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A workshop introducing and evaluating laboratory accessibility to improve engineering experience for students with physical disabilities

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Abstract

It is increasingly important to develop a diverse engineering workforce to tackle engineering challenges creatively and effectively. Laboratory courses are critical components of an engineering education, fostering practical skills, belonging, and engineering identity. However, laboratory environments are often inaccessible to students with physical disabilities, contributing to their underrepresentation and exclusion in STEM fields. This paper addresses the accessibility challenges faced by physically disabled students in laboratory settings and presents the design and iterative prototyping of a workshop aimed at raising awareness and facilitating actionable solutions for laboratory accessibility. The workshop engages participants with a presentation and group discussions, ultimately guiding participants to evaluate laboratory spaces, identify barriers, and brainstorm accessible changes. Reflections from two workshop implementations reveal a widespread lack of prior consideration of lab accessibility, a strong desire for practical guidance, and the importance of collaborative, interdisciplinary approaches to creating inclusive lab environments. Recommendations for future workshop iterations emphasize immersive experiences and targeted discussions on lab activities. This work underscores the urgent need for continued research, education, and proactive design to ensure laboratories are accessible and inclusive, thereby supporting the retention and success of people with physical disabilities in STEM.

Note on language used in this article

Due to author preference, person-first (e.g. 'person with a disability') and identity-first (e.g. 'disabled person') language is used interchangeably in this article. The authors recognize that preference varies throughout the disability community.

Introduction

Laboratory courses are valuable educational experiences that provide students opportunities to apply theory in real-world applications. Laboratory experiences have been shown to foster feelings of belonging and engineering identity [1]. We must question to what extent this is true for physically disabled students when laboratories are often designed only with able-bodied students in mind [2]. Belonging is associated with higher levels of retention and success in higher education [3]. Therefore, when inaccessible lab environments are common in academia, we are excluding physically disabled students from engineering.

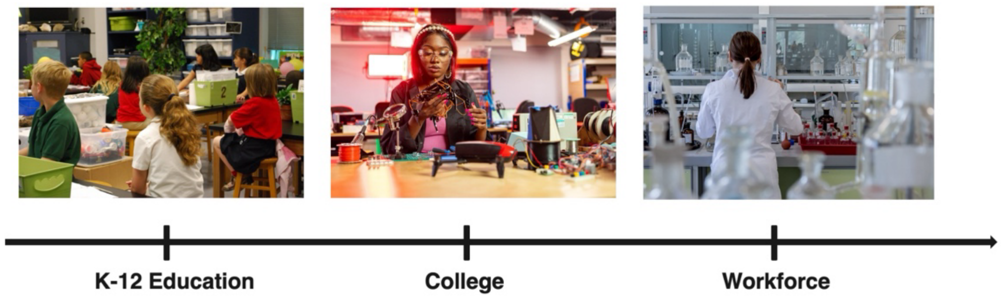

Figure 1. Timepoints where individuals may encounter laboratories during STEM trajectories (Photos from pixabay, CCY4.0).

Laboratories are a substantial component of a STEM education and career (Figure 1), and inaccessible laboratory environments result in a disparity of participation for people with physical disabilities in STEM. Young students are often first exposed to laboratory experiences in K-12. Teachers in K-12 have reported feeling unprepared to teach science to students with disabilities [5] and these students are less likely to be encouraged to pursue STEM in higher education and college than their nondisabled peers [6]. Fewer students with disabilities choose to pursue higher education in STEM and only 3% of the STEM workforce discloses a disability (Figure 2). Some physically disabled students avoid taking laboratory courses during their STEM education, electing to take theory courses instead, or choose to not pursue a STEM career altogether despite an interest due to anticipated barriers in laboratory environments [7]. This suggests that the retention of physically disabled students through STEM careers and into the workforce can be improved by intentionally designing accessible laboratories.

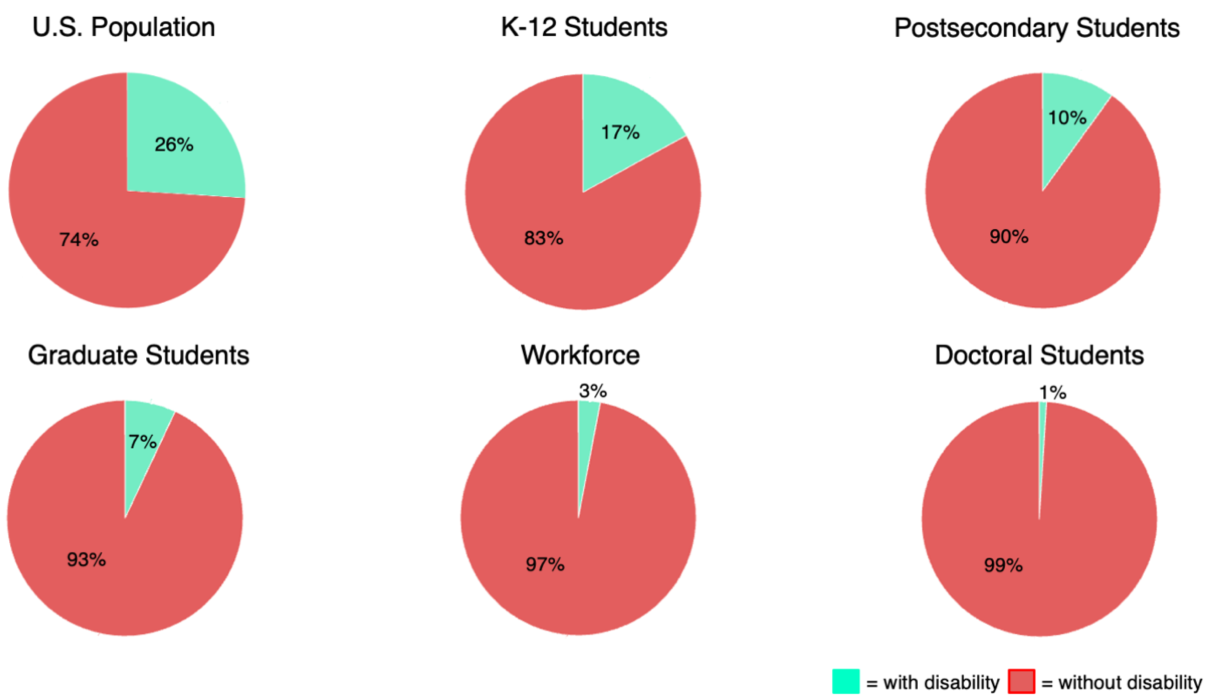

Figure 2. Percentage of individuals with disabilities (all types) in STEM trajectory stages [8][9][10].

Existing regulations mandate that federally funded schools and universities in the U.S. provide accessible educational experiences [11] for people with disabilities in accessible buildings [12]. For college students with disabilities, letters of accommodation issued through a disability services office often meet this requirement for accessible educational experiences under Section 504 [11]. To assemble an effective letter, students must preemptively know which supports will create equal opportunity to participate in their coursework compared to their nondisabled peers. In laboratory coursework, where students are constantly learning new procedures, methods, and equipment, it can be difficult for a student to know what issues they may encounter and to suggest alternatives before the semester begins. The Americans with Disabilities Act ensures that buildings are structurally accessible and include the appropriate fixtures, ramps, and elevators [12]. These regulations represent the minimum requirements for accessible lab environments but can be poorly implemented [13] and are not lab-specific. The Accreditation Board for Engineering and Technology states in Criterion 7 that, for accredited programs, "…laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning. Laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes" [14]. We must reflect on how accessible labs can be designed beyond these regulations to truly achieve inclusion for physically disabled students.

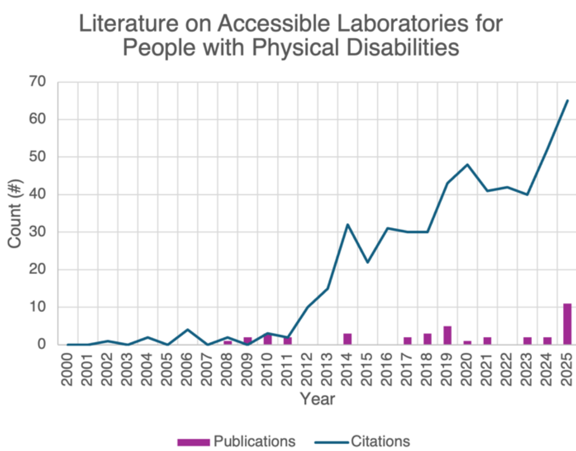

Figure 3. Publications and citations from 2000-2025 pertaining to accessible laboratories for people with physical disabilities. Search terms: physical* AND disabil* AND laborator* AND accessib*.

Laboratory instructors, staff, departments, and physically disabled students deserve more research into accessible laboratories to create a more inclusive future in engineering education (Figure 3). In our Web of Science search with terms: physical* AND disabil* AND laborator* AND accessib*, we see an upward trend in scholarship and citations in this area. However, upon review, many papers do not fit within topic scope leading to overrepresentation of scholarship in this area. Another study found that as little as 5% of the literature on supporting students with disabilities in STEM focused on physically disabled students or students with mobility impairments [15]. Virtual labs have been proposed as an accessible alternative to in-person laboratory exercises for people with disabilities [16]. Physically disabled students have also reported intentionally being assigned passive, observational roles [17] or computer-based tasks [18] in the laboratory due to their disability. While these strategies may be effective in supporting students to complete necessary laboratory prerequisite courses, they do not build physically disabled students' confidence in their ability to perform in-person laboratory activities as future workers in academia or industry. Accessible laboratories should allow students with physical disabilities to be active and independent participants in laboratory activities.

To create accessible laboratory experiences for physically disabled students, we must first identify barriers to full participation for these students and then propose and implement solutions that address these barriers. Jeannis et al. (2020) conducted an extensive study to identify barriers pertaining to task execution and the learning and architectural environments [17]. Potential solutions to accessibility and inclusion barriers in laboratories can be created using universal design. Universal design is an approach that focuses on designing products and environments to be used by all people to the greatest extent possible without the need for adaptations [19]. Several studies have assembled recommendations for making laboratories more accessible [20][21][22]. Recommendations include wide aisles for navigation, storage at accessible heights, providing a variety of tools or methods to complete an activity, and using adjustable-height tables. The iterative process of identifying and removing barriers is essential, both to improve the accessibility of individual lab environments and to discover what it means for a lab to be truly inclusive for people with physical disabilities.

In this paper, we describe the design and implementation of a workshop created to facilitate the process of barrier identification and solution ideation in laboratory environments through a human-centered design process. Workshop participants were able-bodied university students, staff, and faculty. This workshop was created in response to the question, "*How can we educate individuals about the importance of laboratory accessibility for students with physical disabilities and equip individuals with the tools and knowledge to create or modify their own accessible laboratories?"* We report on (1) how the workshop can be used as a model to support conversations on laboratory accessibility and (2) reflect on its impact and lessons learned during workshop prototyping. We present this replicable workshop model as a potential tool to improve lab accessibility and raise awareness of this topic.

Methods

This workshop was developed with the following objectives: (1) Introduce participants to the importance of laboratory accessibility, (2) provide participants with suggestions on how lab accessibility can be implemented, (3) foster discussions around accessible and inaccessible aspects of presented lab spaces, and (4) provide opportunities for participants to discuss accessibility concerns in their own lab spaces.

Workshop Design

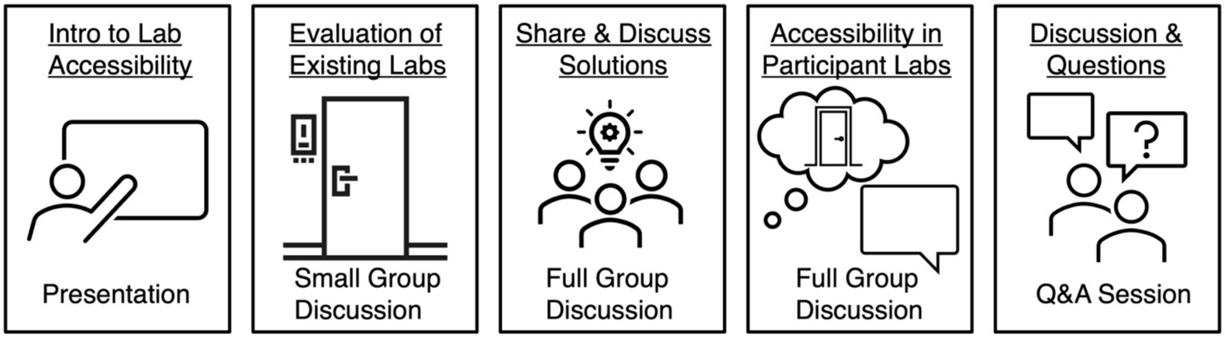

Figure 4. The five potential workshop components.

This workshop consists of five parts (Figure 4). First, a presentation, 'Intro to Lab Accessibility' describes the current state of inclusion for physically disabled students in laboratories. The presentation includes much of the information contained in the introduction to this article and describes potential barriers and recommendations from literature for accessible modifications that can be implemented in the lab. Next, in a small group activity, participants are assigned a specific lab space photo (Figure 5). This activity encourages participants to discuss barriers or supports that they see in the photos. Workshop participants are given a table of accessible lab recommendations from Taylor et al. [20] and a list of disability types to support these discussions (Table 1). After small group discussion, a facilitated large group conversation asks groups to share what they found, with a focus on collectively brainstorming what changes could be made to remove identified barriers. Next, a second large group discussion allows for individuals to speak about accessibility concerns in their own lab spaces for group brainstorming. Lastly, time for general discussion and questions addresses any remaining thoughts that participants wish to address on the topic.

Figure 5. Examples of lab space photos that can be evaluated by workshop participants. A. Design lab for bioengineering students. B. Lab for assistive technology development research. C. Instructional lab for physiology courses.

Table 1. Examples of physical disability types and access needs.

1. Balance or coordination impairments
2. Blind/low vision
3. Chronic fatigue or limited endurance
4. Colorblindness (red/green)
5. Deaf/hard of hearing
6. Limb weakness or paralysis
7. Limited hand strength or dexterity
8. Short stature
9. Tremor disorders
10. Wheelchair users

Workshop Prototyping

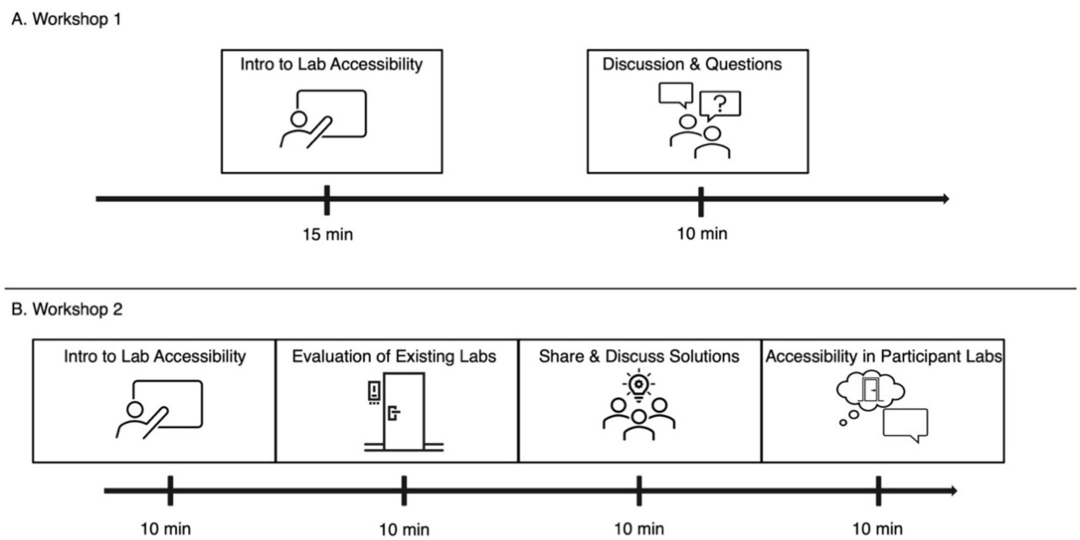

Figure 6. Two workshop variations were held during prototyping. A. Workshop 1, at a student organizational meeting. B. Workshop 2, at a national conference focused on STEM accessibility.

Two variations of the workshop were conducted (Figure 6). Workshop 1 consisted of an approximately fifteen-minute 'Intro to Lab Accessibility' presentation followed by ten minutes of general discussion and questions, held by one facilitator. This workshop was held at the authors' university at a student organization meeting. The workshop was attended by eight students and two faculty.

Workshop 2, held by the same facilitator, was conducted one month later at a national conference focused on STEM accessibility. This inaugural conference was hosted by a university in the Southeastern United States. Eight participants (an unknown mix of faculty, staff, and students) attended the workshop. This workshop consisted of four parts, each intended to last ten minutes. Due to unanticipated delays, the actual time allotted to each part of the workshop was slightly less. After an 'Intro to Lab Accessibility' presentation, participants broke into smaller groups to discuss barriers and supports in their assigned lab spaces. Figure 5A and Figure 5B were used for this workshop. Following these discussions, each group's two most important findings were shared and debriefed with all participants in a large group discussion format. The facilitator supported participants through brainstorming potential solutions to any noticed barriers. Lastly, using the same large group discussion format, participants were invited to share accessibility concerns in their own labs or personal strategies for creating more accessible labs.

Reflections

Facilitator reflections were analyzed to identify recurring themes across the two workshop implementations. Analysis was done using an inductive approach.

Theme 1: Some people had never considered laboratory accessibility as a potential issue before.

Many participants from both workshops shared afterward that they had not thought about laboratory accessibility before. These participants appreciated the opportunity to learn about what makes labs inaccessible and how they can be made more accessible. One student participant from Workshop 1 asked if the workshop could be facilitated at a different student organization meeting to raise awareness of this topic. While it might be expected that student participants from Workshop 1 would be unfamiliar with lab accessibility, many participants from the STEM accessibility conference shared this perspective. Even within STEM-focused accessibility communities and researchers, lab accessibility can be understudied and not well understood. We must continue to have dialogue around laboratory accessibility so that more people are attentive to accessibility concerns in labs and equipped to address them.

Theme 2: People want guidance, but it is difficult to find.

Many participants desired feedback on their own lab spaces and environments. One student from Workshop 1, who works in a campus makerspace, shared that the staff had been considering how to make their space more accessible to students with physical disabilities but was unsure how to identify barriers. It was suggested that the makerspace recruit physically disabled students to participate in a walkthrough of the space and discuss any noticed or anticipated barriers. At the authors' university, recruitment can be done through the weekly newsletter sent to all students registered with campus disability services. Another participant, a faculty member who sits on an inclusion committee for their department, inquired about other department-related accessibility concerns beyond labs and asked for advice regarding an ongoing non-lab accessibility issue. Overall, we the authors believe most people are willing or even eager to modify labs and other environments to help people with physical disabilities have better STEM experiences. However, there is not sufficient guidance on practical steps for creating accessible labs. One student participant from Workshop 1 asked which disabilities are important to consider in lab accessibility discussions, which resulted in the creation of Table 1 for Workshop 2. Without lived experience of disability, or even a specific disability, it can be difficult to anticipate access needs. We must all work together, with our different perspectives and lived experiences, to ideate more effectively what it looks like when a laboratory is designed for accessibility.

Theme 3: People can be pessimistic about lab accessibility.

During Workshop 2's small group lab evaluations of lab spaces, participants correctly identified potential barriers such as harsh lighting, sliding cabinet doors (Figure 5A), and insufficient lighting (Figure 5B). However, participants sometimes misidentified barriers. For example, participants mentioned that the concrete is cracked in Figure 5B and that tools on the back wall are not stored at accessible heights for wheelchair users when in fact the heights were designed with wheelchair users in mind. This lab is associated with the wheelchair track and field program at the authors' university and was designed and is used in part by wheelchair users. This emphasizes that photos, while a great low-cost resource, often don't tell the full story. Simulations in virtual reality (VR) or augmented reality (AR), CAD renderings, in-person tours, or videos can provide a more immersive experience, but are more costly to develop and implement.

Participants spoke about some supports, such as wide aisles for navigation (Figure 5A and Figure 5B) but mentioned significantly fewer supports in the spaces than barriers. Participants did not identify many of the supports that were intentionally added to these spaces. These include vises, propped-open doors (Figure 5A), and lightweight chairs with wheels (Figure 5A and Figure 5B). It is likely that participants attended the workshop with more prior knowledge related to barriers than supports in lab environments. This preexisting bias could explain why it was more difficult for participants to identify barriers than supports during the lab space evaluations. Vices are common supports even for able-bodied students in engineering labs but are rarely seen in chemistry or biology labs. Most participants from Workshop 2 were not engineers, which could explain why these supports in Figure 5A went unnoticed. It is important that disciplines share information regarding accessible lab practices with one another to benefit all students, scientists, and engineers.

We the authors believe barriers in Figure 5B were misidentified partially because the space is visually outdated. During Workshop 2, this prompted a discussion on the importance of 'working with what you have' when it comes to accessible modifications for existing laboratories. For spaces that cannot be built from the start with accessibility in mind, supports may be imperfect. For example, it may be unavoidable that some storage areas in a lab space must be out of reach for wheelchair users. However, efforts can be made to place items that are most used by students, or needed for a particular lab exercise, in accessible storage locations. In general, imperfect supports are better than no supports toward creating better lab experiences for people with physical disabilities.

Theme 4: Some people feel isolated in their accessibility efforts.

One participant from Workshop 2, who works as a teaching assistant within the science department for their university, described feeling unsupported in making accessible changes to lab spaces. They attended the workshop to learn how to create an accessible lab environment for a student with a disability that would be taking their class in the upcoming semester. The student had expressed in conversations with the participant that they would make do with the lab environment as-is. However, the participant was very worried and wanted to address storage and contamination concerns before the start of the semester. They spoke about a lack of knowledge from campus disability services on appropriate modifications and felt isolated in their efforts. The student with a disability deserves better than to settle for a lab environment where everything will ‘probably work out.’ Likewise, we should strive for these spaces to be proactively modified in accessible ways rather than waiting until physically disabled students enroll in a lab course. Lab accessibility should be a priority that is supported not just by teaching assistants and the physically disabled student themselves, but by universities, departments, and faculty.

Future Workshop Iterations

Here, we propose improvements to the workshop that can enrich participants’ experiences (Table 2). The lab photos shown in Figure 5 should be replaced by pictures of the facilitator’s own laboratories. As an alternative to analyzing lab photos during barrier and support discussions, participants could watch a video or participate in a walkthrough of the laboratory spaces. This change could support a better understanding of the lab spaces. Participants in our workshops primarily mentioned issues with access to spaces and equipment. However, many physical disabilities also make it more difficult to use lab equipment or perform specific lab procedures. To encourage these conversations, we recommend providing a list of lab activities that are performed in the specific lab space. This workshop could be presented to people with physical disabilities if the primary objective is evaluating specific lab spaces rather than participant education. Additionally, this workshop could be leveraged as professional development for lab staff or instructors. Facilitators should design workshops using components from Figure 4 after reflecting on their objectives and intended audience.

Table 2. Potential resources and audiences for future workshops compared to past workshops.

<table>
<tr><th></th><th>Workshop 1</th><th>Workshop 2</th><th>Future Workshops</th></tr>
<tr><td rowspan="8">Workshop Resources</td><td colspan="3">‘Intro to Lab Accessibility’ presentation</td></tr>
<tr><td rowspan="7"></td><td colspan="2">Lab space photos</td></tr>
<tr><td rowspan="4"></td><td>Lab space videos</td></tr>
<tr><td>In-person lab tours</td></tr>
<tr><td>AR/VR lab renderings</td></tr>
<tr><td>CAD lab renderings</td></tr>
<tr><td colspan="2">Disability examples list</td></tr>
<tr><td></td><td>Lab activity examples list</td></tr>
<tr><td rowspan="2">Audience</td><td rowspan="2">Able-bodied students and faculty from one university</td><td rowspan="2">Able-bodied students, faculty, staff from several universities</td><td>Individuals with disabilities to consult on lab accessibility</td></tr>
<tr><td>Lab faculty and staff for professional development credits</td></tr>
</table>

Conclusion

In this paper, we detailed (1) the need for workshops on laboratory accessibility and (2) an iterative process to prototype a workshop for this purpose. Despite a lack of literature on the topic, there is a sense from the community that more information and guidance are desired by laboratory staff and instructors. Our iterative prototyping process was informed by an editorial journal article, a workshop delivered to a campus student organization, and a workshop delivered at a disability-focused conference. This paper is intended to serve as a template for others who want to deliver a similar workshop. Table 2 outlines recommendations for potential future workshops. While the information presented in workshops has been generally well received, the need for more research is evident. We welcome the use of these materials and believe the community will benefit from facilitators sharing their own experiences in future publications. Education, iteration, and human-centered design principles can support the pathways of students with physical disabilities succeeding in STEM.

Acknowledgements

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