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GUEST EDITORIAL

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Beyond buildings: Designing and maintaining classroom laboratory spaces for physical accessibility

1 | INTRODUCTION

Laboratory training and research experiences enhance educational and cultural experiences for students but necessitate a disruptive approach to achieve full inclusion of engineering students with physical disabilities. We, the authors, are a group of faculty and students with and without disabilities who conduct research in assistive technologies, participatory design, and engineering education. We posit that engineering departments and instructors need increased research highlighting best practices and policies to meet the needs of physically disabled engineering students. This will promote the development of inclusive laboratory environments to effectively train the next generation of innovators to join the engineering workforce. In the absence of sufficient literature providing guidance on accessible laboratories and curricula, we focus herein on the actions that individual faculty or departments can take immediately to create a more inclusive environment for physically disabled students.

Existing literature and statistics are sparse and often neglect to specify disability type. Consequently, we draw from the experiences of the disability community more broadly to describe the current inclusion of physically disabled students in engineering laboratories. Under our definition, physically disabled students include wheelchair users, students with visual impairments, or students with limited mobility who use no assistive devices. In this paper, the term "disability" alone refers to a wider definition that includes nonphysical disabilities. We also chose to use "person-first" (e.g., "people with disabilities") interchangeably with identity-first language (e.g., "disabled people") based on our preferences but we recognize that language preferences vary throughout the disability community. We continue our perspective on accessibility in teaching laboratories with these definitions in mind.

Laboratory experiences provide students with salient opportunities to contextualize theory and practice team-based project work. This training is essential to the development of workforce-ready engineers (Rohde et al., 2019). Laboratory environments facilitate the development of skills, concepts, cognitive abilities, and applications in engineering (Feisel & Rosa, 2005). Furthermore, design and team-based lab work can positively influence engineering identity (Dannels, 2000). Curricular and extracurricular laboratory experiences, including undergraduate research, can increase feelings of belonging for engineering students (Jones et al., 2013). However, some physically disabled students avoid taking laboratory courses by deliberately taking theory courses or choosing not to pursue a science, technology, engineering or mathematics (STEM) career despite an interest (Mansoor et al., 2010). Inclusion in laboratory exercises, access to laboratory spaces, and culture within those spaces signal to students who is welcome in engineering. When physical laboratories are outdated and inaccessible, we are excluding talented students with valuable lived experiences from engineering practice.

Disability statistics reveal a clear participation disparity for disabled students in STEM. Nearly 26% of the U.S. population discloses a disability (National Center for Science and Engineering Statistics [NCSES], 2021). Physical disabilities are one of the most prevalent (12%) among U.S. adults (Centers for Disease Control and Prevention, 2024). The National Science Foundation reports that 10% of STEM students entering postsecondary education disclose a disability (National Center for Science and Engineering Statistics [NCSES], 2021). However, graduation rates for these students are lower than those of their nondisabled peers (Leddy, 2010). Only 7% of students entering graduate school and 1% of doctoral students report a disability (National Center for Science and Engineering Statistics [NCSES], 2021). When students see faculty like themselves in their learning environments, feelings of belonging are significantly enhanced (O'Keeffe, 2013). However, this is difficult when the percentage of faculty with disabilities (4% in the U.S.) is significantly lower than the population of disabled students (National Center for Science and Engineering Statistics [NCSES], 2021). Improving accessibility in engineering laboratories will ensure that the next generation of faculty includes more people with physical disabilities to serve as role models for students.

2 | LOOKING BEYOND ACCESSIBILITY REGULATIONS

International educational accreditation standards aim to support students with disabilities by requiring engineering programs to maintain accessible spaces. Accreditation Board for Engineering and Technology (ABET) Criterion 7 states that, "laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes" (ABET, 2023). In the U.S., for example, federally funded schools and universities are also required to provide accessible educational experiences (U.S. Department of Health and Human Services, 2024; U.S. Department of Justice Civil Rights Division, 2010). Regulations and standards can be poorly implemented and represent *minimum* accommodation requirements in laboratories on engineering campuses (Jeannis et al., 2018). Beyond initial construction and inspection of ramps, elevators, and emergency exits (International Building Code [IBC], 2021), long-term room maintenance inside buildings is not heavily regulated. Therefore, it is ultimately the role of departments, laboratory managers, and individual instructors to foresee and undo laboratory barriers with readily achievable actions.

Laboratory barriers extend beyond physical spaces. ABET requires that students acquire collaboration skills and can effectively function as part of a team (ABET, 2023). In our work, physically disabled students have reported being sidelined to observatory roles that do not involve using laboratory equipment (Jeannis et al., 2020). Accommodations for students with physical disabilities should not hinder their progress in achieving learning outcomes essential to their success as engineers. If we ensure accessibility in the educational laboratory, physically disabled students will be more prepared and successful as engineers in continuing education or the workforce.

3 | PERSISTENT BARRIERS AND RECOMMENDATIONS FOR INCLUSIVE LABORATORY SPACES

Improving the lab experiences for physically disabled students means identifying and addressing barriers within the educational environment. Our prior work presented a comprehensive study on physically disabled students' experiences in labs (Jeannis et al., 2020). Architectural barriers include benchtop height, obstructive laboratory floors, and narrow spaces between benches that worsen when backpacks and other belongings fill the room. Able-bodied students, in addition to instructors, must be aware of how their treatment of laboratory spaces can impact peers with physical disabilities. Students have reported difficulty grasping tools, manipulating equipment, or meeting time constraints. Providing an assortment of tools or assistive technologies and exploring alternative ways to complete tasks may minimize these barriers. Even when students cannot complete a laboratory task using provided supplies, it is imperative that they are taught the process. Social environments can impede students' learning due to barriers such as low instructor expectations and excessive lab assistant aid (Jeannis et al., 2020). Even in our own work, most existing research focuses on creating

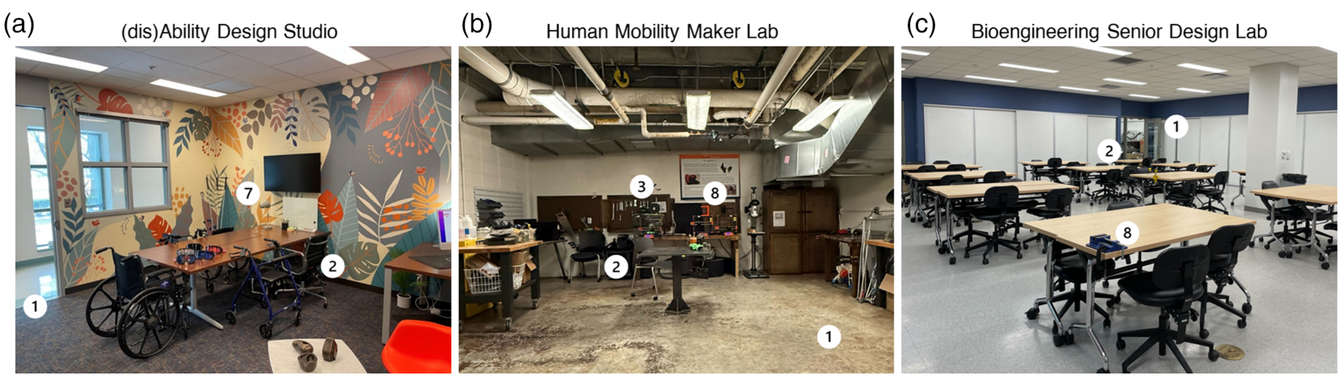

FIGURE 1 Three laboratories on the campus of the University of Illinois Urbana-Champaign. Numbers highlight recommendations in action from Table 1. (a) The (dis)Ability Design Studio includes open doors (1), variable and lightweight chairs (2), and subdued lighting options (7). (b) The Human Mobility Maker Lab includes an open floor plan (1), lightweight chair options (2), accessible height tools (3), and 3D printers for fabricating assistive technology. The (dis)Ability Design Studio and the Human Mobility Maker Lab were intentionally designed with accessibility in mind. (c) The Bioengineering Senior Design Lab was modified after the original design to implement recommendations. This includes propping open internal doors (1), installing an ADA-compliant sink (2), and providing clamps and helping hands around the lab (8).

architecturally accessible lab spaces (Duerstock et al., 2014). However, we collectively agree that it is critical to address all types of barriers so that physically disabled students can have a holistically positive lab experience.

4 | RECOMMENDATIONS IN PRACTICE

Participatory design, including disabled people in the design process, and "designed *by*, not designed *for*" (Peters et al., 2023) strategies are critical for addressing accessibility challenges in engineering. Our design work increasingly recognizes the importance of end-user involvement early in the design process (McDonagh & Formosa, 2011) so that user insights can be fully integrated into the design. What if we focused our efforts beyond simply incorporating the feedback of disabled people as end-users, but on supporting their retention in becoming the designers and engineers creating these products themselves with accessible studios, laboratories, and maker spaces?

Laboratory spaces across the UIUC, the home institution for many of us authors, specifically address the needs of students with physical disabilities. The spaces in Figure 1 were developed based on years of research into participatory design. Figure 1a shows the newly established dis(Ability) Design Studio, located on the engineering quad within a center for advanced science and technology. This design studio welcomes people with and without disabilities and is intentionally untraditional, with subdued lighting options and assistive technologies surrounding the meeting table. It offers a dedicated space for design and usability studies and for discussing disability and innovation. It is not only about accessible space, but also inclusive experiences within the space to promote collaboration and parity in technology design.

The Human Mobility Maker Lab directed by coauthor Adam Bleakney is a dedicated maker space that offers an accessible environment where students and faculty with and without disabilities work together to design, build, and

TABLE 1 Recommendations for proactive measures that engineering faculty can apply in instructional laboratories.

Recommendations	Examples
1. Ensure open spaces	• Consider paths, obstacles, and travel time to class (Lee et al., 2024) • Reduce force required to open doors or prop open heavy doors[a] • Clear floors and counters of unnecessary boxes and storage and ensure wide aisles for navigation (Peters et al., 2023)
2. Incorporate accessible furniture	• Variety of chairs that are lightweight, with and without wheels (Peters et al., 2023) • Powered variable height tables with low options, and use variability (R. A. Cooper et al., 2019) • Install ADA-compliant fixtures (sinks, faucets, safety showers, eye-wash stations) (U.S. Department of Justice Civil Rights Division, 2010)
3. Make equipment storage accessible	• Store small items at accessible heights, avoid high and low shelf storage (Peters et al., 2023)
4. Minimize experimental safety hazards	• Provide multiple methods to carry hot or liquid items (Jeannis et al., 2020) • Prevent slippery floors or other potentially hazardous surfaces (Candiotti et al., 2023) • Provide accessible safety gear—face shields or glasses, aprons, and shoe coverings (Swanson & Steere, 1981)
5. Post signage	• Communicate expectations for lab cleanliness and tidiness[a] • Inform about potential hazards (Jeannis et al., 2020) • Provide signage in braille, in high contrast, and large-print (Burgstahler, 2012)
6. Use secondary indicators	• Avoid using color alone on data presentation, in text, and on electrical components (Berisso, 2018; Chen & Wang, 2016) • Include tactile models when possible (Williams et al., 2014)
7. Offer variable lighting options	• Provide overhead and task lights, lamps with adjustable intensities[a] • Natural lighting and well-lit workspaces (R. A. Cooper et al., 2019)
8. Provide an assortment of tools and equipment	• Equip lab with clamps, clips, and other ergonomic "helping hand" tools (R. A. Cooper et al., 2019) • Provide variable-sized and adaptive hand tools (R. A. Cooper et al., 2019) • Design adaptive tools and equipment with CAD and 3D printing[a]
9. Prioritize continuing education	• Regular professional development for faculty (Pearson Weatherton et al., 2017) • Teaching assistant training (Pearson Weatherton et al., 2017)

[a]Indicates an example inspired by the authors' collective work to improve accessibility in our own labs.

test prototypes (Figure 1b) (Peters et al., 2023). This lab has an open floor plan for easy maneuverability. Stationary worktables are placed against the walls, while tables elsewhere have wheels for easy repositioning. Lightweight chairs with wheels are stackable, while smaller items are stored on walls to maximize floor space. It is undeniably easier to address accessibility concerns at the architectural design stage than retroactively. But we cannot wait for new buildings to start making accessible changes in our laboratory spaces. Figure 1c shows small changes that were made to an existing engineering design laboratory to improve accessibility. Faculty should not dismiss the positive impact that even small changes can make on the experiences of physically disabled students in their labs.

Our collective research, own accessible laboratories, and lived experiences emphasize that it is possible and imperative to take immediate action to improve access to spaces and experiences that increase feelings of belonging and persistence in engineering for the students in our classes and laboratories today. We also recognize that it is impossible to anticipate the needs of each student. Faculty can work with students to address accommodations together as needed. Instructors striking a balance of "being ready" and "being responsive" creates an environment where all are expected, included, and welcomed. Table 1 outlines recommendations to improve laboratory accessibility and provides examples of what this could look like in practice. We aim to provide recommendations that can be implemented at any university regardless of significant financial commitments or support from campus disability resource centers. These centers may help realize some of these recommendations but may be uninformed about laboratory-specific concerns. The recommendations below are not exhaustive but serve as a starting point.

5 | A FUTURE OF INCLUSION FOR STUDENTS WITH DISABILITIES

In conclusion, while buildings may be designed to meet minimum accessibility standards, how those buildings are used once they are filled with faculty, staff, and students is up to us as engineering educators. It is a rare case that there is constant administrative oversight of cardboard box storage, backpacks' locations during class, or chair placement. How instructors maintain laboratory spaces signals who belongs in engineering education and practice. In this editorial, we outlined present challenges, the research (or lack thereof) into the experiences of physically disabled students, and actions that the engineering education community can enact today in instructional laboratories. Prioritizing accessibility in laboratory spaces signals to physically disabled students that they are welcome and encouraged to pursue engineering.

KEYWORDS
accessibility, inclusion, laboratories, physical disability

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