active collaboration in STEM instruction are positive ways to support STEM learning for high-school SWD and increasing opportunities for both in-school and out-of-school learning. Because education in the U.S. is decentralized, individual schools and districts would need to take the initiative to create these opportunities, in addition to any federal programs or resource that could be utilized.

Another implication of this review is that greater focus and attention needs to be given to the IEP process and transition planning for SWD starting at age 14, to identify and incorporate STEM activities into their high-school learning experiences to adequately prepare for college and or STEM career pathways. There is also a need for specialized STEM focused pre-service training and in-service professional development. Because STEM continues to evolve and technology continues to advance, these special educators will need to stay up-to-date in their knowledge, including the emerging research around STEM identity development for SWD.

Implications for research

Despite the limitations of this qualitative literature review, there are important implications for research. Our review has revealed that there is room for much further investigation in a few key areas. One area is research into STEM enrichment programs (e.g., "Camp Can Do'), which provide out-of-school seasonal or periodic STEM learning opportunities for SWD based on disability category, gender, and race/ethnicity. This type of intersectionality research will also show the complexity of STEM learning, which manifests in different growth trajectories for high-school SWD based on these demographic characteristics (Wei et al., 2012). Second area of research is STEM identity and social-emotional learning, and how they influence SWD readiness to pursue STEM career pathways. These longitudinal studies will be key to understanding how SWD develop the necessary resilience and persistence over time, from high school and into college/university, and career in STEM. The third area involves STEM-focused high-school transition services in special education and their link to post-high school outcomes of SWD (i.e., IDEA requirement Indicator 14). This is an important area of special education that is becoming a greater focus of administrators and policymakers. Because high-school SWD are legally entitled to these services, conducting research to more closely analyze how IEP (Individualized Education Program) are structured for high-school SWD to prepare for post-high school STEM (i.e., college, career) could lead to developing best practices in transition services.

Conflict of Interest Statement

The authors declare there is no conflict of interest.

Declaration of Funding

This study is part of research funded by the National Science Foundation grant 1657015.

Ethics statement

This paper was a review of extant literature and not a study involving human or animal subjects in research.

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TABLE 1.
SUMMARY OF ARTICLES (N=53) SELECTED FOR THE QUALITATIVE LITERATURE REVIEW

Authors	Journal	Design	Sample	Disability	Ethnicity	Gender	Topics
Bargerhuff (2013)	American Secondary Education	Qualitative	education professionals (N=9)	Not Available	Not Available	females (n=7), males (n=2)	Project-based STEM learning, problem-solving
Basham & Marino (2013)	Teaching Exceptional Children	Position paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	UDL in STEM instruction
Basham, Israel, & Maynard (2010)	Journal of Special Education Technology	Essay	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Framework for more accessible & effective STEM instruction
Boyle (2012)	Learning Disabilities Research & Practice	Literature review	Not Applicable	Learning Disability	Not Applicable	Not Applicable	High school content areas, note-taking
Brigham, Scruggs, & Mastropieri (2011)	Learning Disabilities Research & Practice	Literature Review	Not Applicable	Learning disability	Not Applicable	Not Applicable	Validated science teaching strategies
Byars-Winston (2014)	The Career Development Quarterly	Essay	Not Applicable	Not Applicable	Not Applicable	Not Applicable	STEM & career, under-represented groups
Carnahan, Williamson, Birri, Swoboda, & Snyder (2016)	Focus on Autism and Other Developmental Disabilities	Quantitative (single subject)	high school students (n=3), special education teacher (n=1)	Autism, ASD	Not Available	males (N=3) ages 15-16	Science text reading
Cease-Cook, Fowler, & Test (2015)	Teaching Exceptional Children	Position paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Work-based learning, career exploration
Dexter, Park, & Hughes (2011)	Learning Disabilities Research	Meta-analysis	7 studies of high school students (total N=232)	Learning disability	Not Available	Not Available	Graphic organizers
Dunn, Rabren, Taylor, & Dotson (2012)	Intervention in School and Clinic	Qualitative (case study)	1 high school student	Learning disability, Other health impairment	Not Available	1 male, transition age	STEM & transition planning
Falkenheim, Burke, Muhlberger, & Hale (2017)	National Center for Science and Engineering Special Report	Quantitative (extant data analysis)	Multiple national samples – NSF, Dept. of Labor, Census Bureau, Department of Education	Disabilities not listed by individual categories	Black, Native American, Alaska Native, Native Hawaiian, Other Pacific Islander, Hispanic, Asian, White	females & males	Women, ethnic minorities, & persons with disabilities in science & engineering education and employment

DOI: 10.14448/jsesd.14.0006

Fore, Feldhaus, Sorge, Agarwal, & Varahramyan (2015)	Teacher and Teacher Education	Qualitative	high-school teachers (*N*=13)	Not available	Black (*n*=1), Hispanic (*n*=1), & White (*n*=11) teachers	females (*n*=6), males (*n*=7)	STEM instruction, teacher professional development
Gottfried, Bozick, Rose, & Moore (2016)	Journal of Disability Policy Studies	Quantitative (extant data analysis)	National Longitudinal Survey of Youth	2405 parents of students with disabilities	24.3% Black, 16.2% Hispanic, 1.2% Mixed Race, & 58.4% White	45.4% female, 54.6% male	CTE, STEM, school-based experiential programs
Gregg, Galyardt, Wolfe, Moon, & Todd (2017)	Career Development and Transition for Exceptional Individuals	Quantitative (survey)	High school students from urban, suburban, and rural schools in Georgia (*N*=91)	ASD (*n*=54), ADHD (*n*=15), ASD (*n*=12), Other (*n*=10)	Minority (n=61), White (n=30)	females (n=40), males (n=51)	Virtual mentoring, STEM persistence, self-advocacy, self-efficacy
Hart &Whalon (2012)	Education and Training in Autism and Developmental Disabilities	Quantitative (single subject)	1 high school student	ASD, Other Health Impairment	Not Available	Male in 10th grade	Video modeling, science instruction
Hwang & Taylor (2016)	Journal of Science Education	Position paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Art & STEM learning for
							students with disabilities
Isaacson & Michaels (2015)	Journal of Science Education for Students with Disabilities	Practitioner paper	Not Applicable	Blindness, low vision	Not Applicable	Not Applicable	STEM, ambiguous speech, Math Speak
Israel, Maynard, & Williamson (2013)	Teaching Exceptional Children	Practitioner paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	STEM & reading instruction, authentic learning, technology supports
Israel, Wherfel, Pearson, Shehab, & Tapia, (2015)	Teaching Exceptional Children	Practitioner paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Computer programming & UDL, explicit instruction & open inquiry
Izzo, Murray, Priest, & McArrell (2011)	Journal of Postsecondary Education and Disability	Mixed methods	high school students (*N*=62)	ASD, Blindness, ADHD, SLD, Deafness, OHI	Not Available	70%+ male	STEM learning communities, transition planning

DOI: 10.14448/jsesd.14.0006

Kaldenberg, Watt, & Therrien (2015)	Learning Disability Quarterly	Meta-Analysis	4 studies (N=112)	Learning disability	Not Available	Not Available	Science instruction, inquiry-based learning
Kahn, Pigman, & Ottley (2017)	Journal of Science Education for Students with Disabilities	Qualitative	new teaching candidates (N=26)	Not Available	Not Available	Not Available	Inclusive science, UDL, content knowledge
King, Lemons, & Davidson (2016)	Exceptional Children	Literature Review	14 studies	ASD	Not Available	71% male	Evidence-based math practices
Leddy (2010)	Journal of Special Education Technology	Literature review	Not Available	Not Available	Not Available	Not Available	STEM & students with disabilities high school to college, STEM workforce
Marino & Beecher (2010)	Learning Disability Quarterly	Position paper	Not Applicable	Learning disability	Not Applicable	Not Applicable	Response to intervention, science education & video games
Mason, & Hedin (2011)	Learning Disabilities	Literature review	Not Applicable	Learning Disability	Not Applicable	Not Applicable	Reading science text, instructional
	Research & Practice						supports & strategies
Mastropieri & Scruggs (2001)	Learning Disability Quarterly	Literature review	Not Applicable	Learning disability	Not Applicable	Not Applicable	Inclusive classrooms, peer tutoring, co-teaching, strategy instruction
Mastropieri, Scruggs, & Graetz (2005)	Cognition & Learning in Diverse Settings	Quantitative (quasi-experiment group)	High school chemistry classroom (N=10)	Learning disability	Not Available	Not Available	Inclusive classroom, peer tutoring versus teacher directed instruction
Mau & Li (2018)	The Career Development Quarterly	Quantitative (extant data analysis)	National Longitudinal Survey of Youth (N=21444)	Not Available	55.3% White, 15.4% Hispanic, 10.4% Black, 8% Asian, & 10.9% Other	49.1% Female & 50.1% Male	Career Aspirations Model, factors for pursuing STEM career
Moon, Todd, Morton, & Ivey (2012)	SciTrain: Science and Math for All	Literature review	High school science and math teachers	Not Available	Not Available	Not Available	UDL & STEM, assistive technology, inclusive teaching

DOI: 10.14448/jsesd.14.0006

Moorehead & Grillo (2013)	Teaching Exceptional Children	Practitioner paper	Not Available	Not Available	Not Available	Not Available	Co-teaching STEM, station teaching
Peters-Burton, Lynch, Behrend, & Means (2014)	Theory Into Practice	Literature review	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Inclusive STEM high school, open enrollment, project-based learning
Plasman & Gottfried (2018)	Educational Policy	Quantitative (extant data analysis	Educational Longitudinal Study (*N*=9410, 10th grade)	Learning disability	66% White, 11% Black, 14% Hispanic, 3% Asian	40% female & 60% male	STEM coursework, school-to-careers, dropout rates, STEM supports
Rakich & Tran (2016)	European Journal of STEM Education	Position paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	U.S. high school STEM, college & career pathways
Rizzo & Taylor (2016)	Journal of Science Education for Students with Disabilities	Literature review	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Science achievement, inquiry-based learning
Rule & Stefanich (2012)	Journal of STEM Education	Qualitative	Pre-service teachers, education professionals	Not Available	Not Available	Not Available	Professional development, supports to students with physical disabilities in STEM
Scruggs & Mastropieri (2007)	Exceptionality	Essay	Not applicable	Not Applicable	Not Applicable	Not Applicable	Science learning and special education, constructed versus instructed learning
Scruggs, Mastropieri, & McDuffie (2007)	Exceptional Children	Literature review	Qualitative research studies	Not Available	Not Available	Not Available	Co-teaching, peer mediation, strategy instruction, mnemonics
Scruggs, Mastropieri, & Okolo (2008)	Focus on Exceptional Children	Essay	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Science and social studies instruction for students with disabilities

DOI: 10.14448/jsesd.14.0006

Seifert & Espin (2012)	Learning Disability Quarterly	Quantitative (quasi-experiment group)	10th high school students (*N*=20)	Learning disability	Not Available	females (*n*=9), males (*n*=11)	Reading science text, combined instructional approaches
Shoffner, Newsome, Minton, & Morris (2015)	Journal of Career Development	Qualitative (focus groups)	9th grade high school students (*N*=28)	Not Available	Not Available	females (*n*=12), males (*n*=16)	Outcome expectations, STEM knowledge, career goals
Sublett & Plasman (2017)	Journal of Career and Technical Education	Quantitative (extant data analysis)	High School Longitudinal Study (started at 9th grade, follow up at 11th grade)	21% with an IEP	11% Black, 17% Hispanic, 9% Asian, 10% Other	49% female, 51% male	Math & science self-efficacy, CTE, applied STEM coursework
Subramaniam, Ahh, Fleischmann, & Druin (2012)	The Library Quarterly	Position paper	Not Applicable	Not Applicable	Not Applicable	Not Applicable	School library programs & STEM learning
Supalo, Isaacson, & Lombardi (2014)	Journal of Chemical Education	Mixed methods	High school students at summer program (*N*=91)	Blindness, low vision	Black (n=16), Hispanic (n=10), Asian (n=7), White (n=58)	41 females (*n*=41), males (*n*=50)	STEM academy, hands on learning
Supalo, Wohlers, & Humphrey (2011)	Journal of Science Education for Students with Disabilities	Qualitative (case study)	High school students at "Camp Can Do" summer program	Blindness, low vision	Youth from Caribbean	Not Available	Exploring chemistry, adaptive technologies, laboratory classes
Taylor, Rizzo, Hwang, & Hill (2020)	School Science and Mathematics	Literature review	Not Applicable	ASD	Not Available	Not Available	Science achievement, science instruction
Therrien, Taylor, Hosp, Kaldenberg, & Gorsh (2011)	Learning Disabilities Research and Practice	Meta-analysis	High school students (*N*=155)	Learning disability	Not Available	Not Available	Science achievement, inquiry-based instruction
Therrien, Taylor, Watt, & Kaldenberg (2014)	Remedial and Special Education	Meta-analysis	High school students (*N*=19)	Emotional & Behavior Disorder	Not Available	Not Available	Science instruction, knowledge & retention
Villanueva & Hand (2011)	Learning Disabilities Research and Practice	Essay	Not Applicable	Not Available	Not Available	Not Available	Science writing heuristic

DOI: 10.14448/jsesd.14.0006

Wang & Degol (2017)	Educational Psychology Review	Literature review	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Factors in STEM gender gap, racial differences
Wei, Lenz, & Blackorby (2012)	Remedial and Special Education	Quantitative (extant data analysis)	Special Education Longitudinal Study (multiple waves)	12 IDEA disability categories	19.33% Black, 13.01% Hispanic, 65.58% white	32% female, 68% male	Math growth trajectories, achievement gaps between groups
Williams, Ernst, & Kaui (2015)	Journal of STEM Education	Quantitative (extant data analysis)	Schools & Staffing Survey (*N*=559300); teachers in science, math, & tech education)	Not Available	Not Available	62% female in science; 65% female in math; 25% female in tech	School drop-out risk,
Yore & Treagust (2006)	International Journal of Science Education	Essay	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Science literacy, models of learning, teacher professional development

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