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Research Report

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RESEARCH REPORT

Equitable STEM Instruction and Assessment: Accessibility and Fairness Considerations for Special Populations

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The landscape for STEM instruction is rapidly shifting in the United States. Attention toward STEM instruction and assessment opportunities is increasing. All students must have opportunities to gain access to the STEM content and show what they know and are able to do. We caution that attention to fairness and accessibility is critical for students from special populations, particularly English learners and students with disabilities. Opportunities for equitable access to STEM instruction and assessment are diminished without accessibility. In this report, we use an assets-based perspective to discuss and reframe common misconceptions and challenges as opportunities. We argue that attention to accessibility at the onset of STEM instruction and assessment is the pivotal foundation for fair opportunities in STEM. We highlight key opportunities and conclude with recommendations for improved fairness and access in STEM.

Keywords STEM; special populations; students with disabilities; English learners; accessibility; fairness; equitable; instruction; assessment

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Increasing attention to diversity, equity, and inclusivity for students in STEM education is gaining traction in the United States (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). This trending priority influences both short- and long-term goals for the field of STEM. We use an assets-based approach with two underrepresented groups in STEM: English learners[1] (ELs) and students with disabilities[2] (SWDs). We argue that ELs and SWDs possess many talents that can be helpful for a career in STEM. However, opportunity and access have traditionally been limited for these students. These limitations make participation in STEM careers a challenge for students without preparation. These limiting factors may include but are not restricted to lack of accessible STEM curriculum, limited availability of access technologies or methodologies making STEM content more inclusive and equitable, and misconceptions of persons in the STEM teacher profession regarding their students' capabilities (Miner et al., 2001).

The shifting priorities mirror the changing demographic landscape of the nation. ELs are increasing in number across states, from 8.1% (3.8 million students) in 2000 to 9.6% (4.9 million students) in 2016 (McFarland et al., 2019). In 2016, ELs represented various home languages including Spanish or Castilian at 7.7% of the number of ELs (3,790,949 students) of the total student enrollment in the United States compared to the top 10 home languages in the nation that include Arabic (0.3%), Chinese (0.2%), Vietnamese (0.2%), and English,[3] Somali, Russian, Hmong, Haitian/Haitian Creole, and Portuguese each at 0.1%, respectively.[4]

Increases in identification for SWDs were observed: 7.0 million (13.7%) in 2017–2018 compared to 6.8 million (13.4%) in 2016–2017 (McFarland et al., 2019). Of these students in 2017–2018, 34% were identified with a high-incidence disability (specific learning disabilities). Students with autism, developmental delays, intellectual disabilities, or emotional disturbances each accounted for 5–10% of SWDs. Students with low-incidence disabilities, such as multiple disabilities, hearing impairments, orthopedic impairments, visual impairments, traumatic brain injuries, and deaf-blindness, each represented 2% or fewer of students identified with disabilities in 2017–2019 (McFarland et al., 2019). Most SWDs in 2017 were included in general education classrooms for most of their school day (63% of students at 80% or more time); 18% spent some time (40–79%) in the general education classrooms, and 13% spent less than 40% of the school day in general education classrooms (for more detail, refer to McFarland et al., 2019).

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Despite the increased numbers and attention to ELs and SWDs, state reporting on student participation, performance, and accommodation use varies in the United States. Only nine states reported disaggregated information for their SWDs in the 2016–2017 school year. Most states do not report assessment information or disaggregate the information to unpack results for ELs or SWDs (Albus et al., 2019). Ultimately, these instructional and assessment reporting efforts are intricately connected to fairness considerations for ELs and SWDs (Stone & Cook, 2016; Zieky, 2016). Historically, fairness can more recently be characterized as stemming from the civil rights era federal policies and laws for educational accountability. These policies were implemented in the United States to protect the rights of all students, including ELs and SWDs. Examples include the Individuals With Disabilities Education Act in 2004 (Pub. L. 94–142) and subsequent reauthorizations in 1997 and 2004; the landmark Elementary and Secondary Education Act in 1965 (Pub. L. 89–10); and subsequent key amendments, such as No Child Left Behind Act in 2002 (Pub. L. 207–110) and Every Student Succeeds Act in 2015 (Pub. L. 114–95).

Previous STEM frameworks have addressed needs for integrated STEM education (Kelley & Knowles, 2016; NRC, 2014), but the need to include ELs and SWDs is largely motivated by federally mandated strides toward fairness and social justice. We recognize that although progress has been made, equitable access to opportunities in STEM education are an ongoing effort (Curran & Kellogg, 2016; Harper, 2010; Prema & Dhand, 2019; Sukhai & Mohler, 2017; Supalo, 2013; Zeidler, 2014). Disaggregated demographic information exists for ELs and SWDs; however, there is still a need to connect these demographics to subsequent ongoing monitoring and meaningful efforts to include ELs and SWDs in the shifting priorities for STEM education and assessment.

We aim to meet this need by addressing challenges and misconceptions regarding the target students and reframing these as opportunities. We lead with an assets-based approach for EL and SWDs (and deliberately denouncing a deficit-based approach), emphasizing awareness for the inclusive and equitable STEM learning and assessment experiences that may minimize marginalization. These marginalization aspects may occur when principles of inclusion are not considered. For example, STEM educators must teach from an inclusive perspective (Moorehead & Grillo, 2013). Students must also be tested on that knowledge, practice, and application of the knowledge in a manner that is inclusive and equitable and ideally based on the methodologies that were used with their instruction in the first place (Clark-Gareca, 2016; Schissel, 2014). If these two guiding statements are implemented together, ELs and SWDs will have more opportunities for equitable learning experiences, which may, over time, help diversify the STEM pipeline. Therefore, accessible and equitable STEM education and assessment is a fundamental priority. In this report, we present an overview of instruction and assessment for special populations (SWDs, ELs) and highlight opportunities and recommendations for future work to enhance equitable opportunities in STEM.

Students With Disabilities

All students possess individual differences, some of which may have a physical, sensory, or cognitive basis. For SWDs, differential recognition, access, and accommodations can be dependent on country-specific policies supporting disability identification and subsequent inclusive instruction and assessment (Davies, 2018; Weigert, 2018). These policies impact students' current educational and career opportunities. The goal to access STEM education and thus careers is not without effort, given that the area of STEM education with SWDs has a large array of challenges that are typically highly dependent upon students' disabilities. Although education of SWDs typically focuses on individualized instruction, a review of the current state of STEM education illustrates key areas of opportunity for SWDs that are flanked by major "challenge areas" in need of improvement: teacher preparation, accessibility, cognitive challenges, and limited research and development (e.g., Supalo et al., 2014).

Opportunities for STEM Instruction for Students With Disabilities

Recognizing that all students inherently possess useful skills and abilities that can help them accomplish any task is a critical mindset to adopt for any student, especially differently abled SWDs. To do this, the field often must be willing to think of new and original ideas that challenge established norms.

Opportunities for Professional Development

With the great need for STEM education and special educators, creating cross-trained STEM/disability experts is a daunting task. However, changes could be made to strengthen our current system in the United States. For instance, personnel preparation programs could include not only a general course in teaching SWDs but also preservice training on collaborative models such as coteaching. If preservice educators are taught how to collaborate with each other across domains, these collaborative skills may support the current service models within schools (Moorehead & Grillo, 2013). But even with the training, P–12 education systems would need to be redefined so that focus and opportunity for collaboration was part of the school's culture.

As preservice educators transition to in-service educators, school systems could establish mentoring and professional development norms that are proactive and focused on teaching ideas that impact all students, such as universal design of learning, differentiated instruction, and coteaching (Hwang & Taylor, 2016). Schools would need to support professional development efforts and create an infrastructure that allows veteran teachers to work together to best support students' needs. These types of collaborative efforts could lead to truly inclusive practices within inquiry-based STEM classrooms (Watt et al., 2013). An opportunity outside of the schools that could support teachers would be to create an international community or consortium that focused on supporting STEM education for SWDs where resources like professional development modules, videos, forums, and webinars could also support both general and special educators.

Opportunities for Greater Accessibility

Accessibility is the benchmark for SWDs to be able to access a free, appropriate public education (Moon et al., 2012). For SWDs to access STEM education, the first step would be for research and development activities to create new materials and technologies that must be *born accessible* (Diagram Center, 2019). This means that accessibility should be included from the beginning of the development of strategies, curricula, and technologies. For example, new websites that intend to provide students with STEM-focused content must not merely meet minimum accessibility standards, but developers should work with the disability community to ensure that the website is completely accessible. To be *completely accessible* means that the individual will be able to not only acquire information from the site but also interact with the website in a similar way to their nondisabled peers.

Opportunities for Innovative Pedagogical Strategies for All Students

Although students with cognitive disabilities may always struggle with advanced STEM content, a vast number of opportunities exist for the development of innovative pedagogical strategies that are founded on Universal Design for Learning (UDL) principles. The UDL framework guides the creation of flexible learning environments, accommodating students with different learning abilities and promoting access through three major principles, including (a) multiple means of representation, (b) engagement, and (c) expression (CAST, 2018; Rose & Meyer, 2002). Development of innovative strategies and differentiated instruction can be accomplished through use of different means of representation, expression, and engagement with STEM content with a community of practice of STEM education and special education experts (CAST, 2018). One approach is to identify current general education practices that have a strong evidence foundation and determine how these practices could be revised for special populations, collaboratively developing new strategies to support STEM education from the most basic levels to the most advanced. By using the principles of UDL, these new strategies could potentially support many students. For instance, a new digital tool may be used and made accessible for students with visual impairments by audio and/or haptic feedback and may have potential to support students with specific learning disabilities (particularly those with print disabilities) and positively impact all students. The field has a great opportunity to focus on creating teaching methods and tools that have the greatest impact on the most students.

Future Enhancements for STEM Instruction for Students With Disabilities

Educator Preparation

One of the greatest challenges for STEM education for SWDs is the lack of meaningful and focused preparation on teaching STEM content to SWDs (Boda, 2018; Norman et al., 1998; Rosenzweig, 2009). For example, in upper grades, most STEM-focused courses (mathematics and sciences) are typically taught by content-trained educators (i.e., biology teacher with a strong biology background). Their preparation is typically a combination of general pedagogy, content-specific pedagogy (possibly one or two courses), and content courses (that have no focus on teaching). Therefore, most "general education"

STEM educators have limited to no preparation to work with SWDs, particularly students with severe cognitive and physical disabilities (Basham & Marino, 2013).

At the same time, the preparation of teachers of SWDs is primarily based on broad-focused instructional strategies to work with the diverse needs of SWDs such as behavior management, collaborative consultation, some disability-specific content, and paperwork management. Most programs require students to complete at least one reading education course and possibly a math education course, but most do not require any coursework related to STEM education (Basham & Marino, 2013).

Traditionally, STEM teachers have been taught to depend upon the special educators to provide support in their classes and the special educator is taught to depend on the STEM teacher to teach the content (Knackendoffel et al., 2018). Often, there is knowledge gap that causes a dissonance in collaboration efforts. In the wake of their inability to support each other effectively, ultimately the student with disabilities has two or more educators who want to help but are not equipped to do so. Therefore, the field has a critical need to prepare general education STEM teachers to teach SWDs (at least globally) while special education teachers are prepared to better support STEM education without becoming content experts.

Accessibility

For most high-incidence populations (e.g., students with specific learning disabilities), opportunities to access to STEM education are not the most significant issues. They may be challenged by the content, but they have fundamental need for access to the materials. But for most students from low-incidence populations (physical and sensory impairments such as cerebral palsy, deafness, and visual impairments), access to accessible materials can be a great barrier to STEM instruction (Moon et al., 2012).

Most STEM content relies on the different senses for true immersion and understanding. For example, geometry is highly visual and requires the students to have the ability to use tools to create figures on their own. Students with physical disabilities struggle because of the exactness of working with geometric images and using tools to create their own images. Another example would be in a physics class during a lesson that uses content-specific terms (such as *vectors*) that do not have an exact sign language equivalent (Higgins et al., 2016). Thus, the student would need extra supports in order to truly understand the academic language (Braun et al., 2018). For students with visual impairments, accessing STEM information is a noted challenge as they may require large print or brailled materials and graphics that are accessible through touch (i.e., tactile graphics; Smith, 2017; Wild & Koehler, 2017).

With the advancement of technologies within the classroom to teach STEM content, students are now being asked to use computer-based technologies to engage in STEM learning. For instance, multiple websites provide opportunities for students to conduct "experiments" online (such as the Phet Interactive Simulations[5]) or use multiple new tools for real-world experimentations in the STEM classroom (such as Vernier probes or devices for the Texas Instruments graphing calculators). However, many of these advanced tools are not fully accessible to students with physical and sensory impairments who can be "left out" of these authentic learning experiences within the STEM classroom. A few commercially available data collection devices that do have some features to provide accommodations for students with specific disabilities only exist in limited cases. More inclusive solutions are necessary to promote equitable access across disability domains.

Mitigating Cognitive Challenges

Parallel to the challenges of physical disabilities, students with cognitive disabilities (specific learning disabilities, intellectual disabilities, etc.) have general struggles with STEM content (Moon et al., 2012). With content that is already deemed challenging, the STEM classroom is not always accepting to students who struggle due to cognitive disabilities (Compton et al., 2012; Norman et al., 1998).

STEM education content becomes quite abstract, particularly in upper grades, adding a dimension of challenge that some students are unable to overcome. For example, mathematics moves from a numeracy focus to the more abstract algebra focus (National Council of Teachers of Mathematics, 2000; Seeley, 2004). The demonstration of knowledge may become more precise as students' progress to focus on the minute aspects of the domain. The STEM vocabulary grows exponentially, the use of advanced mathematics within the science classroom appears, and the topics move from basic concepts to more advanced principles. For students with cognitive disabilities, these advances should not pose barriers to their progression, but of all the challenges found in STEM education for SWDs, the impact of cognitive disabilities is recognized as the most challenging aspect to overcome by educators (Browder et al., 2010).

Increasing Research and Development

Further expanding the challenges in the field is the ongoing need for cross-cutting, ground-breaking research and development in STEM education for SWDs (Moon et al., 2012). Due to a lack of educational researchers and developers with both the content and disability-specific expertise, collaboration is crucial. Establishing productive research and development teams is quite challenging, and even with advanced communication and collaboration tools, the ability for consistent innovation is difficult. Often, researchers and developers complete their work in isolation, leading to fragmented innovations within the field.

English Learners

With the overview of SWDs in STEM education, it is evident that multiple opportunities exist to enhance access to meaningful and equitable instruction. Similarly, the STEM field is changing for ELs, which impacts EL instruction and assessment.

The release of the report *English Learners in STEM Subjects: Transforming Classrooms, Schools, and Lives* (NASEM, 2018) is timely, as three emerging forces shape the changing landscape of K–12 science education. First, demographics of the nation's student population are rapidly changing, including the fast-growing subpopulation of ELs (National Center for Education Statistics, 2018). Second, STEM subjects, especially disciplinary practices (e.g., developing models, arguing from evidence, constructing explanations), are both academically rigorous and language intensive. Third, computer science, including computational thinking, is becoming increasingly important for all students.

Of the STEM subjects, the mathematics education community presents a contemporary view of mathematics instruction to promote mathematical proficiency, practices, and discourse. These three aspects of mathematics instruction are evident in reforms initiated by the National Council of Teachers of Mathematics in the 1990s, *Adding It Up* (National Research Council [NRC], 2001), the Association of Mathematics Teacher Educators (2017), and the *Common Core State Standards for Mathematics* (National Governor's Association Center for Best Practices & Council of Chief State School Officers, 2010). Likewise, the science education community presents a contemporary view of science instruction to promote three-dimensional learning of science and engineering practices, cross-cutting concepts, and disciplinary core ideas. These three dimensions of science instruction are evident in reforms initiated by Project 2061 (American Association for the Advancement of Science, 1989, 1993), *National Science Education Standards* (NRC, 1996), *A Framework for K–12 Science Education* (NRC, 2012), and the Next Generation Science Standards (NGSS Lead States, 2013). Engineering education is a relatively recent addition to K–12 education, and *A Framework for K–12 Science Education* and the NGSS articulated a new vision for three-dimensional engineering education. Following this, *Building Capacity for Teaching Engineering in K–12 Education* (NASEM, 2020) reiterated key considerations and a call to educator preparation, particularly from underrepresented groups in STEM. Technology education is interpreted in a variety of ways, and currently there is no coherent conception of technology education including computer science or computational thinking (NRC, 2010).

Recently, parallel shifts in STEM subjects and second language acquisition have occurred (NASEM, 2018). In STEM subjects, contemporary views emphasize that students make sense of phenomena and problems in the classroom community (*knowledge-in-use*), whereas traditional views have focused on individual learners' mastery of discrete elements of content. In second language acquisition, contemporary views emphasize that language is a set of meaning-making practices learned through participation in social contexts (*language-in-use*), whereas traditional views have focused on discrete elements of vocabulary (lexicon) and grammar (syntax) to be internalized by learners. Recognizing these instructional shifts as mutually supportive can promote rigorous STEM learning and rich language use with all students, including ELs (Lee et al., 2013). When ELs are engaged in STEM disciplinary practices in which STEM experts and professionals regularly engage, ELs learn STEM subjects and language simultaneously.

As ELs learn STEM subjects while engaging in disciplinary practices, they use language to learn disciplinary content and communicate disciplinary meaning through social interactions with peers and the teacher in the classroom community. ELs use language and other meaning-making resources purposefully in the service of "doing," learning, and communicating ideas about STEM subjects. ELs can communicate their ideas using less-than-perfect English (Lee et al., 2013).

Traditional Instructional Approaches

With its charge to reimagine instructional approaches to promote STEM learning and language development with ELs, the following summary of key points from the NASEM (2018) report describes traditional instructional approaches as compared to contemporary views. First, it is a misconception that disciplinary vocabulary is equivalent to disciplinary language. Whereas contemporary views recognize that disciplinary vocabulary is one key feature of disciplinary language when the vocabulary is used in context, language in STEM subjects extends far beyond vocabulary to also include scientific discourse necessary to discuss scientific practices. In STEM classrooms, ELs use language to engage in disciplinary practices, learn disciplinary content, and communicate disciplinary meaning. Through this engagement, ELs learn language as a product.

Second, a misconception exists that a certain level of English proficiency is a precursor or prerequisite to meaningfully engaging in STEM learning (Callahan, 2005). This misconception has led to preteaching and frontloading of vocabulary before students have had opportunity to experience the scientific idea (Weinburgh et al., 2014). Instead, contemporary views highlight the functional use of language in social interactions and view language as a product, not a precursor or prerequisite (NRC, 2012).

Third, in content-based language teaching, which has been common practice until recently, EL teachers are asked to develop "content objectives" and "language objectives" (MacDonald et al., 2017). Typical language objectives focus on grammatical forms (past tense) or only on a particular function out of context ("compare. .."). Instead, contemporary views highlight language use while engaging in STEM disciplinary practices (e.g., "I predict … because … " and "I observed … because … ") and learning language as a product resulting from those scientific practices (NASEM, 2018).

Finally, sheltered instruction with ELs often provides "highly simplified content that seldom satisfies grade-level STEM content expectations" (NASEM, 2018, p. 38; see also Dabach, 2014 and Saunders et al., 2013). This approach fails to meet the goal of content standards that are expected of all students, including ELs (NASEM, 2018). Moreover, emphasis on building background (often through vocabulary instruction) and providing comprehensible input (often through simplification of language to simplify content in sheltered instruction class settings) can have unintended consequences for ELs. For example, as cause and effect is a crosscutting concept across STEM subjects, shortening a sentence by eliminating words that establish a causal relationship (e.g., because, therefore) can make it more difficult for ELs to understand disciplinary content. Contemporary views highlight amplifying language to support and challenge ELs with academically rigorous content (NASEM, 2018).

Contemporary Instructional Approaches

A shift is taking place in education by promoting an asset-oriented view of ELs as compared to a deficit view that has dominated EL education and, in particular, STEM education (NASEM, 2018). ELs bring a wealth of cultural and linguistic resources that are rooted in their families, communities, and/or home countries to STEM classrooms. These resources contribute to their multicompetence, which not only promotes their own STEM learning but also can be leveraged to benefit their peers' STEM learning. Whereas the dominant narrative regarding ELs in STEM subjects continues to be that ELs require support, the NASEM report takes the view that ELs require both support and challenge to learn academically rigorous content standards that are expected of all students (de Araujo et al., 2016).

The NASEM report (2018) further explicates recommendations for future instruction and assessment strategies that forego the misconceptions and are instead grounded in contemporary views illustrated earlier on language and STEM subjects. For example, ELs learn disciplinary content and communicate disciplinary meaning through engaging in disciplinary practices in the classroom community. As STEM teachers explicitly focus on language in teaching STEM, they encourage ELs to draw on a full range of linguistic and cultural resources and strategically use multiple modalities and specialized registers to communicate disciplinary meaning. As opposed to traditional instructional approaches described previously, the report identifies five promising instructional strategies (see NASEM, 2018, pp. 99–122 for details about each strategy):

- Engage students in disciplinary practices in STEM subjects.
- Engage students in productive discourse and interactions with peers and the teacher using language as meaning-making resources.

- Utilize and encourage students to use multiple modalities strategically and increasingly specialized registers to meet the communicative demands of different types of interactions.
- Leverage multiple meaning-making resources, including physical objects, gestures, everyday language, home language, and translanguaging.
- Provide some explicit focus on how language functions in the discipline (i.e., metalanguage or language about language).

Standardized Assessments for Special Populations

Along with the shifting instructional landscape, assessment needs have also changed to require ELs and SWDs to show their knowledge, skills, and abilities through standardized assessments. In this context, standardized assessments refer to content, administrative, and scoring procedures that have been designed to evaluate and compare test takers' performance by allowing minimal, prescribed flexibility across test takers. Assessments can help students progress and access STEM courses and careers; but, if not designed appropriately, assessments can also hinder students' access to the content (Redmond-Sanogo et al., 2016). It is of utmost importance to ensure that STEM assessments balance accessibility, standardization, and opportunity for individualization to meet the needs of diverse students everywhere.

This balance is typically accomplished by attending to best practices in the test design (e.g., plans, conceptual, and applied underpinnings as articulated in a testing framework) and test development, supported by accommodations frameworks and adding accommodations to items during the test delivery (Partnership for Assessment of Readiness for College and Career [PARCC], 2016; Smarter Balanced Assessment Consortium, 2014; Thurlow et al., 2000). These are standard procedures for test development, guided by several considerations including assessment guidelines and accessible practices.

Creating Accessible Assessments

Guidelines promote the practice of fair and accessible test development. *The Standards for Psychological Testing* (henceforth, *The Standards*; American Educational Research Association et al., 2014) is one example that addresses critical test design process components needed to enhance the end product. Specific to SWDs and ELs, *The Standards* provide guidelines to improve test validity and fairness. The International Test Commission (2018) also provides guidelines to support developers' efforts to make content accessible. Guidelines to enhance digitally delivered assessments have been championed by global committees. These committees include the Web Accessibility Initiative of the World Wide Web Consortium (W3C; which produced the Web Content Accessibility Guidelines [WC3, 2021]) and the IMS Global Learning Consortium. Collectively, guidelines enhance the development of computer-based tests to ensure that the digital delivery of the content is accessible based on common standards.

Similar to the UDL considerations raised in the previous section, Universal Design for Assessment (Thompson et al., 2002, pp. 6–20) builds on UDL and recommends seven principles to ensure that the initial assessment design process takes into consideration the need to be accessible:

- acknowledge the target population of the assessment (including any special populations within the target population);
- design constructs so that each item measures what it is designed to measure (i.e., minimizing construct-irrelevant variance);
- ensure that items are accessible and nonbiased;
- ensure that items can be accommodated without compromising the validity of the test scores;
- ensure that the instructions and general testing procedures are simple, clear, and intuitive;
- ensure that the language in the items is accessible and promotes maximum readability and comprehensibility (i.e., minimize construct-irrelevant variance for nonreading items);
- ensure presentation details such as font, style, spacing, contrast, and white space do not become sources of construct-irrelevant variance.

Taken together, these components function to produce a test that is maximally accessible and minimizes construct-irrelevant variance for all students.

Accommodations on STEM Assessments

In the United States, assessment accommodations make content accessible for SWDs. Accommodations are specified through an individualized education program (IEP) or Section 504 plan (from Section 504 of the Americans With Disabilities Act). Historically, categories of accommodation for SWDs are characterized by types of support (e.g., linguistic, timing, equipment supports; Thurlow et al., 2000) whereas accommodation categories for ELs focus on direct and indirect linguistic support (Rivera & Collum, 2006). Current models associated with the development of next-generation computer-based assessments to measure college and career readiness are different from those used in the past. These next-generation computer-based assessments use a distinct, but related categorization method for the allowed supports on their test (e.g., Smarter Balanced mathematics assessment [Smarter Balanced Assessment Consortium, 2014], PARCC mathematics assessment [PARCC, 2016]).

The common distinction between these categories is *access*. The first tier offers universal supports considered helpful for any student taking the assessment. For example, a digital highlighting tool is allowed for anyone who wants to highlight important information with a visual cue. The second tier is the designated resources where supports are available to select students as determined by various combinations of teacher judgment and/or combinations of student or parent input. Often, these supports are like traditional supports used for ELs (e.g., a version of the test in their home language or a glossary in their home language, or these supports are like a variation of SWD accommodations, such as allowing a scribe to record answers. The third tier houses the traditional SWD accommodations where an IEP or Section 504 plan is needed for access. These categories are not mutually exclusive. Teachers and students can select from these categories depending on the level of documented student need.

STEM Assessments

Our review included a survey of STEM test accommodations. We reviewed various sources, including major search engines and state department of education web pages in 2017. Search term criteria included combinations of K–12, assessment, test, science, math, mathematics, STEAM, STEM. Review criteria included multiple categories. These categories include test purpose, target population, test type (initial assessment, interim, summative, end of course), delivery mode (paper/pencil test), and allowable accommodations and descriptions thereof.

Overall, of the tests being used for Title I[6] accountability purposes we found variation in the test descriptions, accommodations, and descriptions of the accommodations (Smith & Amato, 2012). Despite recent attention to STEM commonalities discussed in the field, publicly available descriptions of the tests do not reflect the more recent interdisciplinary standards. Instead, the descriptions reflect discrete content labels such as a mathematics test or a science test. Such an approach can introduce unintended consequences when selecting appropriate accommodations and preparing students to access these test accommodations. For example, accommodations may have face validity. The same accommodations may introduce construct-irrelevant variance because they lack efficacy. One instance of this is when a science item includes mathematical notation. This science item should include math content in the Nemeth Braille Code for Mathematics and Science Notation or Unified English Braille (UEB), the braille code used for STEM content and the regularly (literary) brailled content (D'Andrea, 2019). UEB and Nemeth Code may represent a hidden element if not specified and prepared for in advance. If students and their teachers do not prepare to learn the braille math technical symbols in UEB or Nemeth Code, the students may have difficulty on the test. The tenuous act of balancing validity and efficacy with the content introduces necessary exercises to promote fair and equitable assessment. However, details necessary to support these considerations were largely missing from the publicly available information. This omission calls into question where and how this detailed information exists for the potential test takers and their teachers.

Next Steps for Accessible STEM Standardized Assessment

Accessibility for STEM content requires more than accommodations. Multidimensional standards like the NGSS or the embedded language demands in the Common Core State Standards pose challenges for instruction and assessment (Quinn et al., 2012). The complexity and novelty of multidimensional standards can impact the design of accessible content and efficacy of accommodations. For example, items designed to measure the NGSS can include mathematical concepts and embedded language demands as part of item context. Applying EL accommodations like a pop-up glossary poses challenges for multidimensional science test development. These challenges require that developers know what language in the item can be glossed without glossing science or mathematical content or impacting with the science and engineering practices that are measured by that standard. The field is in its infancy in exploring how to most effectively accommodate assessments designed to measure these complex standards for ELs or SWDs.

Multiple opportunities exist to promote accessible STEM assessment design. Recognizing that born-accessible items is a gold standard for assessment design and the benefits of UDL that have been lauded in earlier sections, UDL alone has limitations (Guzman-Orth et al., 2016; Kamei-Hannan et al., 2017; Liu & Anderson, 2008). For example, minimizing language load for ELs taking a mathematics or science assessment may require adding graphics to support students' comprehension. However, graphics pose challenges for students with visual impairments who may not derive an equal benefit. One way to mitigate these tensions is to create equitable content that is comparable and authentic to how students most likely learned the content.

Some equitable approaches include developing content that is born accessible from the onset (Capiel, 2014; Wentz et al., 2011) or improving the accessibility of existing designs through twinning (English Language Proficiency Assessment for the 21st Century, 2016; Shaftel et al., 2015). Twinning is a conceptual approach to item design that uses a disciplined multistep process to redesign and replace inaccessible content with accessible content (Guzman-Orth et al., 2018). Twinning is one such way to recognize students' individualized needs and attend to those needs while enhancing the authenticity and equitable nature of the items. This process is applicable across content areas but most recently has been applied to STEM-based assessments to promote accessibility for students with visual impairments (Guzman-Orth et al., 2018). Although born-accessible designs are recommended to meet accessibility needs, more research should be conducted to identify when twinning could be useful to balance accessibility and authenticity.

Other approaches may hold promise for supporting the needs of ELs taking their assessments in English. One example involves the use of translanguaging, as suggested in NASEM (2018). Translanguaging is the act of making meaning through using the entirety of one's linguistic resources, both verbal and nonverbal. Students can use their home language and English. On assessments, developers must carefully use methods to ensure that holistic evaluations are used for evidence of students' mastery (for more, refer to Guzman-Orth et al., 2017). These components are designed and prototyped in assessments to provide students individualized support and independence as they interact with test content (Lopez et al., 2015, 2019; Lopez et al., 2017a, 2017b). There are various resources to make content accessible (for an overview of EL accommodations and their mixed validity and efficacy, refer to Kieffer et al., 2009; Pennock-Roman & Rivera, 2011), but another unique example is through illustration glossaries. Instead of text-based glossaries to help ELs unpack content-and-grade-level language, including illustrations may reduce the language load for ELs (Solano-Flores et al., 2014; Solano-Flores et al., 2019; Solano-Flores & Wang, 2015). While the evidence for these approaches is still in the early stages, these innovations show key opportunities worth exploring to ensure that ELs also have access to STEM-based assessments.

Conclusion

Enhancing accessibility for STEM instruction and assessment is a fundamental priority. Access to opportunities to learn and show their mastery of STEM content is a priority for all students, especially those from special populations. In this endeavor, it is critical to adopt a mindset of an assets-based perspective rather than a deficit perspective. There are undoubtedly multiple barriers that can prohibit access in STEM for ELs and SWDs. But with careful, thoughtful attention, we can eliminate barriers and promote fair and equitable experiences for all students. In this paper, we have asserted accessibility as a critical lynchpin in promoting fair and equitable STEM experiences for ELs and SWDs. We illustrated key misconceptions and opportunities to enhance access for ELs and SWDs in both instruction and assessment. We also shared considerations for enhancing fair and equitable STEM experiences for special populations. It is our goal that awareness of accessibility for special populations through an assets-based perspective can influence ongoing and future STEM work. Ultimately, attending to accessibility at the forefront of STEM instruction and assessment helps ensure that ELs and SWDs are meaningfully included so the field may benefit from the skills that these students possess.

Critically, we further argue that in addition to accountability on multiple levels, high expectations for students from special populations to achieve meaningful equitable outcomes comparable to their monolingual or non-disabled peers are also necessary. For example, a fundamental skill common across ELs or SWDs in STEM fields is the inherent ability to meaningfully engage and perform fundamental problem solving. A person with a specific disability must problem solve to overcome their physical and/or cognitive limitations (Willoughby et al., 1989). SWDs can overcome challenges with methodological and technological interventions. For example, using solid colored paper behind containers to enhance low vision use, adding handles to containers in the laboratory to allow people with dexterity issues to lift items for use, or use of Wikki Stix® to serve as a raised line indicator for people with visual impairments. With a little online research and individual creativity by STEM educators, equitable experience can be made possible (Winograd & Rankel, 2007). Whatever the "workarounds" may be, it is likely that the desire and commitment to be included in the STEM workforce is unparalleled given the obstacles one must surmount to work in this area (Neybert, 2017).

Underlying innovative means to enhance equitable opportunities can be achieved through exploring the affordances of technology. As technology advances, and assessments innovate, so too will expectations of educators of students. As the education profession evolves to push the proverbial envelope of possibility, so to should the expectations for ELs and SWDs. However, caution should be exercised when exploring technological innovations. Technology, including assistive technologies, should be appropriately prototyped and used in the classroom before it is integrated into standardized assessments. Students should be familiar with the technology so that it produces an efficacious outcome. Technology should not introduce fairness issues of opportunity for access or learning on a widespread scale. Any fairness issues related to opportunity to learn would impact the ultimate potential to use the technology in a standardized assessment context.

Once the field achieves equity and inclusion for STEM instruction and assessments, only then can more doors of opportunity be open and available for ELs and SWDs. Although there have been several isolated instances where people from special populations have broken down the barriers to access to STEM careers, it is this small number that does not correspond equally with the rest of the general population. Thus, this is an indicator that more barriers to access need to be removed. Expectations of both legal guardians and SWDs themselves also need to commit to the mindset that STEM access is possible. Once the misconceptions of educators and students can be set aside, then more opportunities for inclusion can occur.

Notes

1 In this paper, while we recognize that assets-oriented framing uses terms like multilingual learners or emergent bilinguals, we use the term ELs to refer to a specific subset of multilingual learners who have formally been identified as ELs through their state's home language survey and English language proficiency assessment process; for more, see Linquanti et al. (2016).

2 In this paper, we refer to SWDs as students' ages 3–21 who have been formally identified and have an active Individualized Education Program or Section 504 plan; for more, see Pub. L. 108-446 from Individuals With Disabilities Act (2004).

3 English is reported as another language for multilingual households; for more, see McFarland et al. (2019).

4 Values do not sum to 9.6% because not all languages are reported; refer to McFarland et al., 2019.

5 For more about PhET Interactive Simulations, visit https://phet.colorado.edu/

6 Title I outlines part of the federal accountability requirements from Every Student Succeeds Act. Federal funds are available to local education agencies to assist schools with large numbers of socioeconomically disadvantaged children. These funds should ensure that the students are meeting high expectations and standards.

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