

Navigating the Unseen: Readiness of Hands-on Labs for Visually Impaired Students

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Abstract

Hands-on laboratory work, a cornerstone of STEM education, helps students engage in active learning, reinforce concepts, develop skills, and build confidence. However, the literature has highlighted a spectrum of challenges that visually impaired students (VIS) face in fully participating in the predominantly visual nature of these lab activities. These limitations, ranging from accessing visual information and manipulating equipment to ensuring personal safety, underscore the critical need for innovative approaches, including assistive technologies, pedagogical modifications, and a collaborative support system.

In this paper, we discussed the findings of a project to identify the gap between faculty members' experience, the concerns of visually impaired students, and the best practices suggested by student accommodation experts. Data collected from a survey of faculty members across campus, suggestions from the panel discussion with experts, and the interviews of visually impaired students from different majors were presented. Cross-examination was conducted to identify deficiencies of the conventional lab environment and in learning activities to accommodate visually impaired students' learning. Lessons learned and practical recommendations were provided to conclude the paper.

Introduction

Institutions of higher education increasingly emphasize diversity, equity, and inclusion, yet students with visual impairments continue to face substantial structural and instructional challenges. According to data from the Northeast ADA Center [1], between 2013 and 2023, an estimated 7.3 to 8.3 million people in the United States reported having a visual disability, encompassing individuals across all genders, races, ages, and ethnic backgrounds. In 2023, the number of non-institutionalized people aged between 21 and 64 with visual disabilities at different educational attainment levels – ranging from less than a high school diploma, with a high school diploma or equivalent, some college/associate degree, to a bachelor's degree or higher – was approximately 0.76 million, 1.3 million, 1.24 million, and 0.79 million, respectively. Although the population of individuals with visual disabilities who earned a bachelor's degree or higher grew markedly from 0.5 million in 2013 to 0.79 million in 2023, they still represent only 19.3% of the visually disabled population, far lower than the national rate of 35.7% for adults aged 25 and over, as reported in the 2022 American Community Survey.

This situation may stem from academics' limited awareness of the challenges faced by students with visual impairments (VI), as well as from insufficient academic support services available to them. Firat reported that students with VI encounter numerous obstacles, including a lack of accessible materials, difficulty obtaining lecture notes, inadequate academic support, issues with readers, limited library resources, and barriers to accessing university facilities and services [2]. Drawing on semi-structured interviews and inductive thematic analysis, Alsamiri found that

students with VI experience substantial academic, social, and psychological barriers that are often unrecognized by faculty [3]. Academic challenges largely stem from difficulties in accessing essential learning materials, while social barriers include peer ignorance, campus isolation, and exclusion from collaborative learning opportunities. Psychological barriers, including faculty members' feelings of helplessness and students' anxiety and diminished self-confidence resulting from repeated accessibility failures, may further discourage students with VI and negatively impact their academic retention.

In specialized academic environments such as Engineering or Technology programs, the curriculum is typically characterized by hands-on activities, visually intensive content, and frequent laboratory work. These features can unintentionally exclude students with VI or discourage them from pursuing these majors. An effective way to address this unintentional exclusion is to cultivate a strong "sense of belonging", ensuring that students with VI feel fully included and recognized as integral members of the learning community. A sense of belonging is a critical factor in student retention and overall success in higher education [4], [5], [6]. For students with VI, however, this sense of connection is often undermined not by a lack of academic ability but by environmental and instructional barriers [7], [8].

This paper presented a case study of a midsize university in the U.S. Midwest, focusing on the College of Applied Science and Technology (CAST), where the curriculum heavily emphasized physical laboratories, technical diagrams, and real-time data interpretation. The study, conducted during the 2023-2024 Academic Year, examined the environmental and instructional modifications needed to make CAST a more welcoming and equitable setting for students with visual impairments. By integrating insights from faculty, experts, and students, the research aimed to identify key challenges and practical, actionable strategies to foster a more inclusive learning environment.

Methodology

This research employed a qualitative, exploratory methodology and utilized a three-pronged data-collection approach to develop a comprehensive understanding of the accessibility landscape. The data sources included: (1) faculty surveys conducted across multiple colleges to establish a campus-wide baseline of current practices related to course delivery, assessment methods, accommodations, and facility support; (2) an three-expert panel discussion aimed at identifying best practices and institutional resources for supporting student access and instruction; and (3) semi-structured interviews with seven students with VI from various majors, focusing on their lived experiences in classroom and laboratory settings. Together, these complementary data sources enabled triangulation and provided a holistic perspective on accessibility challenges within CAST.

Current Instructional Baseline

A campus-wide faculty survey was administered through Qualtrics following approval from the university's IRB, yielding 50 usable responses (out of 1,194 tenured, tenure-track, and non-

tenure-track faculty members). The survey examined faculty perceptions in four areas: course delivery, assessment strategies, accommodation formats, and the preparedness of campus facilities and support services. Findings indicated that, although instructors generally express willingness to support students with visual impairments, many depend heavily on centralized accommodation services and have limited firsthand experience with accessible instructional design. Course delivery and assessment practices often presume visual engagement, leading faculty to overlook how factors such as formatting, contrast, or spontaneous assessments influence accessibility. While campus facilities and support services are available, their effectiveness relies heavily on early communication and coordination.

Course Delivery	CAST	CAS	CoB	CoE	WKCFA	MCN
Response Count (% of College Total)	8 (5.7%)	19 (4.9%)	6 (5%)	10 (6.9%)	3 (2.2%)	4 (8%)
Text-based content (e.g., readings, etc.)	100.0%	94.7%	100.0%	90.0%	100.0%	100.0%
Static materials (e.g., images, diagrams, etc.)	87.5%	73.7%	100.0%	80.0%	100.0%	100.0%
Audio content (e.g., recording, podcast, etc.)	25.0%	47.4%	66.7%	80.0%	66.7%	25.0%
Video-based (YouTube, simulation, etc.)	62.5%	89.5%	83.3%	70.0%	100.0%	100.0%
Others (Please specify)	25.0%	21.1%	16.7%	30.0%	33.3%	25.0%
Assessment Strategies	CAST	CAS	CoB	CoE	WKCFA	MCN
Response Count	8	19	6	10	3	4
Written assignments or recordings	75.0%	94.7%	100.0%	80.0%	100.0%	75.0%
Hands-on lab activities and reports	87.5%	31.6%	66.7%	70.0%	66.7%	75.0%
Oral presentations (individual or group)	62.5%	68.4%	83.3%	50.0%	100.0%	75.0%
Group projects	75.0%	52.6%	66.7%	50.0%	100.0%	75.0%
Exams or quizzes	87.5%	84.2%	66.7%	50.0%	66.7%	50.0%
Others (Please specify)	12.5%	31.6%	16.7%	20.0%	0.0%	25.0%
Assessment selected by students						
Yes	25.0%	5.3%	0.0%	40.0%	33.3%	0.0%
Maybe	12.5%	31.6%	33.3%	50.0%	33.3%	25.0%
No	62.5%	63.2%	66.7%	10.0%	33.3%	75.0%
Accommodation	CAST	CAS	CoB	CoE	WKCFA	MCN
Response Count	5	14	6	7	3	4
Alternative Formats for Course Material						
Yes, a wide range of options	20.0%	0.0%	16.7%	0.0%	0.0%	0.0%
Yes, some options	0.0%	64.3%	66.7%	57.1%	0.0%	25.0%
No, very limited options	20.0%	28.6%	16.7%	28.6%	100.0%	50.0%
No, no options	60.0%	7.1%	0.0%	14.3%	0.0%	25.0%
Assignment or Project Options						
Yes	20.0%	14.3%	0.0%	28.6%	33.3%	50.0%
Maybe	0.0%	50.0%	66.7%	28.6%	33.3%	50.0%
No	80.0%	35.7%	33.3%	42.9%	33.3%	0.0%
Need Consideration for VI Students						
Yes, consistently.	40.0%	7.1%	50.0%	28.6%	0.0%	25.0%
Yes, to some extent.	0.0%	50.0%	16.7%	28.6%	0.0%	25.0%
No, limited consideration.	0.0%	42.9%	16.7%	14.3%	33.3%	25.0%
No, minimal consideration.	60.0%	0.0%	16.7%	28.6%	66.7%	25.0%

Table 1. Faculty survey results on course delivery, assessment, and accommodation

Campus-wide Faculty Survey

Facilities & Supports	CAST	CAS	CoB	CoE	WFCFA	MCN
Response Count (% of College Total)	5 (3.6%)	13 (3.3%)	6 (5%)	6 (4.1%)	3 (2.2%)	3 (6%)
<i>Accessibility for College Physical Spaces</i>						
Very accessible	0.0%	0.0%	33.3%	0.0%	33.3%	0.0%
Somewhat accessible	40.0%	61.5%	50.0%	33.3%	0.0%	33.3%
Not very accessible	40.0%	23.1%	16.7%	50.0%	0.0%	66.7%
Not accessible at all	20.0%	7.7%	0.0%	0.0%	66.7%	0.0%
Not applicable (e.g., online courses)	0.0%	7.7%	0.0%	16.7%	0.0%	0.0%
<i>Work with Specialists for VI Student Support</i>						
Always	0.0%	7.7%	0.0%	16.7%	0.0%	0.0%
Most of the time	0.0%	7.7%	16.7%	33.3%	0.0%	0.0%
About half the time	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sometimes	40.0%	7.7%	0.0%	16.7%	0.0%	0.0%
Never	60.0%	76.9%	83.3%	33.3%	100.0%	100.0%
<i>VI Student Support Effectiveness</i>						
Very effective	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Somewhat effective	20.0%	30.8%	0.0%	0.0%	33.3%	0.0%
Moderately effective	20.0%	7.7%	16.7%	33.3%	0.0%	0.0%
Ineffective	20.0%	0.0%	0.0%	16.7%	0.0%	0.0%
No experience with support services	40.0%	61.5%	83.3%	50.0%	66.7%	100.0%

Table 2. Faculty survey results on facilities & supports on campus

Tables 1 and 2 depict the results from the cross-campus faculty survey on *course delivery*, *assessment*, *accommodation*, and *facilities & supports*. Faculty members from the following colleges participated in this survey, including College of Applied Science and Technology (CAST), College of Arts and Sciences (CAS), College of Business (CoB), College of Education (CoE), College of Fine Arts (WKCFA), and College of Nursing (MCN). The percentages for course delivery and assessment were calculated by dividing the number of positive responses by the total number of responses for that college. For example, 100% of the eight CAST faculty members used text-based content, while the same person may also use other delivery formats. For accommodation in Table 1 and facilities & supports in Table 2, the percentages for each college added up to 100%.

The data revealed a stark picture of the institution's instructional landscape: across all colleges, course materials remain predominantly visual. Within CAST, all surveyed faculty (8 total) reported using text-based materials, and 87.5% relied on static visual resources, such as images and diagrams. This "visual-first" approach placed students with visual impairments at an immediate disadvantage, requiring them to devote additional time and cognitive effort to convert these materials into accessible formats. Assessment practices reflected similar patterns: 87% of CAST faculty used lab activities and exams that present substantial visual information, and 75% incorporated group projects into summative evaluations. Under these conditions, students with VI might feel particularly discouraged and inadequately supported.

Moreover, although faculty were experts in their respective disciplines, significant gaps remained in their training related to accessibility. Beyond a lack of familiarity with the varying degrees of visual impairment, most faculty across departments reported that they "never" or "rarely" collaborate with specialists to adapt their instructional materials for students with VI.

Additionally, 60% of CAST faculty reported giving only “minimal consideration” to the specific needs of students with VI during the initial planning of their courses. Together, these findings pointed to a largely reactive, rather than proactive, approach to accommodation.

Insights from the Expert Panel Discussion

A panel discussion was convened two months after the campus-wide faculty survey, featuring leadership from Student Accessibility and Accommodation Services (SAAS), the Director of Scholarly Teaching, and a faculty member with firsthand experience teaching mathematics to a student with visual impairments. The discussion centered on three guiding themes: “first encounters,” “success in the classroom and laboratory,” and “curriculum design.” Panelists emphasized that early, open communication was essential for supporting student success. They noted that students with VI were most successful when they experienced a strong sense of belonging and psychological safety comparable to that of their peers.

The discussion further underscored the importance of working collaboratively with accommodation services to create customized instructional materials, particularly for laboratory environments. Experts emphasized that many accessibility barriers arose not from unwillingness but from a limited understanding of students’ needs. Because faculty and staff often lacked students with VI’s perspective, they might be unaware that certain materials were inaccessible to some learners. This highlighted the need for enhanced faculty training and the broader adoption of universal design principles. The curriculum conversation also stressed that learning objectives do not necessarily require identical tasks for every student. By incorporating Universal Design for Learning (UDL) principles, instructors could offer multiple means of engagement and representation, thereby supporting the success of all learners, regardless of disability status.

Findings from Student Interviews

With support from SAAS, seven students with visual impairments were interviewed to share their insights and experiences. These students represented a range of majors, including business, computer systems technology, and elementary education. Participants received a gift card as compensation, and the interview focused on three primary areas: learning methods, resources and assistance, and hands-on laboratory experiences.

1. Preferred learning methods: All seven students expressed a strong preference for auditory learning, including lectures, discussions, and audio-based materials. Five students also favored kinesthetic approaches, such as tactile diagrams and hands-on interaction using non-visual senses. Although reading and writing remained important, these activities often depended on screen readers and other assistive technologies, fundamentally shaping how students engaged with written content. Taken together, these findings pointed to a significant opportunity: If laboratory activities were designed to be tactile and supported by audio, they could become highly effective learning environments for students with VI rather than among the most challenging.

2. Availability of resources and assistance: Most students preferred receiving aid only when they requested it, rather than through automatic intervention, and they particularly valued one-on-one support from instructors. They emphasized that professors were the most significant factor in their academic success. However, delays in coordinating with accommodation services created challenges, especially when assessments or lab activities were unexpectedly changed.
3. Challenges in lab environments: Laboratory experiences presented the most significant barriers for students. They reported ongoing issues such as inaccessible lab manuals, insufficiently trained teaching assistants, and a heavy reliance on visual-based tools. Common difficulties included safety concerns, challenges in reading instruments, and the need for additional time to complete sequential procedures. Group work further complicated accessibility when peers were unwilling or unprepared to adjust their workflows. Collectively, these obstacles caused significant frustration and, in some cases, led students to avoid CAST majors altogether.

These interviews made clear that technology alone was not a complete solution. Students consistently identified their instructors as their most valuable resource. They preferred direct, one-on-one communication with professors over navigating the bureaucratic processes of accommodation offices. A strong sense of belonging was most evident when instructors took the time to understand each student's individual perspective.

CAST Lab Environment and Sense of Belonging

The laboratory was the heart of the CAST experience, yet it was also a high-stakes barrier and the site of the greatest exclusion. Issues included:

1. Technical and logistical hurdles: Students reported that lab manuals frequently contained small fonts and complex layouts that were difficult for screen readers to interpret. In addition, the growing reliance on digital platforms, particularly online lab environments, introduced its own challenges. One student noted that during online labs, an aide had to verbally describe every action occurring on the screen, resulting in a secondary, filtered experience rather than direct engagement with the material.
2. The "pace of learning" problem: In laboratory settings, information was often presented and acted upon simultaneously. For students with VI, the need to use magnification or screen-reading tools while performing physical tasks made it extremely difficult to keep pace with their peers. This timing mismatch could leave students feeling "behind" from the outset, undermining their sense of belonging.
3. Safety and perception: Safety emerged as a recurring concern. Students worried about injuring themselves or others in crowded, high-activity laboratory environments where they could not see moving parts or chemical reactions. This fear functioned not only as a physical barrier but also as a psychological one; several students reported choosing non-CAST majors specifically to avoid the additional "effort" and "safety concerns" associated with technical laboratory courses.

In summary, students characterized CAST as an environment with considerable promise but uneven accessibility. Although many computer-based tasks could be adapted using magnification tools or screen readers, software limitations and visually dense interfaces continued to create significant obstacles. The combined effects of safety concerns, mismatched instructional pacing, and limited transparency regarding available accommodations further weakened students' sense of belonging and reduced their confidence in navigating CAST programs.

Recommendations

Based on the findings, this study recommended the following actions: (1) establish early and structured communication protocols among students with VI, faculty, and accommodation services; (2) provide targeted training for faculty, facility coordinators, and teaching assistants on visual impairments and accessible laboratory practices to provide real-time support without alienating the students; (3) review lab layouts to ensure clear paths of travel for students with VI, and invest in tactile measurement tools and high-contrast equipment; and (4) implement Universal Design for Learning principles to shift the burden of accommodation away from the students in need.

Across all data sources, communication emerged as the most critical factor influencing accessibility and students' sense of belonging. When faculty engaged proactively with students and accommodation services, many barriers were significantly reduced. In contrast, reactive or fragmented approaches placed an undue burden on students to advocate for and coordinate their own accommodations. These findings align with the existing literature on inclusive education, underscoring the importance of universal design principles and ongoing faculty development for creating sustainable, equitable learning environments.

Limitations

This study has several limitations. First, the sample size of seven student participants and survey responses from less than 5% of the faculty body limited generalizability; however, this exploratory research aimed for depth of insight rather than broad statistical representation. Second, all participants were drawn from a single institution, which might reflect institution-specific practices and resources. Third, the faculty survey data were limited in scope and based on self-reported perceptions rather than direct observation of instructional practices. Despite these limitations, triangulating student, faculty, and expert perspectives enhanced the credibility and robustness of the findings.

Implications for Practice and Future Research

The findings of this study held significant implications not only for CAST programs but also for related initiatives aimed at improving engineering and technology programs in higher education institutions more broadly. Faculty development initiatives should integrate disability awareness and accessible laboratory design as core competencies rather than optional add-ons. Institutions should also invest in accessible instructional technologies and establish standardized review processes for lab manuals and digital learning materials. Future research could extend this work

by incorporating multiple institutions, comparing accessibility practices across different CAST disciplines, or quantitatively examining the relationship between accessibility efforts and student retention in applied science and technology programs.

Conclusion

The gap between the highly visual demands of CAST coursework and the needs of students with VI was substantial but not insurmountable. By adopting a proactive accessibility model where all visual content was consistently paired with auditory or tactile alternatives, CAST could significantly reduce the additional effort required of these students. Genuine belonging would be achieved when a student could enter a laboratory with the same confidence and sense of safety as their peers. It was the institution's responsibility to ensure that this level of access was possible.

Nevertheless, enhancing the sense of belonging for visually impaired students in CAST required more than compliance-driven accommodations; it called for intentional, proactive, and inclusive design across curriculum, instruction, and learning environments. By elevating student voices, strengthening collaboration with accommodation services, and applying Universal Design for Learning principles, CAST programs could meaningfully reduce barriers and promote equitable participation. Developing accessible laboratory environments and improving communication practices were essential steps toward ensuring that visually impaired students not only persisted in CAST majors but also experienced full inclusion and academic success.

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