Volume 20

Spring 2026

Assistive Technology Outcomes and Benefits

Integrating User Experiences to Promote Inclusive Design and Implementation of Assistive Technology

Anya S. Evmenova, PhD

Editor-In-Chief

Assistive Technology Industry Association

Published by the Assistive Technology Industry Association (ATIA)

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ISSN 1938-7261

Assistive Technology Outcomes and Benefits Integrating User Experiences to Promote Inclusive Design and Implementation of AT

Volume 20, Spring 2026

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Assistive Technology Outcomes and Benefits Editorial Policy

Aim and Scope

Assistive Technology Outcomes and Benefits, published by the Assistive Technology Industry Association, is an open access, peer-reviewed journal that publishes articles specifically addressing the benefits and outcomes of assistive technology (AT) for Persons with Disabilities across the lifespan. The journal's purpose is to advance the AT industry by (a) fostering communication among stakeholders interested in the field of AT, including manufacturers, vendors, practitioners, policy makers, researchers, consumers with disabilities, and family members; (b) facilitating evidence-based demonstrations and case-based dialogue regarding effective AT devices and services; and (c) helping stakeholders advocate for effective AT devices and services.

Assistive Technology Outcomes and Benefits invites for consideration submissions of original papers, reports and manuscripts that address outcomes and benefits related to AT devices and services. These may include (a) findings of original scientific research, including group studies and single subject designs; (b) qualitative and mixed methods studies, such as focus group and structured interview findings with consumers and their families regarding AT service delivery and associated outcomes and benefits; (c) marketing research related to AT demographics or devices and services; (d) technical notes and usability studies regarding AT product development findings; (e) project/program descriptions in which AT outcomes and benefits have been documented; (f) case-based reports on successful approaches to service delivery; and (g) consumer perspectives on AT devices and services.

Submission Categories

ATOB welcomes scholarly contributions. However, many stakeholders engaged in the field of AT do not have an academic background. ATOB offers a unique opportunity for these stakeholders to contribute their expertise and experience in the context of achieving successful outcomes and beneficial impacts. ATOB understands that many potential authors may lack experience in authoring papers for peer- reviewed journal publication. Therefore, the ATOB Editorial Board is pleased to offer support in preparing and refining relevant submissions. Articles may be submitted under three categories:

Voices from the Field

Articles submitted under this category should come from professionals who are involved in some aspect of AT service delivery with persons having disabilities, or from family members and/or consumers with disabilities. Submissions may include case studies, project or program descriptions, approaches to service delivery, or consumer perspective pieces. All submissions should have a clear message and be written with enough detail to allow replication of results. See ATOB Editorial Policy for more details.

Voices from Industry

Articles submitted under this category should come from professionals involved in developing and marketing specific AT devices and services. Case studies, design, marketing research, or project/program descriptions are appropriate for this category. See ATOB Editorial Policy for more details.

Voices from Academia

Articles submitted under this category should come from professionals conducting research or development in an academic setting. Submissions are likely to include applied/clinical research, case studies, and project/program descriptions. See ATOB Editorial Policy for more details.

Types of Articles

Within each of the voices categories, authors have some latitude regarding the type of manuscript submitted and content to be included. However, ATOB will only accept original material that has not been published elsewhere and is not currently under review by other publishers. Additionally, all manuscripts should offer sufficient detail to allow for replication of the described work.

Applied/Clinical Research: This category includes original work presented with careful attention to research design, objective data analysis, and reference to the literature.

Case Studies: This category includes studies that involve only one or a few subjects or an informal protocol.

Design: This category includes descriptions of conceptual or physical design of new AT models or devices.

Marketing Research: This category includes industry-based research related to specific AT devices and/or services, demographic reports, and identification of AT trends and future projections.

Project/Program Description: This category includes descriptions of grant projects, private foundation activities, institutes, and centers having specific goals and objectives related to AT outcomes and benefits.

Approaches to Service Delivery: This category includes descriptions of the application of assistive technology in any setting (educational, vocational, home-life) to improve quality of life for people with disabilities.

Consumer and Caregiver Perspectives: This category offers an opportunity for product end users, family members, and caregivers to share their experiences in achieving successful outcomes and benefits through the application or use of AT devices and services.

Mandatory Components of All Articles

Authors must include a section titled Outcomes and Benefits containing a discussion related to outcomes and benefits of the AT devices/services addressed in the article. Authors must include a short description of the article's Target Audience and indicate the article's relevance to that target audience.

Publishing Guidelines

Review detailed Manuscript Preparation for Authors for information on formatting requirements and submission guidelines.

For More Information

Please see ATOB's Editorial Policy for more details regarding the submission and review process, ATOB's Copyright Policy, and ATOB's Publication Ethics and Malpractice Statement.

Assistive Technology Outcomes and Benefits Integrating User Experiences to Promote Inclusive Design and Implementation of AT

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. viii-xii
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Introduction to Volume 20

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Integrating User Experiences to Promote Inclusive Design and Implementation of Assistive Technology

This special issue seeks to highlight the growing recognition that assistive technology (AT) is most effective when individuals with disabilities are positioned as active collaborators throughout the design, development, implementation, and evaluation processes. Across educational, clinical, workplace, and community settings, user experiences provide critical insights into accessibility barriers, usability challenges, contextual factors, and long-term adoption. Inclusive design approaches grounded in lived experiences have the potential to improve not only the functionality and reliability of AT, but also user satisfaction, independence, participation, and quality of life. As emerging technologies such as artificial intelligence, wearable technology, and adaptive communication tools continue to reshape the AT landscape, there is an increasing need to ensure that innovation remains responsive to the authentic priorities, preferences, and everyday realities of individuals who rely on these technologies. This volume therefore aims to demonstrate how user engagement informs decision-making across all aspects of AT innovation. It includes Voices from Academia (Azam & Ramamurthy; Berner et al.; Geist et al.; Huang et al.; Kluth et al.), Voices from the Industry (Cowart et al.; Hanuschock et al.), and Voices from the Field (Bay et al.; Fugate et al.; Rutledge & Officer; Lenartowicz & Lenartowicz).

Voices from Academia

In the first article in the Voices from Academia category, *User Experiences with SmartVision Glasses: Barriers and Insights*, Azam and Ramamurthy explore how user experiences can inform more inclusive design and implementation of AT for individuals with visual impairment in India. By interviewing both users with visual impairments and low-vision practitioners, the study emphasizes that successful AT adoption depends not only on technical innovation, but also on how well devices align with users' daily routines, comfort, social experiences, and expectations. Participants identified barriers related to usability, connectivity, device weight, outdoor mobility, aesthetics, and social stigma, while practitioners highlighted the importance of structured training, expectation management, and compatibility with existing mobility aids. Overall, the article contributes valuable evidence showing that integrating authentic user experiences is essential for creating AT devices that are functional, acceptable, and sustainable in real-world contexts.

In their study, *Intercollegiate AT Hackathon: The Perspectives of Co-designers*, Kevin Berner and colleagues highlight the critical role of integrating user experiences into the inclusive design of AT through an intercollegiate hackathon model that positions individuals with disabilities as active co-designers rather than passive recipients of technology. The study demonstrates how collaborative partnerships between community members with disabilities, students, clinicians, engineers, and designers resulted in customized AT solutions grounded in authentic daily living needs. Co-designers contributed directly to identifying functional challenges, shaping design priorities, testing prototypes, and refining solutions, ensuring that technologies addressed authentic usability and user needs.

Lori Geist, Patrick Regan, and Sofia Benson-Goldberg discuss *Participatory Design in Action: Creating a Scalable Keyboard for Communication*. Exploring the lived experiences of an adult AAC user with spinal muscular atrophy, the project demonstrates how meaningful collaboration between users, researchers, designers, and programmers can produce communication tools that better address real-world accessibility needs. The study emphasizes that AT users must be involved "early and often" throughout the design process, not merely as testers but as active contributors and decision-makers shaping design priorities and refinements. Importantly, the project reveales that many usability improvements – such as adjustable keyboard positioning and reduced physical fatigue – emerged directly from the AAC user's experiences and iterative interactions with prototypes.

The article *GOALS: Developing an IDD Employment Support with User-Centered Design* by Morris Huang, Leslie Emery, and Cathy Bodine provides a strong example of how integrating user experiences into the design and implementation of AT can improve accessibility, usability, and employment outcomes for individuals with intellectual and developmental disabilities (IDD). Through the development of the Goal Oriented Automated Learning System (GOALS), the authors employ a comprehensive user-centered design process that actively involves employees with IDD, job coaches, and workplace supervisors in multiple phases of technology development, including focus groups, prototype evaluation, and usability testing. The study demonstrates that meaningful inclusion of stakeholders helps identify critical design priorities such as simplified language, customizable supports, multimodal instruction delivery, intuitive navigation, text-to-speech functionality, image-based prompting, and centralized communication among vocational stakeholders. Importantly, the

research highlights that users with IDD possess highly diverse support needs and workplace experiences, making iterative feedback and co-design essential for developing flexible and accessible AT solutions.

In their article titled *Facilitating Independence through Automated Accessible Chart Creation*, Timothy Kluthe and colleagues present the open-source solution for statistics to support users with blindness or low vision working in the field of data science. The system creates “structured charts” with embedded screen-reader navigation, hierarchical exploration, and mathematically generated descriptions directly tied to the underlying data and statistical analyses. The authors evaluated the system through a randomized controlled study involving participants with blindness or low vision. The findings suggest that interactive, structured navigation may provide more effective and independent access to chart information than static alternative descriptions alone. Thus, accessibility is positioned not as an add-on feature, but as an intrinsic component of chart creation and data analysis.

Voices from the Industry

Both articles in the Voices from the Industry category share examples of inclusive design and implementation within industry-research collaborations. *Engaging Leaders with Disabilities in Design of Online Request Processes for Testing Accommodations* by Delaney Cowart, Kathy Dixon, and John Morris presents the results of a multi-year collaboration between Microsoft and the Accessibility User Research Collective (AURC) focused on improving the process for requesting testing accommodations within Microsoft certification programs. The paper documents how user-centered research informed redesigns of accommodation policies, webpage organization, documentation requirements, and communication procedures. The research team engaged individuals with blindness, low vision, mobility disabilities, neurodivergence, hearing disabilities, and learning disabilities through interviews, surveys, and numerous usability testing studies. Overall, the paper illustrates how iterative, community-informed research can lead to measurable improvements in access to career and technical education opportunities for people with disabilities.

William Hanuschock and colleagues demonstrate how integrating user experiences is essential for promoting inclusive development of MABLE, an AI-powered indoor navigation application in their article titled *Initial User Feedback on a Novel Indoor Navigation Application for People Who are Blind or Have Low Vision and People with Mobility Impairments*. Using a community-based participatory research approach, the study actively incorporated feedback from intended users during the early stages of design and evaluation to ensure that the application reflected authentic navigation needs and lived experiences across disability groups. The study revealed that while disability groups shared many common priorities, each group also identified unique accessibility needs that could only be recognized through direct engagement with users themselves. The authors emphasize that AT developers must consider both shared and distinct user experiences to create equitable, universally useful systems that support independence, safety, and mobility across diverse contexts.

Voices from the Field

"It Has to Fit Right": Customization in Assistive Technology by Stephanie Bay and colleagues kicks off the Voices from the Field category. This article is a great illustration of promoting more inclusive, effective, and sustainable outcomes through a highly personalized AAC customization process. Centering the lived experiences and preferences of co-author and AT user Cami Smith, the study demonstrates the importance of person-centered, multidisciplinary collaboration among the user, family members, speech-language pathologists, occupational therapists, rehabilitation engineers, and design specialists. Rather than adapting Cami to existing technologies, the team customized the technology to fit her physical abilities, communication preferences, mobility needs, and daily routines, resulting in a custom-built lap tray and AAC setup that supported both communication access and functional participation. Throughout the process, Cami actively shaped design decisions by identifying what worked, what caused discomfort, and what features were necessary for long-term usability, including tray dimensions, padding materials, touchscreen accessibility, stylus placement, and compatibility with eating and wheelchair mobility.

The article *Tactile to Tangible: Lessons from the Monarch Braille Display* by Regina Fugate, Jennifer Wenzel, and Willow Free is another example of integrating user experiences into the inclusive design and implementation of an AT device, specifically a Monarch multiline refreshable braille display. Drawing from pilot testing, classroom implementation, and practitioner perspectives, the authors demonstrate how the experiences and needs of blind and low vision (BLV) students informed the use and evaluation of a device designed to improve tactile access to text, graphics, data, and coding environments. User feedback from students and educators revealed increased motivation, independence, and confidence when learners could interact with paragraphs, graphs, spreadsheets, tactile graphics, and computer code in more natural and accessible ways. The study further illustrates how inclusive AT implementation requires alignment among users, educators, developers, accessibility standards, and policy initiatives, particularly through the integration of eBraille standards and real-time tactile graphics functionality.

The Nevada Special Education Technology Assistance Project (NSETAP) is highlighted in Felicita Rutledge's and Nathanael Officer's Voices from the Field article, *Learn Lead Launch: Reimagining Assistive Technology Professional Learning*. NSETAP developed a statewide professional learning model grounded in Universal Design for Learning (UDL), interdisciplinary collaboration, and continuous educator feedback to improve AT awareness, selection, and implementation across Nevada schools. A central theme throughout the article is that AT implementation is most effective when educators, service providers, administrators, AT users, and district leaders actively shape learning opportunities based on authentic experiences and local needs. The article further demonstrates how inclusive design principles were embedded into professional learning itself by modeling multiple means of engagement, representation, and action through accessible materials, interactive technologies, hands-on exploration, audiovisual supports, digital tools, and collaborative learning activities. Importantly, the findings showed that educators reported increased AT knowledge, greater confidence in implementation, reduced professional isolation, and meaningful changes in instructional practice after participating in the program.

We wrap this issue with a powerful user-driven critique of assistive technology and augmentative and alternative communication implementation by Adam and Joseph Lenartowicz titled *A User's Perspectives on Implementation, Quality and Outcomes for AAC and AT*. The authors emphasize that inclusive design must extend far beyond initial user consultation to encompass the entire product development, testing, deployment, and quality assurance cycle. Drawing on 25 years of lived experience using AAC and AT systems, this article demonstrates how seemingly minor design flaws, software failures, inaccessible interfaces, and poor implementation decisions can significantly undermine independence, safety, communication, and long-term technology adoption. The authors also raise critical concerns about "feature creep," where commercial pressures and enthusiasm for emerging technologies may unintentionally compromise accessibility, consistency, reliability, and user safety. Overall, the article contributes an important perspective on inclusive AT implementation by demonstrating that authentic integration of user experiences requires continuous, rigorous, and meaningful participation from users with disabilities across the full lifecycle of AT development and support systems.

Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 1-22
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from Academia

User Experiences with Smart Vision Glasses: Barriers and Insights

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Abstract

Wearable smart assistive devices provide features such as text-to-speech, object recognition, and navigation support to enhance independence in individuals with visual impairment. However, limited evidence exists regarding real-world challenges experienced by users and practitioners. This qualitative study explored barriers to Smart Vision Glasses (SVG) Gen 2.0 version manufactured by SHGs Technologies, Bangalore, India, use through in-depth telephone interviews with 10 visually impaired adults who had used SVG for at least six months and 10 low-vision practitioners involved in SVG training. Interviews were transcribed, coded, and thematically analyzed. Users reported barriers related to usability, device performance, connectivity, comfort, and social acceptance, while practitioners emphasized steep learning curves, limited functional integration, and unrealistic expectations. Both groups highlighted the need for structured training, hardware improvements, and better compatibility with mobility aids. Findings indicate that, although SVG provide valuable functional support, their effectiveness is limited by technical, functional, and social barriers.

Keywords: assistive device, barriers, smart vision glasses, visual impairment

Smart Vision Glasses: Qualitative Insights from Users and Practitioners

Visual impairment, including low vision and blindness, is defined as decreased visual function that limits a person's ability to perform activities of daily living, such as reading, driving, and watching television (Şahlı & İdil, 2019; Sapp, 2010). According to International Agency for the Prevention of Blindness (IAPB), visual impairment is a global health concern, affecting approximately 596.2 million people worldwide, of whom 43.3 million are blind. In India alone, approximately 137.2 million individuals live with visual impairment, including 9.17 million who are blind (Bourne et al., 2021; James et al., 2018). Blindness describes those who have a complete lack of light perception, documented as no light perception. Visual impairment is associated with reduced quality of life, higher risk of falls and injuries, psychological distress, and increased dependence on caregivers (Chia et al., 2006; Kempen et al., 2012; Langelaan et al., 2007; Lord, 2006). Beyond health outcomes, visual impairment also imposes substantial economic and social burdens on individuals, families, and society (Felson et al., 1989; Köberlein et al., 2013).

Rehabilitation services and assistive technologies have therefore emerged as essential tools to enhance independence, safety, and participation in society for people with visual impairment (Santiago-Pintor et al., 2009). Globally, more than one billion people require at least one form of assistive technology; a figure expected to rise to nearly two billion in the next decade (WHO, Assistive Technology). Yet, it is estimated that only 10% of those who could benefit currently have access (WHO). In response, the World Health Organization launched the "Global Cooperation on Assistive Technology" initiative in 2014, establishing a list of 50 essential assistive products, 16 of which were specifically tailored for individuals with visual impairment (WHO, Health Products Policy and Standards). Despite these advances, gaps in accessibility and affordability remain profound, particularly in low- and middle-income countries (Chiang et al., 2011).

Target Audience and Relevance

The target audiences for this paper are professionals who work with individuals who are blind or have low vision, particularly those supporting independence through assistive technology. A primary audience includes low-vision practitioners and optometrists who provide training and rehabilitation services, as the findings highlight usability barriers, training needs, and strategies for expectation management. The study is also relevant to researchers and developers of assistive technology, especially those designing or refining smart vision devices, because it identifies real-world challenges and opportunities for user-centered improvements. In addition, policymakers and program planners concerned with accessibility in low- and middle-income contexts may benefit from insights into affordability and adoption barriers.

Background

In recent years, substantial advances in wearable assistive technology have expanded options for individuals with blindness and low vision (Han et al., 2024). Several smart assistive wearable devices now integrate Artificial Intelligence (AI), Optical Character Recognition (OCR), and computer vision to support reading, object recognition, navigation, and daily functioning for people with visual impairment. AI-based wearable assistive technologies glasses are available either as vision substitution devices such as Smart Vision Glasses (SVG), manufactured by SHGs Technologies, Bangalore, India, and OrCam MyEye, or as portable vision enhancement devices such as Aira, and esight (Ramamurthy et al., 2024).

Aira is an assistive wearable technology system that provides remote assistive technology to the visually impaired. Users connect via smartphone or smart-glasses camera to trained remote agents who interpret their surroundings and assist with navigation, reading, and decision-making in real time. Previous studies on Aira have shown significant improvements in mobility confidence, independence, and patient-reported quality of life among individuals with severe visual impairment (Nguyen et al., 2018; Park et al., 2020).

eSight Eyewear is a high-resolution, virtual reality-based head-mounted electronic visual aid that uses near-eye displays and real-time video processing to enhance residual vision for reading, mobility, and facial recognition for individuals with low vision. Previous studies showed significant improvements in quality of life and functional visual ability following structured telerehabilitation or training protocols (Lorenzini & Wittich, 2021). After clinical evaluations, eSight Eyewear also showed significant improvement in visual function, including distance and near visual acuity, contrast sensitivity, and reading performance. Users showed enhanced task-based visual performance during activities such as reading text and recognizing faces under controlled conditions (Wittich et al., 2018).

OrCam MyEye is an AI-based, clip-on wearable device that attaches to a user's spectacles and uses OCR and computer vision to read text, identify faces, and recognize objects and products. Previous studies showed that OrCam MyEye enhances reading performance, object identification, face recognition task performance, and quality of life in individuals with visual impairment (Moisseiev & Mannis, 2016;) (Nisanova et al., 2024). Studies have also reported improvements in task performance and overall quality of life across diverse populations, including individuals with blindness (Amore et al., 2023; Moisseiev & Mannis, 2016), patients diagnosed with stroke and brain tumor (Nisanova et al., 2024), and patients with retinal dystrophy (Nguyen et al., 2022). These studies consistently highlight increased independence in daily activities such as reading printed text, handling currency, recognizing familiar faces, and performing routine tasks, underscoring OrCam's role as a valuable assistive technology for people with blindness.

SVG is one of several recent innovations. It is a multifunctional assistive device for people with visual impairment. SVG is an AI and machine learning (ML) based wearable device manufactured by SHGs Technologies, Bangalore, India. SVG has three available models produced by the company—SVG Gen 2.0, SVG Pro, and SVG Premium, which differ primarily in processing speed, camera performance, and feature integration. The current study exclusively examined the SVG Gen 2.0 model, as this is the version most widely used within Indian low-vision rehabilitation services. SVG Gen 2.0 (Figure 1) is a spectacle-mounted, lightweight device designed as a vision substitution aid. The system provides audio output based on real-time environmental input captured by its camera. It is equipped with a front-facing 5-megapixel camera offering a 72-degree field of view, a flashlight, and LiDAR sensors. The operating platform is braille-coded, with touch buttons corresponding to specific functions. After connecting to a smartphone via a wired connection, SVG functions through an Android application, delivering audio feedback either through the smartphone speaker or Bluetooth-enabled earphones.

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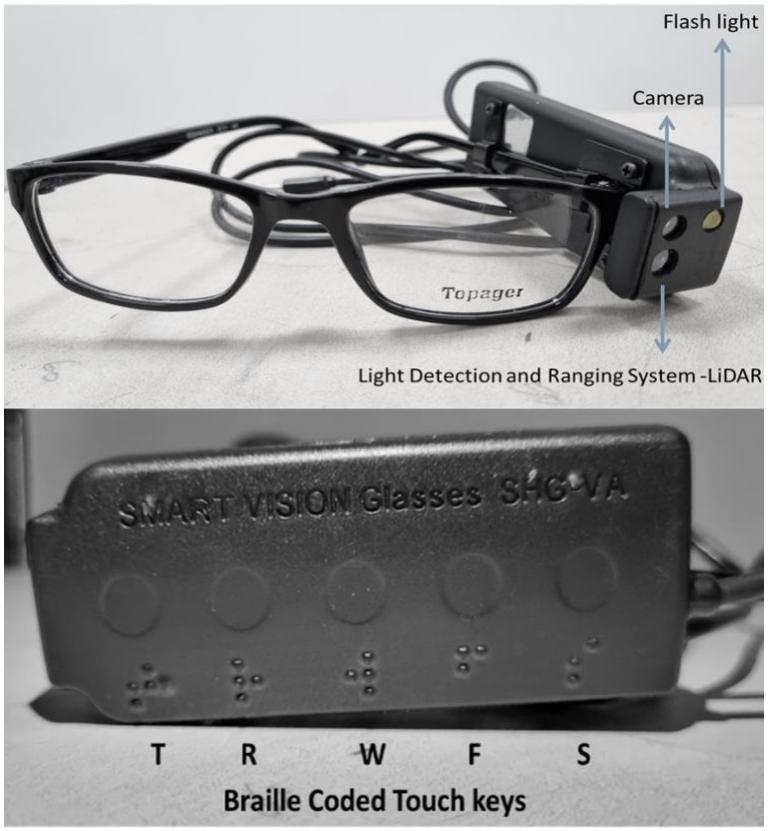
SVG offers four primary functions— “Things Around You,” “Reading,” “Walking Assistance,” and “Face Recognition”—which correspond to functional domains of ultra-low vision: visuomotor performance, reading, wayfinding, and visual information gathering. Each function is accessed using braille-coded touch keys labelled “T,” “R,” “W,” and “F,” respectively. An additional standby touch key allows users to return to the main menu and switch between functions. As a sensory substitution device, SVG delivers audio descriptions across all functions. Notably, it does not feature a visual display or electronic vision enhancement system (Udayakumar et al., 2025).

Previous studies on SVG have shown encouraging results: A multicentric Indian cohort demonstrated that over 70% of users found the “Reading” function useful, and nearly two-thirds used the device for an hour or more per day, underscoring its potential to support independence in education and daily living (Udayakumar et al., 2025). Similarly, a six-month case series found that 88.5% of participants rated SVG as “satisfactory” or “outstanding,” particularly for face recognition and reading functions, though limitations in walking assistance and currency identification were noted (Varshney et al., 2025).

While existing studies on smart wearable assistive technologies including SVG, OrCam MyEye, eSight, and related devices have demonstrated promising outcomes, the literature has been predominantly quantitative, with a primary focus on functional performance, task completion, and device efficacy (Lorenzini & Wittich, 2021; Moisseiev & Mannis, 2016; Udayakumar et al., 2025; Varshney et al., 2025; Wittich et al., 2018). However, evidence examining real-world usability, user satisfaction, and barriers to sustained adoption remains limited, particularly in low- and middle-income contexts such as India, where access to assistive technology is already constrained. Importantly, the perspectives of both individuals with visual impairment and low vision practitioners who play a critical role in device recommendation, training, and long-term use are underexplored (Kaminsky et al., 2014; Sivakumar et al., 2020). Without insights into lived experiences, barriers related to usability, design, training demands, connectivity, and affordability risk being overlooked, thereby limiting the broader impact of these technologies.

Figure 1: *Smart Vision Glasses Mounted on the Eyepiece Frame, Featuring a Camera, Flashlight, and LiDAR Sensor*



Note: *The device also includes Braille-coded touch keys: T (Things around you), R (Reading mode), W (Walking assistant), F (Face storing), and S (Standby)*

Within the Indian context, access to assistive smart wearable devices such as OrCam MyEye, eSight, and Aira is limited due to high cost. In contrast, SVG is more affordable and more widely available across tertiary eye-care and low-vision rehabilitation centers in India. Despite its growing clinical use, prior research on SVG has largely focused on quantitative functional outcomes, with no published qualitative studies systematically exploring user- and practitioner-identified barriers, facilitators, and real-world experiences. Consequently, the present study focused exclusively on SVG Gen 2.0 to address this important evidence gap. This focus reflects considerations of availability, cost, and relevance to the Indian rehabilitation setting.

The present study addresses this gap by qualitatively exploring the perceptions of visually impaired adults and low-vision practitioners regarding Smart Vision Glasses through in-depth semi-structured interviews. By focusing on barriers, facilitators, and real-world experiences, this study aims to generate insights that can inform user-centered design, optimize rehabilitation strategies, and guide the integration of emerging smart assistive technologies in the Indian context.

Methods

Study Design

This study adopted a descriptive qualitative design to explore the experiences of visually impaired adults using SVG and the perspectives of low-vision practitioners who provide training and support. The study followed the Consolidated Criteria for Reporting Qualitative Research (COREQ) guidelines to ensure methodological rigor (COREQ checklist is provided in Appendix A; Tong et al., 2007).

Ethical Considerations

The study received ethical approval from the Institutional Ethical Committee (Approval No. 8827). The study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained verbally via telephone and audio recorded before each interview.

Participants and Recruitment

Two participant groups were recruited: (a) Smart Vision Glasses Users and (b) optometrists/low-vision practitioners.

Smart Vision Glasses Users

Purposive and convenience sampling were used to recruit visually-impaired patients (aged 18–35 years who have used SVG Gen 2.0 for at least six months and could communicate in English, Tamil, or Hindi). Purposive sampling was employed to deliberately select participants who met specific inclusion criteria, ensuring that only individuals with sufficient experience using SVG were included to provide rich, relevant insights into their lived experiences and device usability. Convenience sampling was used to enhance recruitment feasibility by approaching eligible participants who were accessible through tertiary eye care centers and low-vision clinics, given the limited population of SVG users and the logistical constraints of recruiting from this specialized group. Individuals older than 35 years or who had not used the device in the past six months were excluded to minimize recall bias and ensure that participants could provide current, detailed feedback on their SVG usage.

All SVG users operated the device using their personal smartphones. All SVG users had prior experience using smartphones for basic functions such as making calls, messaging, and using common mobile applications before adopting the device, ensuring a baseline level of digital familiarity across participants. All participants used Android smartphones, predominantly mid-range models running Android versions 10–13, as the SVG Gen 2.0 device is compatible only with the Android platform. None of the participants used iOS devices. Most users accessed SVG functions through standard 4G mobile data connections, offered through the common telecom services available in India, namely, Jio, followed by Airtel and Vodafone.

Optometrists/Low-Vision Practitioners

Optometrists who were practicing low vision in tertiary eye care centers were recruited through purposive and snowball sampling to assess their perspectives on the utilization of SVG and the challenges faced by their patients in daily activities. Purposive sampling was chosen to target practitioners with specialized expertise in low-vision rehabilitation and direct experience with SVG, ensuring that their insights were informed by professional knowledge and patient interactions. Snowball sampling was used to expand the sample by leveraging referrals from initial participants, as the population of low-vision practitioners familiar with SVG is relatively small and geographically dispersed. Low-vision practitioners who were actively involved in SVG training for patients for at least 6 months were eligible for inclusion, ensuring that they had sufficient exposure to the device and its practical challenges. This combined sampling approach maximized the recruitment of qualified participants while addressing the challenge of accessing this niche professional group.

The sample size was determined based on the data saturation technique. In other words, interviews were conducted until the time it was realized that no new information was being obtained from the subsequent interviews.

Interview Guide and Data Collection

The interview guide with probes was developed based on literature and qualitative studies on the barriers faced by blind and visually impaired individuals while they use assistive devices (Kaminsky et al., 2014; Sivakumar et al., 2020). The interview guide included three major themes: (i) patient-related issues, (ii) vision-related issues, and (iii) device-related issues. The interview guide was peer-reviewed by qualitative research experts and piloted with two individuals (one SVG user and one practitioner). Minor revisions were made to refine question clarity and flow before data collection. The interview guide for Smart Vision Glasses Users (SVGU) is provided in Appendix B, and the guide for Optometrists/Low-Vision Practitioners is provided in Appendix C. The sample size was determined by data saturation, with interviews continuing until redundancy was obtained.

The interviews were conducted by the first author (RA), who had prior training in qualitative research and experience in low-vision rehabilitation. To minimize interviewer bias, RA maintained a neutral stance, adhered to the guide, and engaged in reflexive journaling after interviews. The interviews were scheduled with eligible low-vision practitioners and people with visual impairment who consented to participate. Separate telephone In-Depth Interviews (IDIs) were conducted, beginning with an introduction and study explanation, followed by background questions and structured prompts. IDIs were conducted via telephone between August and December 2024, in English, Tamil, or Hindi depending on participant preference. Interviews lasted 15–30 minutes for SVG users and 25–40 minutes for practitioners, and were audio recorded with permission.

Data Management and Analysis

The interviews were audio-recorded using a smartphone (Xiaomi Lite NE). The AUDIPO: Audio Speed Changer application (Google Play Store) was utilized to adjust playback speed during transcription to ensure accuracy. Verbatim transcriptions were carried out by the investigator (RA) and stored in Microsoft Excel and Microsoft Word for organization and analysis. Interviews conducted in Tamil were translated into English. No specialized qualitative data analysis software was employed; instead, manual coding was performed using Microsoft Excel and Word.

Thematic analysis was conducted following Braun and Clarke's six-phase framework (Ahmed et al., 2025). This method was selected for its flexibility in identifying, analysing, and reporting patterns (themes) within the data while aligning with the exploratory objectives of the study. The analysis followed these steps:

(i) Familiarization: RA and DR read each transcript several times to develop a thorough understanding of the data and identify initial patterns.
(ii) Coding: Using an inductive approach, codes were generated directly from the data to capture new insights. Transcripts were manually segmented in Excel into meaningful units and assigned appropriate codes.
(iii) Theme Development: Codes were organized into subthemes and broader themes.
(iv) Theme Refinement: Through iterative discussions, RA and DR reviewed and refined themes to ensure alignment with the data and research objectives, adjusting names and codes where needed for clarity and coherence.
(v) Validation: To enhance credibility, investigator triangulation was implemented. RA and DR independently coded a subset of transcripts, cross-checked their coding for consistency, and resolved discrepancies through discussion.
(vi) Reporting: Final themes were organized to address the core aspects of the research questions, establishing a clear link between the data and the study's objectives.

Data triangulation was achieved by gathering perspectives from two distinct participant groups, Smart Vision Glasses Users and low-vision practitioners, to provide a comprehensive understanding of SVG utilization and challenges. Internal validity was further strengthened through the rigorous application of Braun and Clarke's framework, independent cross-checking of codes and themes by RA and DR to confirm that the findings accurately reflected participants' experiences.

Results

A total of 20 participants were included in the study: 10 visually impaired patients (mean age: 26.5 ± 3.64 years) and 10 low-vision practitioners (mean age: 29.5 ± 5.5 years). Demographic details and interview details are summarized in Table 1.

Table 1: *Demographics of the participants and information of the IDIs*

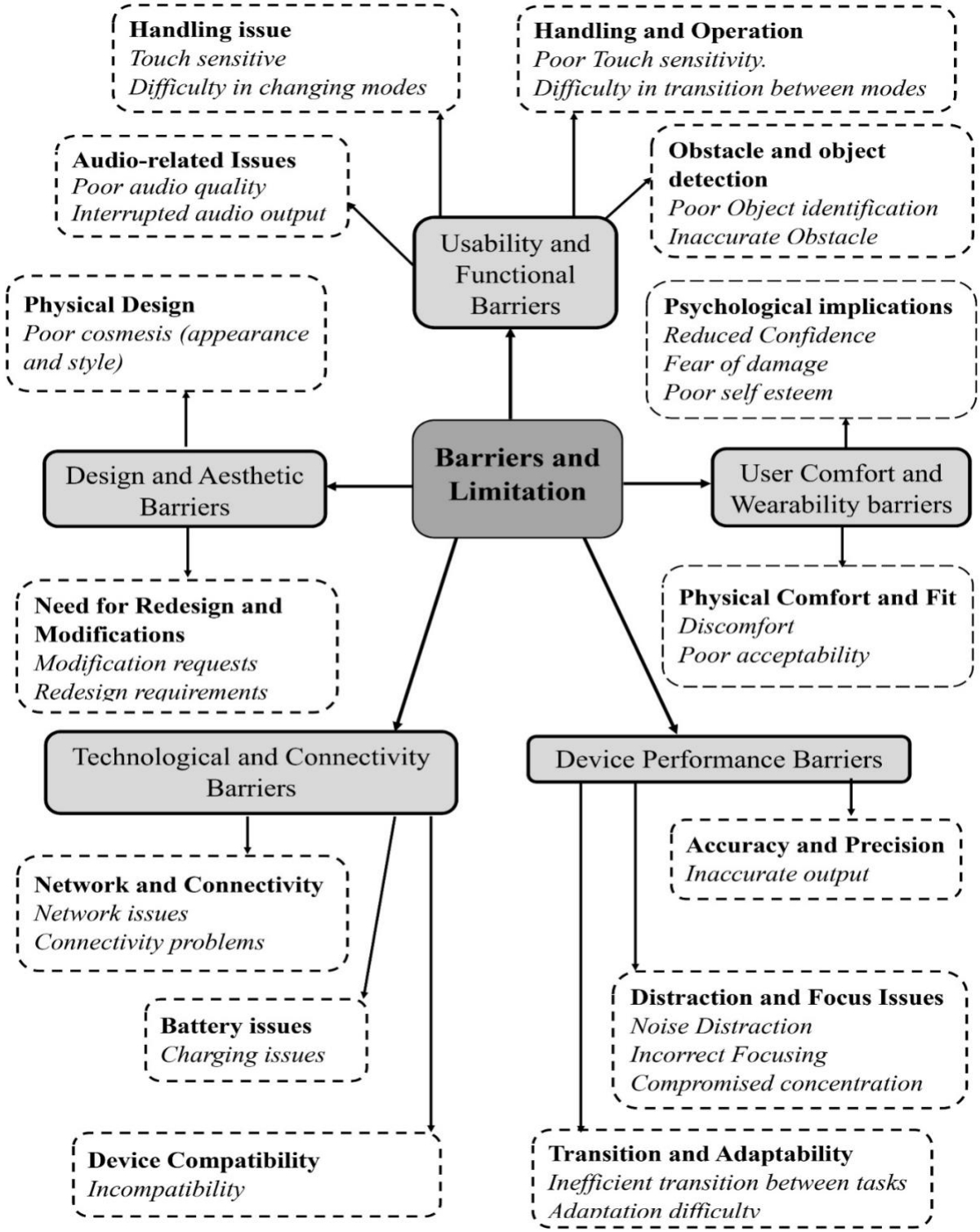
Category	Values
SVGUs - Male: Female ratio	8: 2
Low vision practitioners – Male: Female ratio	1: 9
Age of SVGUs (Mean ± SD) years	26.5 ± 3.64
Age of low vision practitioners (Mean ± SD) years	29.5 ± 5.5
Duration of using SVG (Mean ± SD) months	11.9 ± 3.20
SVG training experience of low vision practitioners (Mean ± SD) years	2.4 ± 1.42
Total number of IDIs conducted	20
Duration of SVGUs interviews (Mean ± SD) (minutes: seconds)	15:46 ± 5:63
Duration of optometrists' interviews (Mean ± SD) (minutes: seconds)	28:35 ± 8:17

Smart Vision Glasses Users

A total of 30 codes and 14 subthemes were identified, resulting in five main themes: (1) usability and functional barriers, (2) technological and connectivity barriers, (3) design and aesthetic barriers, (4) user comfort and wearability barriers, and (5) device performance and reliability barriers. Figure 2 provides a representation of these themes, illustrating the key barriers and limitations faced by SVGUs.

Figure 2 summarizes the thematic analysis, which revealed five overarching categories of barriers experienced by SVG Gen 2.0 users. These included usability and functional barriers (such as challenges with touch controls, mode switching, and inaccurate object or obstacle detection), device performance barriers (including audio interruptions and charging issues), and technological and connectivity barriers (such as unstable network performance and device incompatibility). Additional themes related to design and aesthetic barriers, where participants expressed concerns about the device's appearance and the need for redesign, and user comfort and wearability barriers, which encompassed physical discomfort, reduced confidence, and social self-consciousness. Together, these themes illustrate the multifaceted challenges that affect real-world use of the device.

Figure 2: *Thematic Analysis of Smart Vision Glasses Challenges and Limitations*



Theme 1: Device Performance and Reliability Barriers

This theme focuses on challenges related to the accuracy and reliability of SVG, particularly in dynamic environments. Participants reported inconsistent performance in object recognition, reading, obstacle detection, and audio output, which reduced the device's effectiveness for tasks like mobility and reading. These barriers are critical as they directly affect the device's core functionality, limiting its utility for visually impaired users in real-world settings: "Sometimes it will say a 30-year-old man is standing in front of you, but they are only 18 or 19 years old when we ask them, which is not accurate" (SVGU6).

Additionally, obstacle detection and reading were inconsistent, particularly for dynamic environments: "Sometimes SVG does not detect obstacles in my surroundings; sometimes it fails to detect" (SVGU9). "It is not capturing bus numbers, which is important for a blind person, but this is not happening" (SVGU5).

Theme 2: Usability and Functional Barriers

Usability issues arise from the device's interface and physical design, which impacted user interaction and comfort during prolonged use. Usability is essential for ensuring that visually-impaired users can effectively integrate SVG into their daily routines. Interface sensitivity and device weight were prominent concerns.

The touch interface was often described as overly sensitive or unresponsive, complicating user interaction: "The touch is oversensitive. Even if I touch the braille dot, the device is activated" (SVGU4). The device's weight also impacted regular use: "It feels heavy on one side, so I'm not using it regularly" (SVGU2).

> I do not use SVG much for outdoor activities, as they are connected to my mobile. I have to hold the mobile in one hand and the cane in the other, which makes it quite difficult and challenging. Therefore, I do not use SVG for outdoor activities (SVGU3).

Theme 3: Technological and Connectivity Barriers

Connectivity issues and device compatibility with smartphones were significant obstacles, limiting the functionality of SVG. Reliable internet and device compatibility are essential for seamless operation, especially for cloud-based features like real-time object recognition. SVG users frequently encountered connectivity issues: "I face issues in connectivity most of the time. It says poor connectivity" (SVGU4). Compatibility problems with smartphones further hindered usage: "SVG doesn't support on my smartphone because of the Android version difference" (SVGU6).

Theme 4: User Comfort and Wearability Barriers

Comfort and wearability issues restricted the use of SVG, particularly in outdoor settings, due to design-related discomfort and safety concerns. Comfort is vital for encouraging consistent device use, especially for mobility-related tasks in diverse environments. Participants avoided outdoor use due to competing sensory inputs, safety concerns and discomfort: “I do not use it outside because the vehicle sound and audio output from the device make it hard to concentrate” (SVGU8).

Theme 5: Design and Aesthetic Barriers

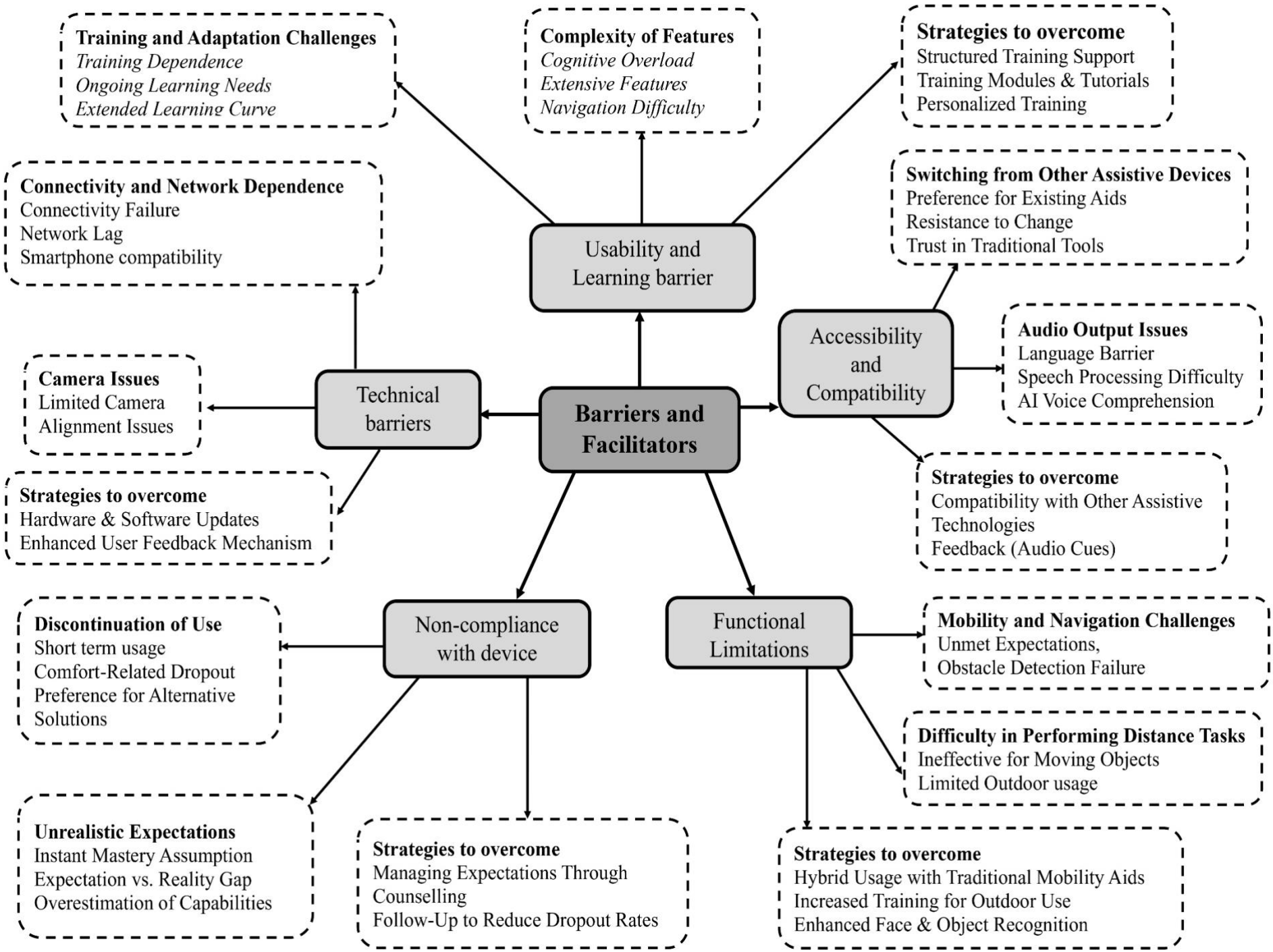
Aesthetic and practical design issues, such as visible wiring, discouraged public use of SVG due to social stigma and inconvenience. Aesthetic considerations influence user confidence and willingness to use assistive devices in public settings. The device’s design, particularly the wiring, was a deterrent: “The wire problem is there, and plugging the SVG with the mobile phone is a little difficult” (SVGU9; SVGU10).

Optometrists / Low-Vision Practitioners

From practitioner interviews, 42 codes and 15 subthemes were identified, yielding five themes: (1) usability and learning barriers, (2) technical barriers, (3) accessibility and compatibility, (4) functional limitations, and (5) noncompliance with the device. Figure 3 illustrates these themes, emphasizing the overlap among usability, technical, and accessibility challenges, which informs strategies for improving SVG adoption.

Figure 3 illustrates the thematic framework generated from the qualitative analysis, highlighting the key barriers and facilitators influencing user interaction with the device. The thematic analysis revealed five major themes: usability and learning barriers, technical barriers, accessibility and compatibility, functional limitations, and non-compliance with the device - each encompassing specific challenges reported by participants. These included cognitive overload, extended learning requirements, connectivity failures, audio-processing difficulties, limited outdoor functionality, and gaps between user expectations and actual device performance. Integrated within the framework are the strategies identified to mitigate these barriers, such as structured and personalized training, regular hardware and software updates, enhanced feedback mechanisms, compatibility with existing assistive technologies, and hybrid use with traditional mobility aids. Additional strategies, including expectation management and follow-up support, were also recognized as essential in reducing discontinuation and improving long-term engagement. Unlike SVGUs’ themes, practitioner perspectives highlight training and expectation management as critical factors.

Figure 3: *Thematic Analysis of Practitioners’ Perceived Barriers and Facilitators*


Barriers and Facilitators
Usability and Learning barrier
Training and Adaptation Challenges
Training Dependence
Ongoing Learning Needs
Extended Learning Curve
Complexity of Features
Cognitive Overload
Extensive Features
Navigation Difficulty
Strategies to overcome
Structured Training Support
Training Modules & Tutorials
Personalized Training
Technical barriers
Connectivity and Network Dependence
Connectivity Failure
Network Lag
Smartphone compatibility
Camera Issues
Limited Camera
Alignment Issues
Strategies to overcome
Hardware & Software Updates
Enhanced User Feedback Mechanism
Accessibility and Compatibility
Switching from Other Assistive Devices
Preference for Existing Aids
Resistance to Change
Trust in Traditional Tools
Audio Output Issues
Language Barrier
Speech Processing Difficulty
AI Voice Comprehension
Strategies to overcome
Compatibility with Other Assistive Technologies
Feedback (Audio Cues)
Non-compliance with device
Discontinuation of Use
Short term usage
Comfort-Related Dropout
Preference for Alternative Solutions
Unrealistic Expectations
Instant Mastery Assumption
Expectation vs. Reality Gap
Overestimation of Capabilities
Strategies to overcome
Managing Expectations Through Counselling
Follow-Up to Reduce Dropout Rates
Functional Limitations
Mobility and Navigation Challenges
Unmet Expectations,
Obstacle Detection Failure
Difficulty in Performing Distance Tasks
Ineffective for Moving Objects
Limited Outdoor usage
Strategies to overcome
Hybrid Usage with Traditional Mobility Aids
Increased Training for Outdoor Use
Enhanced Face & Object Recognition

Theme 1: Usability and Learning Barriers

Practitioners noted that the complexity of SVG features and the steep learning curve posed significant challenges, particularly for users unfamiliar with advanced technology. Effective training is essential to ensure that users can navigate the device's features confidently. Practitioners observed cognitive overload due to the device's numerous features: "Some people get confused because there are too many options in one small unit" (Optometrist 10).

Compared with traditional optical devices, the learning curve associated with SVG is steep. It requires ongoing training and adaptation: "Compared with other optical devices, SVG require more training" (Optometrist 1). Strategies to overcome: Structured training modules and personalized follow-up sessions were recommended. "We can conduct hands-on training and provide follow-up sessions" (Optometrist 3).

Theme 2: Technical Barriers

Technical limitations, such as restricted camera range and connectivity issues, hindered the device's performance and user satisfaction. Addressing technical reliability is crucial for ensuring consistent functionality across diverse environments. Camera range and connectivity issues were frequently reported: "The camera range is only up to one or two meters. Beyond that, it is not effective for mobility" (Optometrist 5). Compatibility problems with certain smartphones also contribute to user frustration, "The device may fail to connect to some smartphones, like not having good RAM and internal storage, causing delays and frustration" (Optometrist 4). Strategies to overcome: Upgraded hardware in the SVG Pro version was noted as a potential solution. "The updated version of SVG, SVG Pro, has addressed many of these barriers through enhanced design and user compatibility" (Optometrist 7).

Theme 3: Accessibility and Compatibility

Language barriers and compatibility issues with other assistive technologies limited the device's accessibility for diverse users. Enhancing accessibility ensures broader usability, particularly for non-English-speaking users or those accustomed to traditional aids. Language barriers were a significant issue: "Some patients struggle with English, as the device provides audio output in English when connectivity is poor" (Optometrist 8).

Patients with prior experience using traditional assistive devices often resist switching to Smart Vision Glasses. "Patients who are already using a cane or mobile apps for reading generally do not prefer smart vision glasses" (Optometrist 3). Strategies to overcome: Integrating SVG with existing aids can show a better result. "Patients can use SVG along with their other assistive devices" (Optometrist 2).

Theme 4: Functional Limitations

The device's limited ability to meet mobility expectations and detect obstacles effectively was a key concern. Functional reliability is critical for user trust and adoption, particularly for outdoor navigation. Practitioners noted unmet expectations in mobility support: "Patients expect the device to help with mobility, but it does not meet those expectations due to delayed responses" (Optometrist 2). Users often prefer indoor use where they feel safer: "Even among those who try using it outdoors, they tend to use the device indoors where they feel safer" (Optometrist 6).

Strategies to overcome: Combining SVG with traditional mobility aids was recommended. "Patients are encouraged to use SVG alongside their cane for enhanced safety" (Optometrist 7).

Theme 5: Noncompliance with Device

Unrealistic user expectations and lack of follow-up support led to discontinuation of SVG use. Managing expectations and providing ongoing support are essential to improve adherence and user satisfaction. Unrealistic expectations often led to disappointment. "Some patients assume they will start using the device like a pro from day one" (Optometrist 1).

Strategies to overcome: Counselling and regular follow-ups were proposed to address noncompliance. "Encouraging patients to return for training sessions can reduce dropout rates" (Optometrist 9). These findings describe participant experiences with SVG Gen 2.0 and are device specific.

Discussion

This qualitative study explored the experiences of patients and low-vision practitioners, focused on a single device, SVG Gen 2.0, highlighting multiple barriers that hinder adoption and consistent use. Rather than isolated technical faults, the issues reported—ranging from unreliable focusing and poor image quality to connectivity failures and design discomfort—reflect broader challenges in aligning assistive technology with the lived realities of visually impaired individuals. These findings reflect the experiences of users and practitioners with SVG Gen 2.0 specifically and should not be generalized to other smart wearable assistive devices, which differ in design, functionality, and performance.

A central finding concerns the device's performance and reliability. Participants frequently described inconsistent recognition of objects and obstacles, as well as slow or inaccurate responses. These limitations are not unique to SVG but resonate with challenges reported in other assistive technologies, where functionality gaps reduce user trust and confidence (Varshney et al., 2025). From a technology-acceptance perspective (Davis, 1989), such usability frustrations diminish both perceived usefulness and perceived ease of use, making adoption less likely without substantial redesign.

Usability and wearability concerns further shaped user experiences. Complaints about device weight, touch sensitivity, and wired connectivity align with prior research showing that assistive devices perceived as intrusive, conspicuous, or uncomfortable are often abandoned (Rudinger, 2023). Design aesthetics also play a critical role, as stigma and self-consciousness can discourage public use. Sivakumar et al. (2020) similarly noted that fear of stigma and social visibility remain major deterrents to adoption of low-vision aids. Our findings suggest that SVG, despite their technological sophistication, may reinforce these social barriers when design does not prioritize discretion and comfort.

Connectivity challenges also emerged as significant barriers, particularly in outdoor environments where stable internet is less reliable. This finding extends broader discussions in digital accessibility research, which emphasizes that dependence on external infrastructure can deepen inequalities for visually impaired users (Kaminsky et al., 2014). Moreover, practitioners reported compatibility problems with smartphones and operating systems, reinforcing the need for scalable, universally accessible designs rather than device-specific solutions. An important contextual factor influencing user experience relates to the connectivity requirements of the SVG device. Because SVG relies on cloud-based processing for several of its functions, performance is inherently dependent on smartphone specifications, network strength, and the user's mobile data plan. Therefore, fluctuations in bandwidth or signal stability are likely to contribute to the connectivity issues reported by the participants. This suggests that some of the perceived technological limitations of the device may be partly related to network connections rather than the device itself, particularly in areas where 4G and 5G connections are inconsistent or unstable.

Another recurring theme was the steep learning curve associated with SVG. Practitioners highlighted the cognitive overload posed by multiple features, as well as the extended training period required for effective use. This echoes earlier studies on assistive technology adoption, which show that structured, ongoing training and follow-up support are essential for long-term engagement (Kibret et al., 2025). Our findings underscore that training cannot be a one-time event; instead, adaptive modules, tutorials, and personalised guidance may help bridge the usability gap.

Importantly, this study highlights the gap between user expectations and device performance. Some participants anticipated that SVG would substantially enhance mobility, but were disappointed by delays in obstacle detection and limitations in outdoor navigation. Similar mismatches between expectation and functionality have been reported in other domains of assistive technology, where unmet expectations often lead to device abandonment (Sivakumar et al., 2020). Managing expectations through counselling, user education, and collaborative goal setting could therefore be as critical as technical improvements.

Our findings also complement a study (Udayakumar et al., 2025) that evaluated usage of SVG, a cost-effective AI-powered assistive device, in a large Indian multicentric cohort. While their participants reported strong acceptance, particularly for reading and object recognition functions,

limitations in walking assistance and obstacle detection were highlighted, echoing the concerns raised in our interviews. Similarly, Varshney et al., (2025) demonstrated usability gains in face recognition and reading among visually impaired and totally blind participants, but again, noted challenges with walking assistance and currency identification. Together, these results suggest that while SVGs are promising tools for enhancing independence, their effectiveness in real-world mobility remains constrained unless iterative improvements and co-design approaches are adopted.

The broader implication of these findings is that technological advancement alone is insufficient. Effective implementation of devices like SVG requires a user-centered and co-design approach, ensuring that end-users are actively involved in shaping functionality, aesthetics, and usability. Incorporating both psychosocial and environmental factors into design may help overcome barriers to sustained adoption. Furthermore, affordability and accessibility remain implicit challenges. Even the most well-designed devices may fail to reach those who need them most if cost and availability are not addressed.

Strengths and Limitations

A key strength of this study is its dual perspective, incorporating insights from both visually impaired users and low-vision practitioners. The use of semi-structured interviews allowed for in-depth exploration of personal experiences, while triangulation of perspectives and adherence to COREQ guidelines enhanced methodological rigor.

Several limitations should be considered when interpreting the findings. First, the study focused on a single smart wearable device model SVG Gen 2.0, which was selected based on its availability, affordability, and integration into low-vision rehabilitation services in India. Consequently, as this is a qualitative study, the findings may not be generalizable and replicable to other smart wearable technologies, such as OrCam MyEye, eSight, or Aira, which differ in design, functionality, and implementation context. Second, the qualitative nature of the study precluded comparison of functional performance outcomes across devices. Third, the study did not systematically capture detailed information on participants' mobile network characteristics or signal strength, which may have influenced reported connectivity issues. Finally, the sample did not include older adults or individuals from rural settings, and thus the findings may not fully reflect experiences across diverse demographic and geographic contexts.

Future research employing mixed methods approaches, multi-device comparisons, and more diverse participant samples may help to strengthen generalizability and to ensure that emerging assistive technologies are designed as well as implemented equitably across contexts.

Outcomes and Benefits

The findings of this study emphasize that while SVG Gen 2.0 provides valuable support for reading, object recognition, and face identification, its broader benefits depend on addressing

usability, design, and connectivity barriers. For people who are blind or have low vision, improvements in reliability and wearability could translate into greater independence in both educational and daily living contexts. Clinicians and rehabilitation specialists benefit from understanding the training and support needs identified, which can guide the development of structured modules and follow-up strategies that improve user confidence and long-term adoption. The outcomes reported here are specific to SVG Gen 2.0 and may not extend to other wearable assistive devices.

Conclusion

This study highlights that SVG Gen 2.0 demonstrates potential for supporting specific tasks and independence, but its usability is constrained by barriers such as unreliable outdoor performance, connectivity limitations, and patient-related challenges. The most important takeaway is that adoption depends not only on technical improvements but also on how well these devices integrate into the daily lives of visually impaired users. Moving forward, clinicians can play a role by providing structured training and personalized support, while developers should adopt concrete user-centered design strategies, such as iterative field testing with diverse users, co-creation workshops with patients and practitioners, and ongoing feedback loops, to ensure that future devices are both functional and acceptable. Researchers, in turn, should continue to evaluate these technologies in real-world contexts to guide evidence-based improvements.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No funding was received for this research. The authors report that there are no competing interests to disclose. This study is part of the primary author’s doctoral research conducted at SRM Medical College Hospital and Research Centre, Chennai, India. The authors confirm that they have no affiliation with SHGs Technologies or any other assistive technology manufacturer, and no industry funding or support was received for this work. The research was undertaken entirely within an academic and clinical environment, independent of commercial interests. The device examined in this study, SVG Gen 2.0, was selected solely based on its availability and routine use in low-vision rehabilitation services across India. The descriptions provided are intended for scientific transparency and reproducibility and should not be interpreted as endorsement or promotion of any specific product.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 23-37
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from Academia

Intercollegiate AT Hackathon: The Perspectives of Co-designers

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Abstract

Assistive technology (AT) supports engagement of individuals with disabilities by improving independence in daily living tasks and societal participation. Access to AT may be limited due to high costs, device availability, and the inability to be customized. AT Hackathons provide an opportunity to educate health profession students, design students, and community members with disabilities while addressing unmet AT needs. No studies exist that examine the perspectives of community volunteers with disabilities in AT Hackathons and similar educational events. The current study examines perspectives from co-designers (community members with disabilities) during the 2024 and 2025 Intercollegiate AT Hackathons. Process and solution examples are described. Quantitative and qualitative content analyses were performed. The analysis found positive self-report outcomes in the area of improved technical skills and understanding of community resources from community co-designers with disabilities in regard to their participation in a volunteer intercollegiate AT hackathon event.

Keywords: assistive technology, design, interprofessional, maker

Intercollegiate AT Hackathon: The Perspectives of Co-designers

Health profession and engineering academic programs recruit community member volunteers, often from the disability community, to participate in experiential learning activities (Lim et al., 2018). Designing solutions without engaging the disability community risks developing impractical solutions to inaccurately perceived problems (Jackson et al., 2022). Engaging members of the disability community in an assistive technology hackathon can address real-life challenges and include authentic factors that cannot be replicated in a case study or simulation (Labattaglia et al., 2023; Narain et al., 2020). However, no studies exist that examine the perspectives of these volunteers with disabilities. The present study examines quality improvement data from the 2024 and 2025 Boston Area Intercollegiate Assistive Technology Hackathon to understand the experience of participant co-designers (community members with disabilities).

Target Audience and Relevance

This study may be meaningful for practitioners, educators, students, and community members who participate in volunteer events and educational opportunities, such as assistive technology hackathons, in the health profession and design fields. Educators and practitioners who are planning such events may benefit from this analysis on the experience of volunteer community members with disabilities and the impact of inclusive co-design. Student participants may benefit by understanding the perceptions of community members when they are called upon to participate in such events.

Literature Review

Hackathons are brief, intense events that can foster collaboration between individuals from diverse backgrounds to solve a problem (Lyndon et al. 2018). Hackathons often bring together public institutions, nonprofit organizations, and community members to innovate solutions to unmet problems or problems with otherwise costly solutions (Yarmohammadian et al. 2021). Although hackathons started in engineering and design fields (Lyndon et al. 2018), they have evolved into positive learning experiences in healthcare and health profession training fields (Aungst, 2015; Berner et al., 2024; Pathanasethpong et al., 2020; Wang et al., 2018).

Assistive technology (AT) is defined as “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities” (U.S. Technology-Related Assistance Act, 2004). AT is critical in supporting independence and participation by people with disabilities, and the World Health Organization (WHO) declared that access to AT is a “human right and a prerequisite for equal participation and opportunities” (WHO, 2022, p. 5). Despite this, numerous barriers exist to acquiring AT globally, including high costs, low availability, and lack of support (WHO, 2022).

Co-designing, a type of user-centered design where developers and product end-users work together on teams, has emerged as a powerful model to address both individual challenges and systemic problems (Labattaglia et al., 2023; Melro et al., 2024; Menash-Gourmel et al., 2024; Narain et al., 2020). The ATHack at the Massachusetts Institute of Technology engaged a total of 75 community-based co-designers with disabilities and 400 students from 2014–2019, where teams developed technologies to address daily living needs (Narain et al, 2020). In Saskatchewan, Canada, a youth mental health services organization used a co-design model to engage 20 youth in developing youth mental health programming (Melro et al., 2024). Collaborating with end-users or devices, services, and supports has been described as essential in order to develop solutions that are relevant and effective (Melro et al., 2024; Narain et al., 2020; Shahnaz et al., 2025).

The Boston-area 2023 Intercollegiate AT Hackathon is a 100% volunteer event that engaged 9 co-designers with disabilities and 27 students from health profession and design fields over one week to develop AT and adaptive devices to address daily living needs (Berner et al., 2024). An analysis of outcomes of student participants found that an intercollegiate assistive technology hackathon was effective to promote learning about AT, the design process, and co-design collaboration strategies (Berner et al., 2024). While 21 student participants (75%) responded to the 2023 post-hackathon survey, only 3 co-designers responded (33.3%), presenting a challenge for analyzing the experience of AT Hackathon co-designers (Berner et al., 2024). It is unclear what benefits and possible burdens exist for people with disabilities when they are called to participate in educational activities, such as AT hackathons. The present analysis aims to understand the volunteer co-designer experience based upon feedback data from the 2024 and 2025 Boston Area Intercollegiate Assistive Technology Hackathons.

Method

The current initiative examines data from the 2024 and 2025 AT Hackathon co-chaired by faculty from Tufts University (Tufts) and MGH Institute of Health Professions (MGH IHP). The goal of this Intercollegiate AT Hackathon was for health profession and engineering/design students to collaborate with a community member co-designer with a disability to design and fabricate a low-tech AT device that could address a self-identified daily living need. The Intercollegiate AT Hackathon was conducted over a one-week timeframe with a budget of $100 per team (provided in kind by a local non-profit). Planning, execution, mentoring, and judging were performed by volunteer event co-chairs, volunteer judges, and volunteer mentors. The 2024 and 2025 AT Hackathons were both conducted over seven days, had the same level of mentorship and communication, had identical budgets for materials, a similar number of hack projects and teams (11 in 2024 and 10 in 2025), and had similar access to community resources such as meeting and design spaces.

Community members with disabilities and students were made aware of the AT Hackathon through outreach from the three event co-chairs. Digital and printed flyers were distributed through university-sponsored maker spaces, contacts at health professions and engineering academic

departments at Boston-area colleges, community organizations such as centers for independent living, past AT hackathon participants, and through the event co-chairs' professional networks.

Co-designers were invited to complete a web-based survey to share their lived experience, the activity they were having trouble participating in, and ideas for a possible AT device to address the challenge. With an emphasis on the cultural and social construct of disability, authors chose not to request or collect specific medical diagnoses but instead asked co-designers to describe their "disability profile/identity."

An anonymous web-based survey was administered inquiring if co-designers had participated in an AT hackathon before and asked each participant to rank their responses to three questions on a Likert scale:

- "I feel confident with the design process (ideate, create, fabricate, reiterate)" with 1 being *I do not feel confident* and 5 being *I feel very confident*;
- "I feel confident in fabricating a custom adaptive solution for an individual" with 1 being *I do not feel confident* and 5 being *I feel very confident*;
- and "I feel comfortable collaborating with community members with disabilities and/or students to address a daily living challenge" with 1 being *I do not feel comfortable* and 5 being *I feel very comfortable.*

Co-designers prepared a two-minute pitch video describing their daily living needs and ideas for a custom low-tech assistive technology device. These pitch videos were shown during the Intercollegiate AT Hackathon virtual launch event, and each represented a unique daily living challenge. The launch event also included details about community resources and makerspaces, and an overview of collaboration strategies.

After viewing the pitch videos at the Intercollegiate AT Hackathon virtual launch event, students completed a form that ranked their top three project preferences and listed their design, collaboration, and AT experiences. The event co-chairs reviewed student participant preferences and curated team assignments. Efforts were made to diversify teams based on design experience, college major/profession, and school of enrollment. Each team was emailed with contact information for team members (including co-designers), and each team was assigned a team mentor to provide logistical support and mentoring on collaboration and co-design. Teams were provided contact information and hours for local design and maker resources that have partnered with the AT Hackathon.

Teams worked at their own pace over a 1-week period in a setting of their choosing. Some worked in on-campus classrooms and design and fabrication spaces, while others met in the co-designers' homes and community-based maker spaces. Mentors communicated with teams and provided connections to resources as needed, helped with problem solving obstacles, and suggested strategies to promote collaboration.

A virtual wrap-up event was held where each team had 10–15 minutes to share an overview of their project with emphasis on their collaboration, design process, and final product. Volunteer judges from the disability community, design field and health professions analyzed projects to select winners for 1 of 3 categories: Most Innovative, Most Functional, and Most Collaborative.

An anonymous web-based participant survey was administered prior to final results while the judges convened. This survey asked the level of participation (i.e. student participant, co-designer), repeated the Likert questions about confidence with design and comfort with collaboration described above, and included open-ended questions about the experience, including “How was your team collaboration experience working with students, co-designers and community partners with differing backgrounds and experiences/perspectives?”

The current inquiry consisted of an observational analysis without a control group. The Institutional Review Board (IRB) of Mass General Brigham (the parent organization of the MGH Institute of Health Professions) was consulted, and it was determined that the participant feedback survey was not human subjects research and therefore was exempt from full IRB review. Quantitative and qualitative data from this participant feedback survey were examined in this analysis.

The authors aimed to improve the response rate of the community-based co-designers with disabilities compared to the 2023 AT Hackathon and analysis (Berner et al., 2024). An anonymous pre-hack survey was distributed a week before the event, and co-designers were encouraged to complete it on their own, with the support of a caregiver, or to reach out for help with an AT Hackathon volunteer. A reminder was sent one day before the launch event. Following the completion of the AT Hackathon, participants were encouraged to complete a post-hack survey. Reminders were sent to co-designers one day after the event with a similar invitation offering assistance if needed.

Pre and post survey responses were treated as independent samples, as the anonymous submissions were not able to be linked. Data from Likert questions examining self-report on knowledge related to assistive technology, the design process, and comfort with collaboration with interprofessional teams were extracted. Qualitative content analyses were performed by event co-chairs, and quantitative analyses were performed by a statistician. Because the self-ratings were ordinal, nonparametric tests were used. To determine whether there was a difference in the self-ratings before and after the intervention, Mann-Whitney tests were performed using IBM SPSS (version 28). Participant responses were analyzed using NVivo qualitative analysis software (QSR International, 2020).

Results

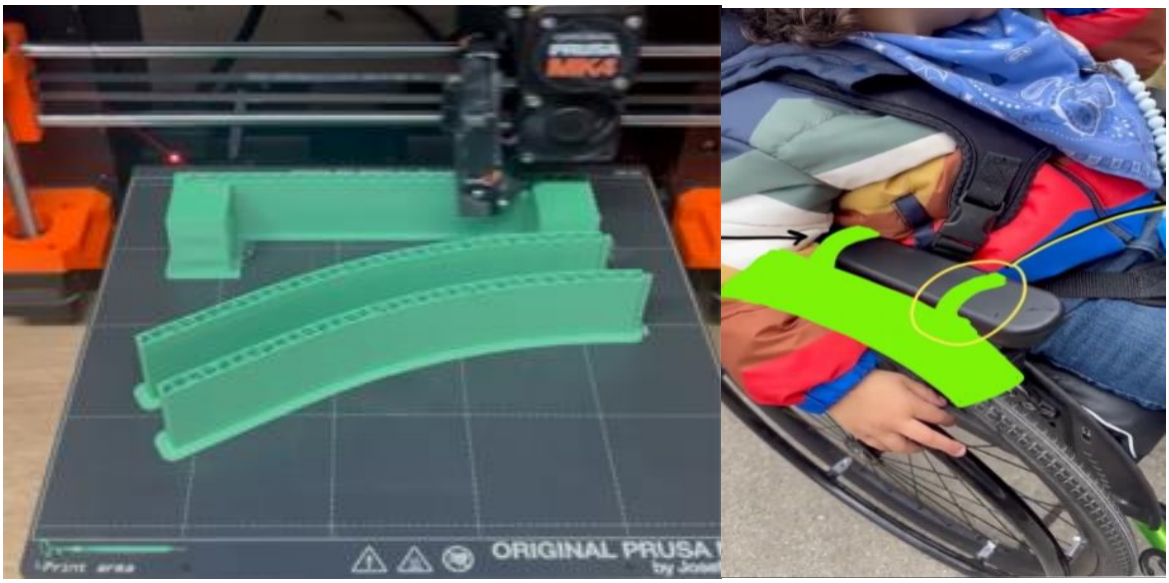
Twenty co-designers participated in the AT Hackathon over the two years reviewed. Each team designed a final product or working prototype and presented it at their wrap-up event. The duration, structure, level of mentoring, materials budget and access to design spaces were comparable between the 2024 and 2025 events, making it reasonable to pool the data.

Eleven co-designers participated in the 2024 AT Hackathon, and nine co-designers participated in the 2025 AT Hackathon. All participants provided descriptions on their disability profile and identity. Some co-designers shared specific diagnoses such as cerebral palsy, FOXG1 syndrome, and cortical visual impairment, while others described in general terms such as “I have a neuromuscular disease,” and “I have different abilities, not disabilities.” Several co-designers described their disability profile/identity with the equipment they use for daily living, such as a wheelchair for mobility, a ventilator for respiratory support, and a left ventricular assistive device (LVAD) for cardiac assistance. Twelve co-designers were adults participating on their own or with the assistance of caregivers, and eight were children participating with the assistance of caregivers.

Each design team had a community-based co-designer who posed a unique daily living challenge, three to five college and graduate students (studying engineering, occupational therapy, speech and language pathology, or other health professions programs), and one project mentor. All 20 participating teams developed detailed design plans, prototypes or finished products during the AT Hackathon. Team E and Team F are both exemplars of collaboration and innovation.

In 2025, Team E worked to develop a solution to keep a pediatric wheelchair user from touching the wheels of his wheelchair for tactile stimulation. The team consisted of an occupational therapy student, a speech and language pathology student, a human factors engineering student, two parents, and the child. The parents remarked that their child would touch and feel the rubber of the wheelchair’s tires while being transported by caregivers or when static sitting, placing him at risk of injury and risk of developing infection or ingesting road chemicals in winter months (as he often placed his hands in his mouth after touching the tires). The team met with the family at one of the participating colleges to meet the child, take measurements of the wheelchair, and learn more about the challenge. Using the fender of a motorcycle as inspiration, the team sketched a design for a tire guard that can strap to the wheelchair’s armrests. The tire guard could be fabricated using the child’s favorite color and included tactile letters that could encourage the child to manipulate and touch. The team used computer-aided design (CAD) software to develop a build for a 3-D printer and decorated the design with acrylic letters cut from a laser cutter. The team designed the tire guard to cover the tire while allowing access to the wheelchair’s pushrims, the preferred method for controlling movement of the wheelchair. Caregivers were pleased with the final product and would install and remove the adaptations when needed (Figure 1).

Figure 1: *Team E Developed Custom Tireguards with Tactile Additions for the Co-Designer's Wheelchair During The 2024 AT Hackathon*



In 2025, Team F worked to develop a custom garment that could support an active adult who uses a Left Ventricular Assist Device (LVAD), a medically necessary durable circulatory support device (Vaidya et al., 2023). The team consisted of three occupational therapy students, two electrical and computer engineering students, and the co-designer. The students met with the co-designer to learn about the LVAD, its necessity for his health, and the limitations of carrying the LVAD on his daily living activities. The team sketched out a wearable solution that could carry the device and its batteries in a sweatshirt while accommodating the power leads. During the hackathon, the team consulted with the project mentor who connected them with a cardiac clinic nurse to respond to questions about LVADs and heart failure, and an occupational therapist with sewing skills. The team gathered on campus of a participating university to adapt a purchased hooded sweatshirt with custom spandex pockets and fabric privacy cover (Figure 2).

Ten total co-designers completed the anonymous pre-hack survey and 10 co-designers completed the anonymous post-hack survey, resulting in a 50% overall response rate over the 2-year span. Table 1 shows the details of survey responses based on year. No co-designers requested assistance to complete the pre-hackathon or post-hackathon survey with support from an AT hackathon volunteer. As the survey responses were anonymous, it is unclear how many of the same co-designers completed both the pre- and post-surveys.

Figure 2: *Team F Outfitted a Hooded Sweatshirt with Custom Pockets and Pass-Through Cuts to Accommodate an LVAD*

Table 1: *Co-Designer Survey Completion*

Participants	2024	2025
Number of Co-Designers	11	9
Co-Designer Pre-Hackathon Anonymous Surveys	4	6
Co-Designer Post-Hackathon Anonymous Surveys	6	4

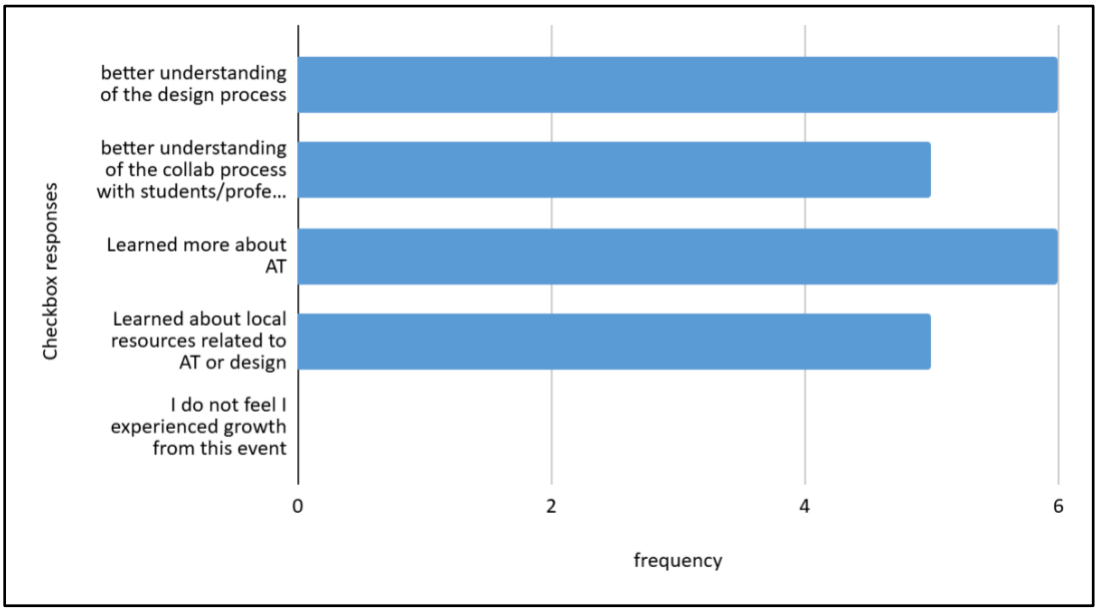
Table 2 summarizes the descriptive and quantitative results from co-designers. The mean score increased between the pre-hackathon and post-hackathon for each of the questions. Differences in scores were not found to be significant, as the calculated p values were not ≤ .05.

All 10 respondents provided multiple select checkbox responses for "*How did you grow from the AT Hackathon experience*?" The most frequent responses were "*I developed a better understanding of the design process*" and "*I learned more about assistive technology.*" No co-designers selected "*I did not grow from the event.*" Details of responses to this question can be seen in Figure 3.

Table 2: *Statistical Summary Table for Co-Designers 2024 & 2025*

Statement	*n*	*M*	*SD*	*Mdn*	*U*	*p*
Pre: I feel confident with the design process (ideate, create, fabricate, reiterate).	10	3.90	1.45	4.5		
Post: I feel confident with the design process (ideate, create, fabricate, reiterate).	10	4.30	0.95	5.0	43.50	.588
Pre: I feel confident in fabricating a custom adaptive solution for an individual.	10	2.60	1.78	2.0		
Post: I feel confident in fabricating a custom adaptive solution for an individual.	10	3.90	0.99	3.5	26.50	.064
Pre: I feel comfortable collaborating with others in my community to address a daily living challenge.	10	4.30	1.06	5.0		
Post: I feel comfortable collaborating with others in my community to address a daily living challenge.	10	4.40	0.84	5.0	49.00	.932

Figure 3: *How Did You Grow from the Event* (*n* = 10)



All 10 respondents included a response for "*How was your team collaboration experience working with students, co-designers, and community partners with differing backgrounds and experiences/perspectives*?" Anonymous responses were reviewed by the authors, and a content analysis was performed. Responses varied from 1 word to 45 words, with a mean of 20 words (standard deviation of 15). Four of the responses were under 10 words, with single-word responses such as "*awesome!*" and phrase-level responses such as "*excellent - a good mix of knowledge and skills*." The remaining co-designer responses were between 20 and 45 words. This co-designer

described obstacles to participating in the AT Hackathon, "I was a co-designer with a very busy week. However, the students were fantastic being flexible with my schedule and we met on Zoom."

This response reflected on a positive experience working with students, "Our experience was wonderful and very informative. The students were insightful, thorough, kind, prompt and professional. They made every step simple and enjoyable!" This response, written by a caregiver with the co-designer, reflected more on the collaborative nature of the team process:

> I was truly impressed with the collaboration of [the Team]. [We] felt like we were part of the team from day 1. We got numerous emails and were part of a WhatsApp text chain. The students had such great questions and ideas.

A systematic analysis of responses was performed with NVivo qualitative analysis software (QSR International, 2020). A codebook of 6 unique codes was developed based on a review of co-designer responses. These codes included comments that included a positive tone, comments that described an inclusive experience, comments that identified obstacles, comments that had positive remarks about the team process, positive remarks about the student engagement, or positive remarks that were unspecified. All 10 co-designers reflected positive overall sentiments in their response. Six co-designers included a general positive remark, while 4 had a positive remark about the team process, and 3 had a positive remark about a student. The frequency of each code that emerged from the content analysis can be seen in Figure 4.

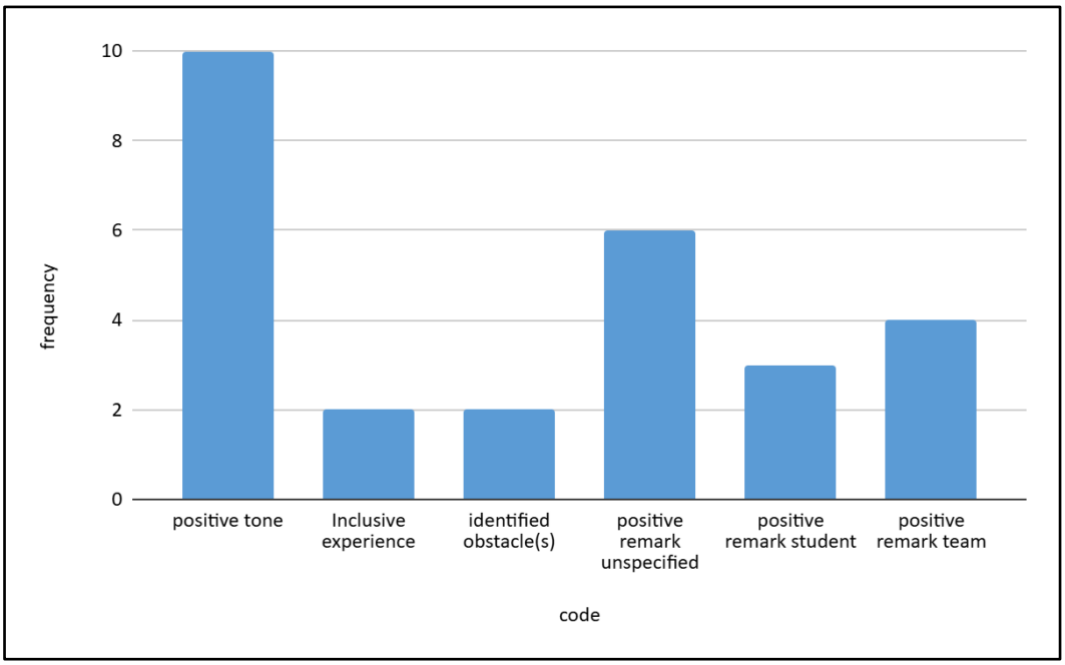
Outcomes and Benefits

The Intercollegiate AT Hackathon experienced excellent sustained participation from student hackers, co-designers, and the administrative and support team over its three years of operation. The events have been voluntary, as program co-chairs, project mentors, and co-designers are not paid for their time, and student engagement did not result in any grade or extra credit. This analysis of data related to the co-designer experience reflects predominantly positive outcomes.

All of the co-designers reported personal or professional growth from the AT Hackathon. Each co-designer had their own takeaways, with 70% of the respondents selecting growth in the technical skills (i.e., better understanding of design or learned about AT) while 70% of respondents described growth with social tools (i.e., learned about local resources or better understanding collaboration with students/professionals). None of the respondents selected that they did not grow from the event, which suggests that the volunteer efforts to participate were valuable.

While the average response increased for each of the Likert questions related to self-report rating of confidence with design (increase from 3.90 to 4.30), confidence with fabrication (increase from 2.60 to 3.90) and comfort with collaboration (increase from 4.30 to 4.40), the difference failed to demonstrate statistical significance. For "*I feel confident in fabricating a custom adaptive solution,"* there was a p-value of 0.064, which is just above the ≤ 0.05 threshold of statistical significance.

Figure 4: *Content Analysis for "How Was Your Team Collaboration Experience Working with Students, Co-Designers, and Community Partners with Differing Backgrounds and Experiences/Perspectives?"* (*n* = 10)



Four of the 10 open-ended responses remarked positively on the team process, for example, "I was truly impressed with the collaboration of [the] team." Another co-designer wrote "it was great, everyone on the team was very thoughtful and really wanted to create a product that was helpful."

Two (20%) of the open-ended responses remarked positively about the inclusive nature of the experience. One co-designer shared, "we were part of the team from day 1," while a caregiver shared "[the co-designer] not only felt heard but she felt like she was part of creating something helpful." This suggests the value and importance of being part of a team and the collaboration process.

Two respondents described personal obstacles to participating, including this co-designer who shared, "the biggest challenge was the designers not having access to the equipment due to us not living close to Boston." While the majority of co-designers resided within Boston or the metro Boston area, where the participating colleges and universities were located, some lived more than 15 miles from Boston. The second obstacle related to timing of the hackathon event, citing "I was a co-designer with a very busy week." Due to the logistics of college breaks, student and co-designer commitments, and coordinating community collaborators, there was limited flexibility to extend collaboration times for specific teams. Aside from these two co-designers who reported personal obstacles, no co-designers reported any negative collaboration experiences. The authors acknowledge that some co-designers may have chosen not to report negative experiences.

Discussion and Conclusion

The current analysis found positive self-report outcomes from community co-designers with disabilities in regard to their participation in a volunteer intercollegiate assistive technology hackathon event. For health profession and design field education, the inclusion of people from the communities we serve is critical to understanding and addressing their needs. These outcomes are meaningful to educators, practitioners, and students who invite community members to participate and/or volunteer in collaborative learning and design activities.

Although there were increases in each of the Likert questions, the change was found not to be statistically significant. Several factors may have resulted in this outcome. To start, the pre-hackathon scores were generally high for each of these questions. For *"I feel confident with the design process (ideate, create, fabricate, reiterate),"* the pre-hackathon score was 3.9/5. For "*I feel comfortable collaborating with others in my community to address a daily living challenge,*" the pre-hackathon score was 4.3/5. These high scores may suggest a ceiling effect, so that it did not provide a context where much improvement could occur. High scores in this area could be a result of the co-designer recruitment strategies. Co-chairs reached out to their personal and professional networks of individuals who may have previously received AT services and support or may have had experiences participating in the design process. While this may have contributed to a positive experience for these co-designers, it resulted in limits on opportunity for self-reported growth in these three areas.

The present study has limitations. A small number of participants and a modest response rate yielded only 10 responses for analysis, and a small *n* has limits for statistical analysis and generalizability. The community-based co-designers were recruited as a convenience sample through professional and personal networks of the AT Hackathon co-chairs and may not be a representative sample of all individuals who identify with the disability community. Although steps were taken (such as anonymous surveys) to reduce bias in data collection and analysis, the possibility for evaluator bias is present. While each survey submission had a unique timestamp, the survey system used did not collect IP addresses to ensure that each submission was from a unique device.

Limitations existed in statistical analyses as well. Use of a Mann-Whitney U test requires an assumption of independent samples. Other statistical tests, such as the Wilcoxan Signed Rank test, requires paired samples. Due to the study design and anonymous nature of the pre and post surveys, it was not possible to pair samples. With a 50% response rate, it cannot be guaranteed that samples were independent either, so there is a chance that this assumption of independent samples was violated.

Analysis of outcomes allowed the authors to reflect on logistical aspects of the Intercollegiate AT Hackathon. Solutions developed by hack teams in the hackathons reviewed were exclusively

low-tech. While low-tech solutions have advantages (simpler development, and ease of implementation), high-tech solutions may also address daily living challenges proposed by co-designers. Several teams reflected on future consideration and development of high-tech options in their wrap event presentations. The brief duration of the AT Hackathon and skill set of participants may be obstacles that prevented design and implementation of high-tech solutions. Event co-chairs may consider extending the length of the event and targeting participant and mentor recruitment to facilitate consideration and design of both low-tech and high-tech solutions.

Future studies should focus on improved participation rates and may enhance statistical analysis by scaling to include a larger number of overall participants, as well as use an improved data collection method that can support pairing of samples and tracking of IP addresses to enhance the strength of the outcomes. Further, additional qualitative data collection methods, such as focus groups or semi-structured interviews, may gather a deeper reflection on experience.

This current inquiry sought to understand the impression and perspective of community members with disabilities who volunteered to participate in an interprofessional AT Hackathon. Analysis suggests that volunteer community members had an overall positive experience by participating in this weeklong event with a dual focus on service and education of individuals in the health profession and design fields.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. The authors declare no non-financial disclosures. The authors acknowledge funding from nonprofit organization Cecropia Strong for the purchase of raw materials, design supplies, and team awards. The authors acknowledge Kathleen D. Lyons, OT, ScD for expertise and consultation on qualitative content analysis.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 38-56
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from Academia

Participatory Design in Action: Creating a Scalable Keyboard for Communication

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Abstract

The project demonstrates an inclusive, participatory design approach to the development of a keyboard simulation for augmentative and alternative communication (AAC). Centering the lived experience of an adult who uses AAC, the team engaged in field study, design workshops, and iterative prototyping using open-source tools. The resulting keyboard adapts to different physical positions and access methods to improve communication across online and in-person contexts. The project leveraged the open-source design and programmer interface (OS-DPI) and GitHub to support team collaboration, rapid feedback, and hands-on exploration. Findings highlight the importance of early and continued involvement of those who use AAC technology in the design process, and the potential for open-source platforms to support inclusive access to participate by a broad range of stakeholders.

Keywords: AAC, inclusive design, participatory design, open-source software

Participatory Design in Action: Creating a Scalable Keyboard for Communication

People who cannot rely on speech alone to be heard and understood often use or may benefit from augmentative and alternative communication (AAC) technologies. AAC designs are primarily developed by mainstream and AAC-specific commercial companies (Higginbotham et al., 2009; Light et al., 2025). Design teams are often led by software programmers and user experience designers, in consultation with practitioners, such as speech-language pathologists, most of whom do not have lived experiences using the technology to support their own communication. Similarly, research studies focused on the design of AAC systems are typically conducted by teams affiliated with engineering and computer science departments (Tönsing et al., 2024). People who use AAC may be enlisted to trial technologies and test new designs to provide feedback, but they are rarely engaged in repeated cycles of early design and prototyping (Kudryashov, 2021; Tönsing et al., 2024). Lack of representation of people who use AAC, early and often in the design process, risks the development of products that fall short of meeting the needs of individual users (Blasko, 2025; Regan, 2025). In response to this lack of representation there has been an increasing call for inclusive and participatory design processes in the field of AAC generally (Blasko et al., 2025; Williams, 2025) and the development of AAC systems specifically (Pullin et al., 2017; Williams & Holyfield, 2025; Zisk, 2025).

Participatory design involves designers working together with the people who use a tool or technology in their everyday lives, to accomplish a shared goal (Bødker et al., 2022). There is a clear call for AAC designers to leverage participatory design practices and make an important shift from designing for, to designing with, people who have lived experience using AAC (see Blasko et al., 2025; Kudryashov, 2021; Pullin et al., 2017; Tönsing et al., 2024). Leading voices among those who cannot rely on speech alone to be heard and understood are calling for opportunities to drive design discussions and for design teams to engage in the collaborative work and mutual learning required to build deeper understanding of accessibility requirements and design priorities (Pullin et al., 2025; Waller, 2021; Zimmerman, 2025). Taking a more inclusive, participatory perspective involves implementing design practices that empower individuals who use the various tools and technology for communication to be active contributors across all stages of research, design, development, and testing (Treviranus, 2018; Zisk, 2025). While the call to action and the potential benefits to the field of AAC are clear, there is a need for increased guidance and examples of how to effectively organize AAC design teams and approach shared projects in ways that reflect participatory design principles and activities (Frisch & Vertanen, 2025).

The current project offers an example of one team's approach to the participatory design of a scalable keyboard simulation aimed at augmenting communication across in-person and online interactions while the user of the design was in different physical positions and using two distinct access methods. Consistent with the idea that both the design outcome and the learning process are legitimate end goals for participatory design projects (Bødker et al., 2022), the current project had two goals: First, to take a participatory design approach to the creation of a keyboard simulation for AAC; and second, to evaluate the fit of available open-source tools for supporting the participatory design approach.

Participatory Design

Participatory design involves teams engaging in mutual learning, collaboration, and reflection while working toward their intended goal (Bødker et al., 2022; Frisch & Vertanen, 2025; Simonsen & Robertson, 2012). Mutual learning is an organizing principle of participatory design, with researchers and designers learning from those who use the targeted tools and technology in their everyday life and end users learning from researchers and designers about new and promising options (Kensing & Greenbaum, 2013). Participatory design has reported benefits including improved alignment with user needs, increased adoption rates, increased innovation, and more equitable solutions (Wacnik et al., 2025).

Participatory design projects often involve (a) *field studies* to understand real-life situations, (b) *design workshops* to promote mutual learning and collaborative understanding, and (c) *cooperative prototyping* (Bødker et al., 2022; Frisch & Vertanen, 2025). *Field study* work is focused on understanding current practices and strategies across common situations, with sources of data and shared information often in the form of direct observations, interviews and video analysis. In contrast, *design workshops* are future focused. After developing an initial understanding of the current practices and strategies, workshops support teams in deepening their understanding of users' needs by providing a forum for those with lived experience to share their design aims and ideas and for the group to exchange information about relevant options and design alternatives (Simonsen & Robertson, 2012). *Cooperative prototyping* often involves simple mock-ups of design ideas and working simulations. Specific to participatory design, the prototyping process and hands-on experience with working examples of design ideas should be fully accessible to all members of the team, and prototypes should be easily modifiable (Bødker et al., 2022).

Open-Source Software

Open-source software refers to computer software with a source code that is available without restrictions. Open-source software is freely modifiable, and users can run the software for any purpose, including to study and modify it (Fortunato & Galassi, 2021). Unlike commercial software that has limitations for collaboration given major restrictions on use and goals of keeping control within a single group (Anand et al., 2018), open-source software development typically relies on virtual communities of users who contribute to the source code in ways that fit their own needs, while simultaneously benefiting as others share their innovations (von Hippel, 2001). Design teams using open-source software are often made up of programmers, manufacturers, and end-users. Importantly, open-source software tends to be sustained by teams and members who are intrinsically motivated (Lakhani & von Hippel, 2003; Liu et al., 2017) and invested in the potential of the open-source tools to contribute to both the social good as well as their specific objectives (Steinmacher et al., 2019).

Open-source models support innovation through collaboration among stakeholders, particularly in the early stages of design work (Ebert, 2007). Examples of how open-source software has been used to develop a variety of assistive technology tools include screen readers (Gaal et al., 2008), mobility navigation systems (Pereira et al., 2015), prosthetics (Niezen et al., 2016), and AAC

applications (Benson-Goldberg et al., 2023; OpenAAC, 2020). Open-source software and tools offer potential for creating and adjusting AAC designs in unique ways and supporting the transfer of technology between research and future products (Higginbotham et al., 2009). Designing communication solutions for unexpected situations and use cases, sometimes referred to as edge cases, is challenging for commercial AAC companies. Edge cases are the relatively rare uses that challenge the flexibility of a design and underlying code. Flexibility in design that accommodates the unexpected uses can make or break the experience for an edge case end-user (Birajdar, 2025). Open-source software provides the necessary flexibility to explore designs for edge cases, as exemplified in the current project, with resulting designs available for use by commercial companies interested in meeting the requirements of a wide range of users and avoiding costly redoes in their proprietary products. Importantly, we posit that open-source software, and the communities that sustain them, offer prime conditions for engaging in the types of inclusive, participatory projects that are being called for and likely to improve existing AAC solutions.

Open-Source Design and Programmer Interface

The participatory design project falls within a larger effort called Project Open. Project Open (https://project-openaac.com/) is aimed at (a) improving in-person expressive communication for individuals who use AAC and (b) enabling a diverse community of stakeholders to design and test AAC user interface (UI) simulations. These UI simulations are developed using a set of open source design tools, called the Open-Source Design and Programmer Interface (OS-DPI), which is situated for use within a public design community on GitHub (2025), called the Project Open Design Community (see https://github.com/UNC-Project-Open-AAC/OS-DPI/wiki). The collective purpose of the OS-DPI and the Project Open Design Community is to promote collaboration among designers who come from a wide range of backgrounds and levels of technical experience. The GitHub environment supports this goal by offering a wiki for sharing field-based insights, examples, and documentation; a discussion forum where participants can exchange ideas from real-world practice; and tools for uploading sketches or conceptual mock-ups that others in the community can help translate into functional simulations. GitHub provides important accessibility options, including support for adding text descriptions to images and customizing the keyboard commands used to access content within GitHub itself. The OS-DPI uses Google's Chrome progressive web application and operates across a variety of other commercial web browsers and a full range of computers and mobile technologies.

Target Audience and Relevance

This work is intended to reach several audiences, including a broad range of stakeholders involved in the design, development, dissemination, and use of AAC technologies. We would like to bring inclusive, participatory design practices to the attention of all those involved in the design and development of AAC systems, including researchers and industry professionals. This paper offers one example of the kinds of inclusive practices that are necessary to meet the call from AAC users for "nothing about us without us" (Blasko et al., 2025, p. 184) approaches to design. We also intend to promote more active involvement of stakeholders without backgrounds in computer science or

engineering, including those with lived experience using AAC, as well as a range of others including caregivers, allied health professionals, and educators, through an illustration of some of the ways they might engage in AAC design. The information provided in this paper is highly relevant to the current discussion in the community about how technologies are designed, developed, and disseminated, and whose voices are included throughout the process. The contents provide an example of one approach to participatory design and the open-source tools for developing prototypes used by our team. Importantly, the open-source platform has been designed to facilitate use by those without computer science or engineering backgrounds. Our hope is that these efforts continue the trend of democratizing the design, development and dissemination of AAC systems that has been noted elsewhere (see Tönsing et al., 2024).

Method

We applied the main activities involved in participatory design, including field study, a series of design workshops to promote mutual learning, and prototyping (Frisch & Vertanen, 2025). This manuscript represents the perspectives of the authors, and the work reported herein was not subject to IRB oversight.

Design Team

The first and third authors have backgrounds in speech-language pathology and AAC research, design and intervention. They both use their physiological voices to communicate and neither has a disability. The second author, Patrick, has used a variety of speech-generating devices (SGDs) for 29 years. He has a neuromuscular condition called Spinal Muscular Atrophy or SMA. Additionally, the lead developer of the OS-DPI, who has a background in computer science and does not have a disability, also participated in some of the early design sessions and provided technical and troubleshooting support for prototype development throughout the project.

Participatory Design Activities

Our approach to field study involved the team engaging in analytic review and discussion of video depicting the use of various AAC user interfaces across different settings and physical positions. After multiple viewings of videos, email exchanges and follow-up discussions via Zoom, our team established an initial shared understanding of the challenges and set a design goal to pursue together based on Patrick's noted access priorities and the feasibility of exploring novel ideas with the OS-DPI. With our goal set to explore keyboard options that address different physical positions and access methods to improve communication across online and in-person contexts, we engaged in a series of design workshops.

As part of our workshopping, we created sketches of initial keyboard ideas using Excalidraw (2023). Sketches were shared on a project discussion forum on GitHub for asynchronous review and discussion and over Zoom for real-time review and discussion. The sketches supported team review

and refinement of various aspects of the desired design, including the scale and portion of the overall screen real estate to be dedicated to the keyboard. In conjunction with the use of sketches, we engaged in cooperative prototyping to provide working simulations for hands-on exploration and to promote the exchange of ideas for design alternatives.

Framework for Replication

Our participatory design followed a replicable sequence of activities that supported mutual learning and iterative refinement. We began with field study, observing current AAC use across physical positions and access methods to understand constraints and clarify goals. These observations informed a series of design workshops in which the team collaboratively defined aims and sketched alternative solutions. Building on these shared understandings, the team engaged in cooperative prototyping to create simulations that allowed all team members to explore design ideas. Prototypes were iteratively refined based on feedback. Finally, we conducted feasibility and translation planning to determine which aspects of the envisioned design could be achieved within the open-source environment and which would require additional engineering, integration work, or future development resources beyond the capabilities of the current open-source tools. See Table 1 for a brief summary.

Table 1: *Participatory Design Framework*

Activity	Description
Field Study	Observe current AAC use across positions and access methods; identify constraints and establish shared design goals.
Co-Design Workshops	Translate observations into design aims; sketch alternative solutions.
Cooperative Prototyping	Build accessible simulations that allow hands-on exploration by all team members, including the AAC user.
Iterative Feedback & Refinement	Update prototypes based on user feedback; document design decisions and rationales.
Feasibility & Translation Planning	Identify development needs that exceed the open-source toolset; plan pathways for integration, evaluation, and future development.

Results

This section presents key insights gathered throughout the participatory design process, including field study, design workshops, and iterative prototyping. It also includes an evaluation of how well the open-source tools supported the project goals.

Field Study

The field study meetings happened from May through December of 2022. During our initial meetings, as we worked to understand the context and shape a collaborative project, Patrick described his work with several groups of adults with disabilities, the responsibilities of his role, and the range of apps and software, beyond his AAC system, that he relies on to effectively lead, participate, and carry out his day-to-day work.

Position-Dependent Access Challenges

Due to his SMA, Patrick lives with positioning challenges that affect both the position of his body and subsequently the position and method of access to his SGD. He explained that his positioning changes are also dictated by the tasks he needs to complete while also using his text-to-speech software. He shared with the team that SMA makes it difficult to move his body against gravity. If he is sitting up, he cannot lean forward to see his SGD if it is sitting on his lap or tray. And he cannot reach out his arm against gravity. So, he uses eye gaze to access his SGD. He explained that when he is in virtual meetings, working on documents or making presentations, he needs to be able to control the software or applications for those tasks, in addition to his speech software. He also described various physical constraints, including not being able to turn his head much or move back and forth between his SGD and a separate computer, which consequently requires him to run all software on a single screen. Patrick described and demonstrated the ways his various positioning and access methods impacted his ability to navigate between AAC software opened on his computer screen and other software that he also had opened and in use, especially in the context of hosting Zoom meetings. When seated, he uses eye gaze but cannot calibrate gaze to a single side of the screen. He demonstrated that because of this limitation of his eye-gaze system, he was more successful alternating between the AAC software and other software using on a split screen, from a lying down position and using a trackball.

Additional details were provided about his positioning, noting that he is only able to access is computer lying down on his left side to use a trackball. In that position he accesses his AAC software on one side of his computer screen, and various other software programs such as Teams, Zoom, and PowerPoint on the other side. He described that in this position he has control over other apps, along with his AAC software. See Figure 1 for pictures of positions and access methods Patrick shared with the team as part of our field study work.

Figure 1: *Positions and Access Methods Used by Patrick*

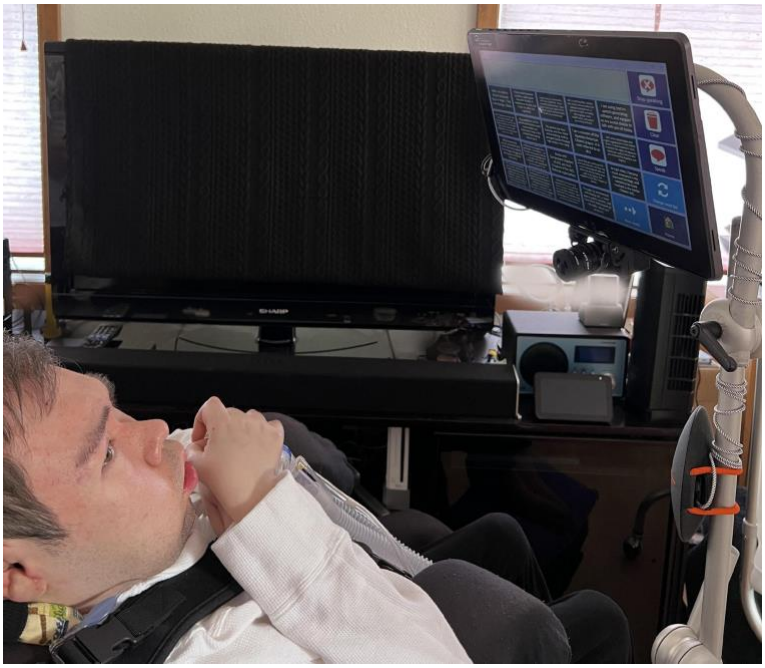
Panel A

Trackball access while lying on left side.

Panel B

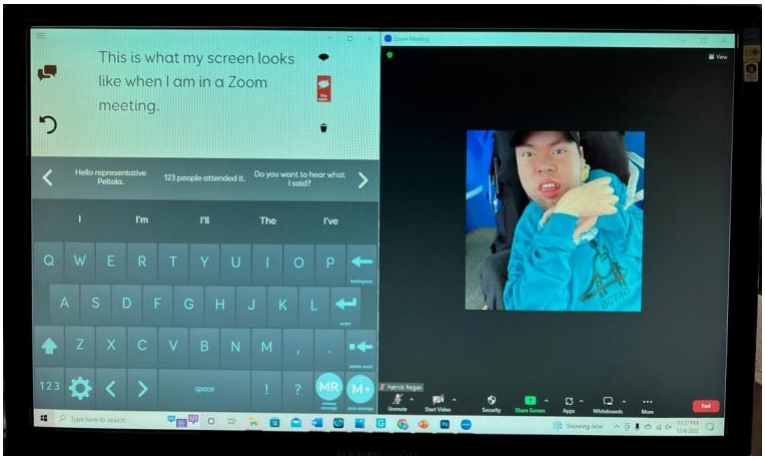
Side-lying body position and rotated monitor for trackball access.

Panel C



Seated posture for eye-gaze access.

Panel D



Screen view showing AAC software and Zoom during trackball access.

Fine Motor and Gaze Selection Demands

Patrick shared that over time his hands have become tighter and weaker, resulting in the need to use the knuckle of his index finger to move the trackball, and the knuckle of his thumb to activate. He described the zigzag motion with the cursor as he navigates the keyboard using his trackball and explained that it would be helpful for the keyboard to be smaller when using this access method. Patrick also described his use of eye gaze when he is sitting up and the benefits of a larger keyboard making it easier to focus his gaze on the buttons that he wants to activate and thus reducing miss-hits. He uses dwell to select, fixing his eyes on the button that he wants to select and holding his gaze until it activates.

We also engaged in detailed discussion and review of a demonstration video about the reasons that a smaller keyboard works when he is lying down, compared to a larger keyboard that would require him to move the cursor back and forth across the entire screen. Patrick further described that while it is easier and faster to use the AAC software when it is reduced to half of the screen compared to full screen, he is even faster using the Microsoft on-screen keyboard (MS OSK) which allows for additional size reduction. During our initial meetings, he described how much faster he can type on the MS OSK and then followed up with video demonstrations for review by the team. He described his technique to resize the MS OSK by dragging one corner of it to reduce the distance he needs to move the cursor across it when using his trackball. He also shared the ease of moving the MS OSK to different places on his screen.

Through our field study work together we gained mutual understanding about Patrick's choice to use distinct access methods depending on his physical position, the contextual demands, his roles in-person and online, anticipated interactions with others, and the technical limitations and barriers in these different meeting spaces. The team gained a shared understanding of the barriers to moving or clicking on buttons of the trackball when seated and the barriers to using eye gaze to control the AAC software on only one side of his screen, since eye gaze cannot be calibrated to just one side. The team discussed the possible use of his SGD to navigate his computer screen using the keyboard, but Patrick described that this would be untenable given the need to click on arrow keys

repeatedly to move the cursor on the screen, regardless of access mode (i.e., eye gaze or trackball), plus the fact that he cannot see the computer behind, above, below or beside his SGD and cannot move his head and body to look around it. He further explained that while the MS OSK had the noted advantages, it lacked access to important capabilities found in his AAC software, including quick access to settings for speech rate, volume and voice, navigational options for moving between sentences or paragraphs, and tools for saving and retrieving lists that provide efficient access to preprogrammed sentences and/or quick phrases. Patrick also mentioned a now-obsolete software program, Discover Screen 2.0, which he and his team used more than 20 years ago to create custom, floating keyboards that could be positioned over any application. He noted that he has not found a comparable tool on the current market. Although beyond the scope of this paper, the disappearance of technological features that once played a critical role in the lives of people with disabilities is not uncommon. Open-source tools and participatory design approaches may offer promising avenues for reviving, sustaining, and integrating such essential features into contemporary products.

Patrick described his need to be able to easily and quickly resize an onscreen keyboard when he changes positions and activities, for both improved access and to reduce the amount of energy and strength required to use the keyboard. He discussed his desire to increase his speed and accuracy, as much as possible, without causing too much fatigue or requiring too much strength.

Design Goal

The design goal was a scalable keyboard that could be efficiently adjusted based on positioning and desired access method. Specifically, the design was to provide access to (a) a large, eye-gaze access enabled keyboard filling the bottom two-thirds of the screen for use when in a seated position and (b) a scaled down, trackball enabled comparable keyboard for use when lying down. Further, the goal was for the keyboard to adjust automatically based on the access method being used.

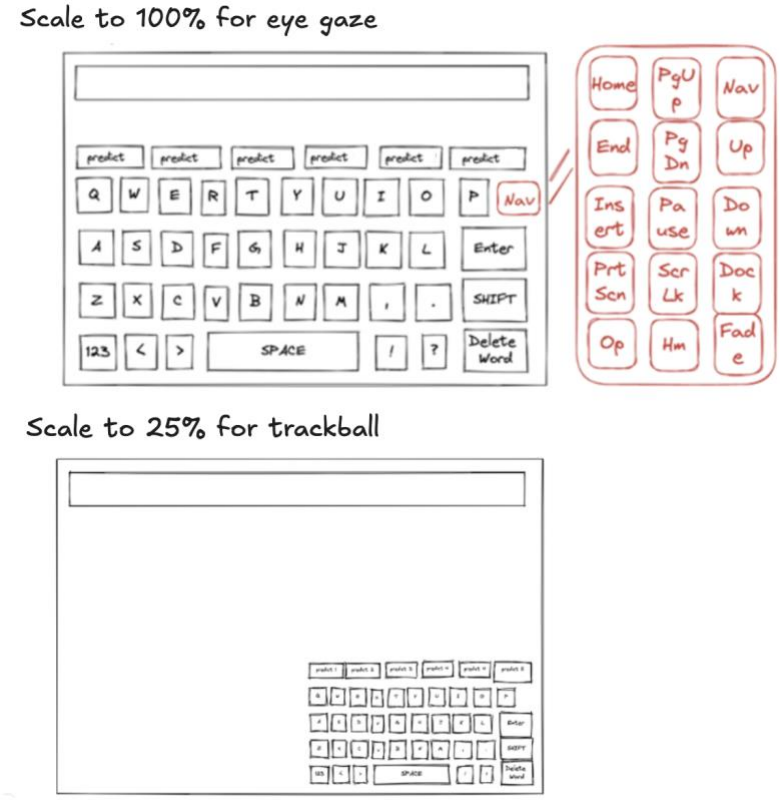
Design Workshops and Prototyping

The team engaged in a series of design workshops, with real-time collaborations happening over Zoom and asynchronous collaborations primarily via GitHub and occasionally email. Design workshops and prototyping happened between December 2022 and December of 2024. After each meeting, the team briefly summarized the design plans in follow-up emails or GitHub discussion forum posts and defined next steps and the targeted timeframe.

The team made use of a free tool called Excalidraw (2023) to sketch out ideas before building working prototypes of various design alternatives in the OS-DPI. See Figure 2 for an example of an initial design sketch. Once it was agreed that this illustrated the intended solution, the first and third authors began designing a series of prototypes in the OS-DPI. Designs were demonstrated to Patrick over Zoom for his feedback during the initial development stages. Simultaneously, designs were posted to GitHub for Patrick to access independently. This iterative process allowed us to continue

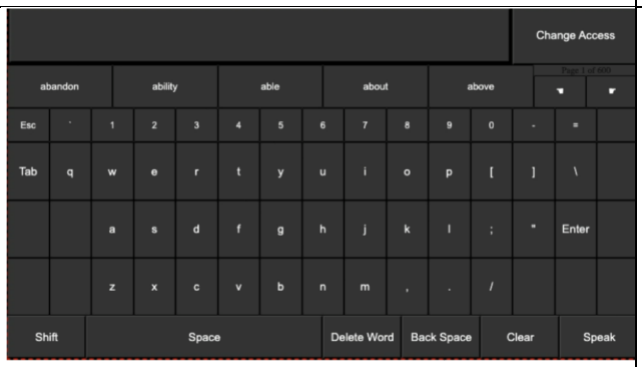
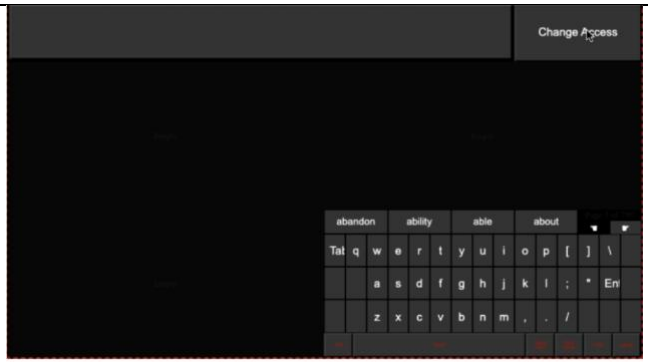
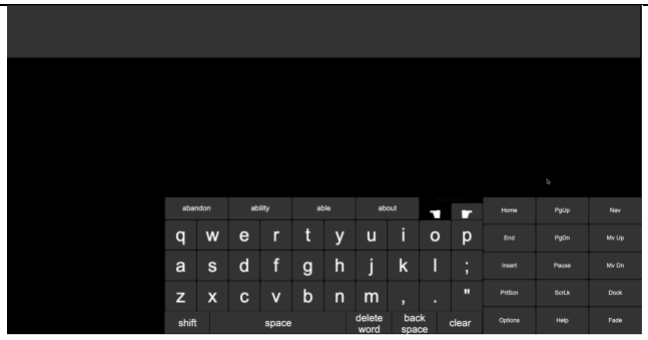
to understand Patrick's needs and respond to his feedback. See Table 2 for examples of prototypes throughout the development process. Important development findings included the need to emulate changing access methods without selecting a button on the screen. This was intended to emulate an automatic scale change based on the software recognizing which access method was being used. In the current simulation (found here: https://go.unc.edu/keysim) users begin in the "small scale" version of the keyboard, intended to be used with trackball or mouse access. To emulate turning on eye tracking, the *t* button is pressed on the external keyboard (i.e., the keyboard attached to the computer). This turns on the front-facing camera and head tracking. Though not the exact method that Patrick uses, the team decided it was sufficiently analogous to demonstrate the intended design principle. When the *t* button is selected, not only is head tracking activated but the keyboard automatically scales to the full screen. To turn off head tracking, and return to the smaller-scale keyboard, one presses the *shift* key and *t* simultaneously.

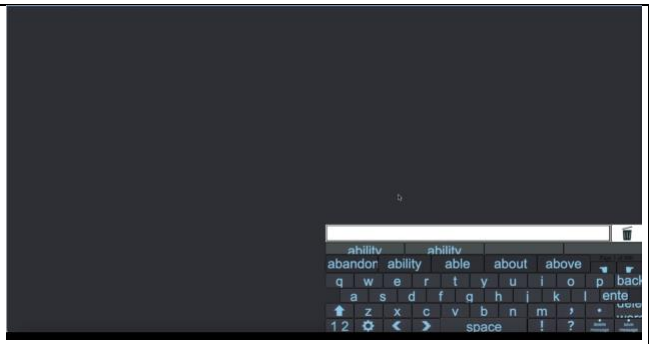
Figure 2: *Initial Sketch in Excalidraw*



Another important finding was that we began our initial sketch with the small-scale keyboard in the lower right-hand quadrant of the screen. This decision was retained throughout the design process while designs were being shared via Zoom. Once Patrick tested the solution himself via GitHub, he noted that it would be helpful to have the ability to reposition the keyboard anywhere on the screen. Likely influenced by lack of firsthand experience using AAC and navigating screens with a disability, the first and third authors failed to consider how placement of the smaller keyboard would affect usability, focusing instead on demonstrating the functionality of rescaling the keyboard.

Table 2: *Prototype Development*

Prototype of Large Scale Keyboard for Eye-Tracking	Prototype of Small Scale Keyboard for Trackball	Description of Prototype
	NA	Early prototype in OS-DPI that required a manual click to change the access method.
		An early iteration attempting to look visually more like PR's onscreen keyboard, still using button to change access method and scale of the keyboard.
		Iteration simulating simultaneous changing of access method and scale of keyboard. Red dot on the large-scale keyboard represents the mouse during eye-tracking.

		Iteration simulating additional features of existing AAC software
NA		Changes based on GitHub exchanges to include ability to move the small-scale keyboard around on the screen.

In the current prototype, the keyboard can be moved by selecting the gear icon on the bottom row. A new grid pops up that allows the keyboard to be moved left to right and top to bottom. This illustrates the importance of including AAC users early and often and promoting hands-on experience with prototypes. Lastly, a novel feature was added to support moving the cursor in the speech display bar, using the left and right arrows on the bottom row. This allows a user to edit without having to delete portions of the message.

Fit of the Open-Source Tools

The OS-DPI provided the necessary capabilities to create working simulations for hands-on exploration and refinement based on Patrick's feedback and recommendations. Changes to the underlying declarative programming were made primarily by the third author, who then shared the updated prototypes directly after completion via GitHub. GitHub met accessibility requirements for all members of the design team. Upon reflection, all members of the team reported that it was an effective forum to discuss ideas, ask questions, and share and evaluate iterative designs and associated working prototypes. Patrick commented that the responsiveness of the design team to the comments or questions he posed in the forum were so quick that it almost felt as though we were communicating in person, and in real time, with suggested changes to the keyboard shared immediately after they were made.

Feasibility and Translation Planning

The participatory design process also revealed important considerations regarding the feasibility of translating the scalable keyboard from a simulation into a fully deployable keyboard for

use across communication environments. While the OS-DPI environment supported prototyping, hands-on exploration, and iterative refinement, the team identified several development needs that extend beyond the capabilities of the open-source tools used in this project. Specifically, full integration of the scalable keyboard with commonly used applications, such as videoconferencing platforms, productivity software, and commercial AAC programs, requires deeper interaction with operating system-level functions, APIs, and application input frameworks. As a result, the project could not pilot the keyboard in the real-world communication and multitasking environments that motivated many aspects of the design goal. The simulation allowed the team to evaluate usability conceptually and qualitatively, but full-scale testing will require development partnerships, additional technical expertise, or collaboration with a commercial AAC manufacturer. This feasibility analysis underscores the need for collaborative engagement across stakeholder groups to achieve its full translational potential.

Outcomes and Benefits

This project offers a replicable example of participatory design in AAC user-interface development and use of open-source tools to promote inclusive innovation. It serves as both a practical guide and a source of inspiration for researchers, developers, and advocates interested in advancing AAC technologies through collaborative approaches. By showcasing the use of the OS-DPI, the project illustrates how freely available resources can support hands-on exploration, iterative prototyping, and rapid feedback integration from all stakeholders, including individuals with lived AAC experience. Ultimately, the project underscores the transformative potential of participatory design and open-source tools to democratize AAC development, making it more accessible, responsive to real-world needs, and inclusive of voices that have historically been underrepresented.

A primary outcome was the development of a keyboard simulation that aligned closely with Patrick's physical positioning and access method requirements. Direct observations and video clarified team understanding of barriers, such as calibration limitations when using eye gaze on only one side of the screen, fatigue associated with large cursor movements when using a trackball, and the need to manage multiple applications within a single display. These insights shaped a design simulation that would scale depending on access method, resulting in a larger keyboard optimized for eye-gaze accuracy when Patrick is seated, and a smaller version that minimizes cursor travel and physical effort when he is lying down. This design was aimed at both efficiency and ease of use. For example, Patrick demonstrated that when using a smaller keyboard with his trackball, he could type more quickly than with his existing AAC software and with less physical exertion than navigating a full-screen keyboard.

Iterative review of simulations led to features that the design team did not initially anticipate, including the ability to reposition the keyboard anywhere on the screen and the addition of left and right arrow buttons for editing text in the display without deleting entire message segments. These refinements addressed practical challenges that emerged through further discussion of Patrick's lived experience, underscoring the importance of making simulations accessible by AAC users early and often.

Mutual learning was another key outcome and benefit of the participatory process. Patrick's demonstrations and explanations of factors like cursor movement when using a trackball and the limitations of alternating between AAC software and other applications strengthened the team's shared understanding and ultimately improved the design.

The use of open-source tools contributed to the project outcomes. The OS-DPI enabled creation and revision of working prototypes, ensuring that Patrick could interact directly with each version rather than relying on static descriptions. GitHub facilitated accessible, asynchronous collaboration, allowing Patrick to review independently, ask questions, and propose adjustments. He noted the responsiveness of the team within the GitHub platform, describing the turnaround time for updates as nearly equivalent to real-time collaboration. These tools supported an inclusive development process in which all team members, regardless of technical background, could participate meaningfully.

Finally, the project produced a replicable model for inclusive AAC design. The combination of field study, sketching, iterative prototyping, and multiple communication channels (Zoom, GitHub, email) demonstrates a framework that can be adapted by researchers, developers, commercial manufacturers, and community collaborators. The scalable keyboard serves as both a functional simulation and an example of how designing with AAC users can generate innovative solutions that address nuanced, real-world needs, including edge cases that may not be the focus of commercial companies. Together, these outcomes illustrate the transformative potential of participatory design supported by open-source tools. The project yielded a set of tangible outcomes demonstrating the value of participatory design and the utility of open-source tools for AAC user-interface development. By centering Patrick's lived experience and integrating his feedback throughout field study, design workshops, and iterative prototyping, the team produced a scalable keyboard simulation aimed at real-world access demands across varied contexts. The outcomes reflect not only the functionality of the final design, but also the process-level benefits that emerged through collaboration.

Future Directions

The current project team is continuing to collaborate to refine the keyboard simulation discussed in this paper and expand the capabilities to simulate access to various settings, and storage and retrieval of preprogrammed messages, sentences and phrases. Future development work should focus on extending the scalable keyboard beyond the simulation environment to enable full pilot testing in the real-world contexts that motivated its design. However, moving from a simulation to a fully deployable tool will require development work that exceeds what is possible within the open-source tools used in this study. Extending the keyboard beyond the OS-DPI environment and integrating it with commonly used applications will likely require additional software engineering expertise, access to proprietary APIs, and development resources not available within the current OS-DPI platform. Importantly, commercial AAC companies have an opportunity to implement this design within their fully functional products. Such collaborations can accelerate integration and help ensure that inclusive, participatory design practices inform future AAC offerings.

Additionally, the broader project team is promoting access and use of the Project Open Design Community on GitHub to solicit new ideas and design input from a diversity of stakeholders, first and foremost those who use AAC in their everyday lives and have unmet design requirements or ideas. To truly democratize AAC development, the field must actively support individuals with lived experience and those outside traditional engineering roles to participate in AAC design as active contributors and decision makers. This means building capacity to engage in inclusive, participatory design practices, and investing in accessible tools and collaborative platforms that empower diverse voices to shape the future of AAC technologies.

Conclusion

This project demonstrates the potential benefits of participatory design and open-source tools for creating AAC solutions. By centering the lived experiences of an AAC user and leveraging open-source software and collaborative platforms like the OS-DPI and GitHub, the team was able to develop a scalable keyboard simulation that responds to real-world needs across varied contexts and access methods. The approach not only yielded a functional design but also fostered mutual learning and innovation. Adopting participatory design practices alongside open-source tools offers compelling potential for meeting the diverse and dynamic needs of AAC users.

Declarations

This content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. This article was produced under a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90DPCP0007). The views expressed herein do not necessarily represent the positions or policies of NIDILRR, ACL, or HHS. No official endorsement by NIDILRR of any product, commodity, service, or enterprise mentioned in this publication is intended or should be inferred. The first author disclosed two non-financial relationships. She is a member of the Editorial Board for the Assistive Technology Outcomes and Benefits journal and a strand advisor for ATIA.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 57-85
Copyright ATIA 2026 ISSN 1938-7261
Available online: atia.org/atob

Voices from Academia

GOALS: Developing an IDD Employment Support with User-Centered Design

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Abstract

This paper explores the application of user-centered design methods to facilitate the development of the **G**oal **O**riented **A**utomated **L**earning **S**ystem (GOALS). GOALS is an AI-supplemented web-based tool developed to support employees with intellectual and developmental disabilities (IDD) by 1) streamlining how supervisors or job coaches explain new or complex tasks to employees with IDD, and 2) helps employees with IDD better understand these instructions. The design of GOALS is informed by user needs elicited from three focus groups divided by user type: employees with IDD, job coaches, and supervisors. A GOALS prototype was then developed and evaluated via usability testing with five pairs of employees with IDD and their workplace supervisor or job coach. Findings indicate GOALS may be effective in reducing job coach burden while preserving instruction quality when supporting employees with IDD who require high-frequency prompting in workplaces with structured tasks, and highlights the importance of user-centered design.

Keywords: Vocational, assistive technology, job coach, IDD, GOALS, AI, job instruction, task prompting

GOALS: Developing an IDD Employment Support with User-Centered Design

The development of effective technological solutions for individuals with intellectual and developmental disabilities (IDD) is a process that requires user-centered design to properly meet user needs. This approach is necessary to address the unique and diverse needs of individuals with IDD with little to no existing design guidelines as a starting point. For example, in the field of mobile application design, the SMASH (Inostroza et al., 2016) and SMART (Joyce & Lilley, 2014) are design guidelines based on general population users, and are used ubiquitously. For individuals with autism spectrum disorder (ASD) – which can co-occur with IDD – there are population-specific software design guidelines to facilitate mobile application development (Aguiar et al., 2020; Lubas et al., 2014). However, it was not until very recently that any comparable design guidelines for individuals with IDD were alluded to (Huang et al., 2025). As such, the need for involving potential users with IDD in the technology design process is critical (especially with complex products), with approaches such as focus groups to elicit user needs that drive design requirements, or the use of usability testing to iterate and refine product prototypes (Abras et al., 2004; Still & Crane, 2017). This paper explores a practical application of user-centered design for a web-based application that supports employees with IDD (referred to herein as “employees”) in vocational settings and discusses the merits of this user-centered design approach.

According to the U.S. Census Bureau and the Rehabilitation Services Administration, in 2020, there were an estimated 8.38 million people in the U.S. with IDD (Larson et al., 2022). For young adults (21 – 24 year old) among this population, only an estimated 39% are currently employed, although many more want to obtain employment (Newman et al., 2011). In contrast, 66% of non-disabled young adults in the same age range are employed. For many individuals with IDD, meaningful employment is a critical aspect of living a purpose-filled life (Readhead & Owen, 2020). Working provides structure, allows individuals to contribute to society, and builds social networks. Employment is also a unique opportunity for individuals with IDD to integrate into society and work alongside individuals without disabilities.

A primary barrier for individuals with IDD to gain and maintain employment is job coach availability. Ideally, employees would be initially assisted in a new position with a job coach, a labor-intensive process that relies heavily on human interaction. Unfortunately, there are simply not enough job coaches to actively support even half of all employees in meaningful employment in jobs. A critically important role in job coaching is task analysis (Brock et al., 2016; Wenzel IV et al., 2022), involving the breakdown of complex tasks into smaller, manageable steps which are easier for people with IDD to independently learn and follow, while supplementing with images and other instruction modalities. Employers are not able to fill this void. With the job coach shortage, researchers have recently considered the benefits of adaptive learning systems in this domain. Within the context of the IDD population, an adaptive learning system (ALS) refers to a system that utilizes technology, such as artificial intelligence, to facilitate personalized and adaptive learning experiences. These systems are designed to cater to the unique needs and abilities of each learner,

offering customized content, pacing, and feedback on task performance (Habib et al., 2022; Standen et al., 2020).

This paper focuses on the implementation of user-centered research methods to inform and assess the design of the **G**oal **O**riented **A**utomated **L**earning **S**ystem (GOALS). GOALS is a web-based tool developed by CreateAbility, Inc. (Indianapolis, IN) that 1) streamlines how employers/job coaches explain new or complex tasks to employees with intellectual disabilities, and 2) helps employees better understand these instructions. Applied user-centered research methods involved three stakeholder groups: employees, job coaches, and supervisors. Specifically, focus groups served as early-stage user research to inform the design for GOALS, and guidance-supplemented usability testing was used to determine the usability, efficacy, and feasibility of the GOALS relative to existing practices for supervisors/job coaches to communicate task instructions to employees.

Target Audience and Relevance

The intended audience for this paper includes both professionals in academia and industry. This paper demonstrates the importance of supporting product development with user-centered research methods, particularly when exploring the application of novel technology for individuals with intellectual and developmental disabilities (IDD). The product examined, GOALS, explores the utility and feasibility of AI-enhanced technologies that assist those with IDD. The importance of user-centered design practices is highlighted by the diverse GOALS design considerations and GOALS usability issues elicited by focus groups and usability testing in this study, respectively.

Methods

Two different user-centered research methods were employed in the development of the GOALS:

1. Focus groups – conducted to determine stakeholder background, needs, and their feedback on the GOALS as a concept. Findings used to inform the development of the GOALS prototype.
2. Usability testing – conducted to determine user satisfaction and usability of the GOALS prototype. Compiled usability issues for refining the GOALS prototype in future work.

Focus Groups

A total of three distinct focus groups were conducted, with one for each of the stakeholder groups described in Table 1. At this stage, participants were only exposed to the GOALS conceptually via a PowerPoint presentation.

Table 1: *Target Participant Eligibility and Sample Sizes – Focus Groups*

User Group	Eligibility Requirements	Sample
Employees with IDD (ED)	-Previous employed and actively seeking employment OR -Currently employed	5
Job coach OR support staff (JC)	- Currently working with employees with IDD - Affiliated with a participating ED (if possible)	4
Supervisors OR employers (SP)	- Currently working with employees with IDD - Affiliated with a participating ED (if possible)	3

Research Questions

Focus group questions *(full list available from the authors upon request)* were tailored according to the participants' respective roles, with the goal of answering the following research questions:

- How do supervisors and job coaches currently provide task instructions to employees, and what are the associated challenges?
- How do employees currently receive and interpret task instructions at work, and what are the associated challenges?
- How are these challenges different in situations involving a new supervisor, job coach, and/or employee?
- How is the proposed GOALS approach perceived? What do the different user groups expect to be helpful or barriers?
- What should be changed to the GOALS prototype to potentially make it more effective?

Participant Experience and Background

Table 2 describes the employees with IDD (ED) participants' work experience and background. Of the employees, participant ED4 was a participant with lower support needs who was self-employed and previously worked as a manager. ED2 was the only participant not currently employed, although they were actively job seeking. A majority of the employees have an employment history involving positions responsible for cleaning and organizational tasks.

Table 2: *Work Experience and Background – Employees with Intellectual Disabilities (ED)*

Participant	Employment History	Position(s)	Average Total Hours (per week)
ED1	Current – Health club [11 months] Previous – Fitness center, different locations [1.5 and 9 years]	Current – Housekeeping (stocking, cleaning) Previous – Custodial	11.5
ED2	Current – Unemployed Previous – Package delivery service	Previous – Mail and packaging	9-12
ED3	Current – thrift store [8 years], library volunteer [1 year]	Current – Production (unloading/sorting)	8 (working), 2 (volunteering)
ED4	Current – Self-employed landscaper [6 months] Previous – Fast food chain [1 year]	Current – Freelance Previous – Manager	30
ED5	Current – Assisted living center [10 months] Previous – Middle school [2 years]	Current – Host/Server Previous – Room Assistant	34

Table 3 describes the job coach (JC) participants' work experience and background. All three participants of the job coach focus group were employed by the same IDD support center. Each fulfilled roles beyond being a job coach, such as JC1 being a program director. Based on an estimation provided by JC1, a more typical full-time job coach would have 4 to 6 cases across multiple employment sites, although they might also work other roles (e.g., at the day program) to fill sufficient hours. Some employment sites have multiple clients (employees), such as King Soopers, FedEx, and coffee shops.

Table 3*: Work Experience and Background – Job Coaches (JC)*

Participant	Employment History	Number of cases/clients	Additional Roles
JC1	Current – IDD support center Previous – Educator	Up to 3	Program Director
JC2	Current – IDD support center Previous – Business and Volunteerism	9 to 10	Job Coach Manager
JC3	Current – IDD support center Previous – Speech Pathologist	~4	Benefits Counselor

Table 4 describes the supervisor (SP) participants' work experience and background. One of the four participants in the focus group for supervisors turned out to be a job coach for a community center board (CCB). SP4 was still retained for this focus group, and he offered his observations of supervisors at thrift stores and other job sites. SP3 was a supervisor at a recycling business built around disability employment, managing 28 employees with IDD. Participants SP1 and SP2 were supervisors at businesses with a few employees with IDD.

Table 4: *Work Experience and Background – Supervisors/Employers (SP)*

Participant	Employer	Employment Length (years)	Position	Number of employees w/ ID	Number of employees w/o ID
SP1	Preschool & kindergarten	19	Director of Schools	4	55
SP2	Health club	1.5	Executive Director	2*	85
SP3	Recycling center	7	Operations Manager	28	7
SP4	Community centered board	1	Job Coach	12	N/A

** One was a volunteer*

Study Design

All focus groups were conducted in person and in accordance with approved research protocol COMIRB#11-0674, including consenting and distribution of gift card incentives under approved research protocol. Pre-consenting by phone was also performed to expedite in-person consenting by addressing participant and researcher questions in advance. Focus groups were conducted in person at a local community-centered board (Stepping Stone Support Center), to best facilitate convenient access for participants because the majority resided or were employed in neighboring areas. A room equipped with one large table, eight chairs, Wifi, and a TV was used for the focus groups. The table was set up with a 360° view webcam (OWL Labs), an upright USB microphone (Blue Yeti), and two laptops – one for primary recording and one for backup recording and notetaking. The primary recording laptop hosted a Zoom meeting that the backup laptop joined, and a cloud and local recording were saved by each laptop, respectively. Note that CU's Enterprise Zoom recordings are HIPAA-compliant, per CU's Office of Information Technology.

One moderator and one observer were present for each focus group. The moderator was responsible for communicating the focus group questions and GOALS presentation, managing the focus group discussion scope and duration, and asking follow-up or clarifying questions if/when necessary. The observer was responsible for monitoring the recorded Zoom meeting (e.g., verifying participant audio is active) and taking notes on discussion themes of interest.

Focus groups were moderated to a target duration of 120 minutes (Table 5), and were preceded by 1-on-1 participant consenting and intake, including 1) administering consent forms (and assent forms if the participants were not their own legally authorized representative or LAR), 2) administering an optional photo/video release, and 3) administering a demographics form. Upon completion, participants were seated collectively at a table set up with video and audio recording equipment. To begin, the moderator provided a brief summary of the objectives for the focus group, followed by a series of short-answer questions to help determine each participant's unique on-the-job experience and perceptions. These initial questions helped verify the existing gap and user needs. After a short break, participants were shown a brief presentation of the GOALS concept and its prospective features, followed by a series of questions for group discussion on the pros/cons of the GOALS concept. These group discussion questions were intended to collect feedback on the GOALS as presented and identify any specific design and implementation requirements for each user group. During the employee focus group, if employee participants had difficulty providing feedback or sustaining discussion, their Legally Authorized Representatives (LARs) were present to facilitate responses or clarifying contexts. Sessions closed with the disbursement of participant incentives ($50 VISA gift cards).

Table 5: *Focus Group Session Schedule*

Activity	Duration	Format
Consenting + Photo Release	10 min	Individual
Demographics Form	10 min	Individual
Focus Group Overview	5 min	Group
Short-answer Questions	30 min	Group
Participant Break Time	10 min	N/A
GOALS Concept Presentation	10 min	Group
Discussion Questions	45 min	Group
VISA Gift Card Distribution ($50)	N/A	Individual

Data collection involved a demographic form that was administered to all participants, including self-reported functional impairments by the employee. Other raw data collection took place via observer notes on a spreadsheet (organized by focus group question and participant) and the Zoom cloud recording using the Blue Yeti mic audio and OWL conference camera video. Automated transcription of cloud recording audio was conducted via Zoom. Additional native Zoom features were used to edit the transcripts via synchronized playback of the audio and auto-transcribed text.

Data analysis of the focus groups involved using the observer notes as the primary source of data, supported by information and quotes from the reviewed transcripts. This analysis was conducted via a two-person discussion of the observer notes while reviewing the focus group transcripts. Coding of this qualitative data was performed independently by two reviewers, as was the subsequent thematic analysis. Differences in codes and resultant themes between reviewers were resolved via discussion to achieve consensus. The primary output was the participants' background and experiences, and the themes and design feedback relevant to the research questions. These findings were compiled in a report to provide the developers at CreateAbility

actionable recommendations to revise and refine the design of the GOALS prototype.

Usability Testing

A total of 5 usability testing sessions were conducted, with the stakeholder sample sizes described in Table 6. Sessions were conducted with one ED paired with their corresponding job coach (JC) or workplace supervisor (SP). At this stage, participants were interacting with the GOALS prototype (described in Results) developed with input from the earlier focus group findings.

Table 6: *Target Participant Eligibility and Sample Sizes – Usability Testing*

User Group	Eligibility Requirements	Sample
Employees with ID (ED)	-Previous employed and actively seeking employment OR -Currently employed	5
Job coach OR support staff (JC)	- Currently working with employees with ID - (Preferred) Affiliated with participating ED	3
Supervisors OR employers (SP)	- Currently working with employees with ID - (Preferred) Affiliated with participating ED	2

Research Questions

Usability testing sessions were conducted to evaluate the GOALS prototype by answering the following research questions:

- Does GOALS provide an improvement in ease and efficacy compared to the standard practices in:

a. assessing employee skills (soft and hard/technical)?

b. creating text-based steps in task instructions?

c. adding images to supplement task steps?

- What about GOALS should be changed or improved?

Participant Characteristics

Tables 7 and 8 summarize the characteristics of the usability testing participants. Note that a different set of participants were recruited, so the participant designations (ED#) do not correspond to that of the focus group participants. Employee participants (Table 7) had held their current jobs for 2 months to 7 years, in roles ranging from teaching assistant to cook. All received workplace instructions verbally (some with additional supplements) and most noted satisfaction with their instruction format but desired some improvements by adding a different instruction modality. Job coach or supervisor (JC/SP, herein referred to as coach/super) participants (Table 8), had held their current jobs for 7 months to 19 years, in roles ranging from preschool director to job coach. Most

provided workplace instructions customized to the employee's needs, with evaluations to determine the employee's comprehension. Three coach/super participants had concerns regarding their instruction format, ranging from lack of consistent instruction by other job coaches or supervisors and insufficient employee family support with task prompting apps like Avail. Coach/super participants also noted a very diverse time needed for employees to learn how to do new job tasks independently, ranging from 30 minutes to 24 total hours, depending on the employee; sometimes, the employee could never achieve independence.

Table 7: *Current Employer & Role, and Workplace Instruction Format & Satisfaction – Employees with IDD (ED)*

Participant	Current Employer	Position [Tasks]	Workplace Instructions	Instruction Satisfaction
ED1	High school [4 years]	Janitor [trash, window washing, surface sanitation]	Verbal, demonstration (if needed)	Helpful, but wants audio-recorded (vision impaired)
ED2	Preschool [6 months]	Teaching assistant [clean table, help kids, serving and clearing lunch, filling water bottles]	Verbal	Helpful, but has issues with fast speech; a written manual is in prep
ED3	Inclusive thrift store [7 years]	Production [tagging/pulling inventory, pairing shoes]	Verbal, demonstration	Demonstration helps retention; verbal reminders are helpful
ED4	Pharmacy [2 months]	Stocker [stock shelves, sweep, bagging]	Verbal, demonstration	No complaints
ED5	Inclusive coffee shop [6 months]	Cook [makes burritos]	Verbal, demonstration	Demonstration most helpful

Table 8: *Current Employer & Role, Workplace Instruction Format & Satisfaction – Job Coach or Supervisor (JC/SP)*

Participant	Current Employer	Position [Tasks]	Workplace Instructions	Instruction Satisfaction
JC/SP1	IDD support center [3 years]	Employment manager and job coach [assigning coaches, liaising with employers, training]	Need-based: modeling, task lists, charts, recordings	Current method effective because custom; new coaches not consistent
JC/SP2	Preschool [19 years]	Director [manage roles, offer support, liaise monthly with ED's job coach]	Reminders via task picture charts, relies on mentor teachers to support ED	Mentor teachers report ED progress; concerned if mentors can support ED properly
JC/SP3	IDD support center [3 years]	Benefits counselor and job coach [counseling, instructing ED, job development]	Step-by-step checklist, prompting app (Avail)	Hard for their EDs to become independent due to functioning; wants ED family buy-in on Avail
JC/SP4	IDD support center [7 months]	Job coach (former IDD client to center) [provide onsite support and ED plan to independence]	Existing step-by-step text or picture instructions; assesses ED comprehension	Likes pushing ED to independence by building confidence; asks ED to try new tasks alone first
JC/SP5	Inclusive coffee shop [2 years]	Inventory and kitchen staff manager [oversee all kitchen employees and duties]	Verbal explanations, demonstration, evaluation	Found their instructions effective, no changes needed

Study Design

All user testing sessions were conducted in person and in accordance with approved research protocol COMIRB#23-0984, including consenting and distribution of gift card incentives. Pre-consenting was also performed by phone to expedite in-person consenting by addressing participant and researcher questions in advance. Usability testing sessions were conducted in person at the same local community centered board (Stepping Stone Support Center) as the focus groups. Two tables were set up on opposite ends of the large room, one for the coach/super, and one for the employee. The specific equipment for each table and their purpose is described in Table 9.

Table 9: *Equipment Per Table – Job Coach/Supervisor versus Employee with IDD*

Equipment	Purpose	JC/SP	ED
Researcher laptop	Connect to webcam, microphone; note-taking	X	X
External webcam	Record participant activity (primarily "packaging task")	X	X
External microphone	Record participant audio (e.g. remarks, responses)	X	X
GOALS tablet	1) For the JC/SP to access GOALS as a manager and design instructions for the "packaging task" 2) For ED to complete skills assessments; for the ED to view task instructions in a PDF format	X	X
"Packaging task" supplies	Tape, scissors, boxes, bubble wrap, products, and shipping label for "packaging task" completed by ED with GOALS	X	X*
MeMinder phone	For ED to view task instructions via a prompting app, MeMinder		X

**"Packaging task" supplies moved to employee's table for their use*

Each usability testing session was attended by an employee and their corresponding coach/super; each were seated at their respective tables with a test moderator from the research team. Each moderator administered consent and demographic forms, turned on participant recording devices, and introduced the session premise. They were then responsible for administering the usability test, providing task assistance when needed, and taking notes on the participants' activities.

The coach/super was asked to 1) complete a pretest questionnaire to determine their current experience with creating job task instructions; 2) undergo training on GOALS's manager interface via the moderator walking them through the GOALS features of skill assessments and task instruction generation on a tablet; 3) use GOALS to create instructions for the pre-defined job task – packing a product for shipment – for the employee to complete; 4) observe their employee attempting the "packaging task" while following the GOALS-created instructions; 5) complete a posttest questionnaire regarding the ease of using GOALS and what they would change; 6) complete the standardized PSSUQ (Post-Study System Usability Questionnaire) on the usability of GOALS. Note that the coach/super participants were provided the final sealed-and-labeled package for the "packaging task," and used it to work backwards (e.g. unsealing the box) to create steps from a starting point where all items were out of the box and the box was open. The coach/super could also self-select to supplement the text instructions with photos they captured with the GOALS tablet camera or generate AI images via text prompting. *(Full testing materials, including training procedures and questionnaires are available from the authors upon request).*

Simultaneously, the employee was asked to 1) complete a pretest questionnaire to determine their current experience with receiving job task instructions; 2) use a tablet to complete skill assessments via GOALS; 3) attempt the "packaging task" by following the GOALS-created

instructions from the coach/super; 4) complete a posttest questionnaire regarding the ease of using GOALS and the instructions created via GOALS, and what they would change; 5) complete the standardized PSSUQ (Post-Study System Usability Questionnaire) on the usability of GOALS. Note that the employee could self-select to use the GOALS-created task instructions in PDF format on their GOALS tablet, or via the MeMinder prompting app on a smartphone, or a combination of both.

Data collection involved the aforementioned pre- and posttest questionnaires (including PSSUQ), as well as recordings and researcher notes of participant activity. Video and audio recordings were captured at both the coach/super's and employee's tables via the two researcher laptops and their external mics and webcams. Additionally, the research laptops also recorded the local participants' device screen(s) (e.g. GOALS tablet for the coach/super) synchronously. This was achieved by hosting a Zoom meeting on the research laptop, adding the local participant devices to the meeting, turning on the devices' screen share, and recording the Zoom meeting. The same research laptops were also used by the moderators to record session data/notes in spreadsheet templates, e.g., any comments participants made during testing. Additionally, mistakes by coach/super participants after training and involving GOALS (or MeMinder) were classified as use errors.

Data analysis consisted of user performance and user preference with GOALS. Given the early-stage GOALS prototype, usability testing was exploratory and involved substantial guidance and training for participants. Correspondingly, there was little performance data collected regarding the usability of the GOALS web-based interface beyond observed coach/super use errors in creating instructions for the "packaging task" after training was provided. The "performance" of the employee in completing job tasks based on GOALS-created instructions was used primarily as direct feedback to the coach/super to help them assess their perceived utility of GOALS. The majority of data collection involved preference-based responses in questionnaires. PSSUQ ratings were compiled across participants, and the mean and sample standard deviation were calculated by PSSUQ category averages (system usefulness, information quality, interface quality) and PSSUQ overall averages. To compare the perceived efficacy of coaches/supers creating and employees receiving job task instructions through current practices versus via GOALS, each participant's ratings (of current practices) in their pretest questionnaire were paired with its corresponding rating (of GOALS) in their posttest questionnaire. For employee participants, the ratings compared were for the usefulness of the received "text instructions," "supplemental photos," and "task-prompting app MeMinder," as well as the perceived difficulty of completing the skills assessments. For coach/super participants, the ratings compared were for the ease of creating "text instructions" and "supplemental photos," replicating the instructions in a "task-prompting app," and administering employee skills assessments. The coach/super participants' perceived usefulness ratings for each of the aforementioned activities were also compared, partially based on the coach/super's observation of the employee performing the "packaging task" with their GOALS-created instructions.

Results

Data collected and analyzed for the two different user-centered research methods included:

1. Focus groups – thematic analysis of 3 focus groups, split employees, coaches, supervisors.
2. Usability testing – mixed methods analysis of 5 tests pairing employees and coaches/supervisors.

Focus Groups

Overall, the focus group data collection yielded the most findings from job coaches, followed by supervisors and employees with IDD. For all user groups, the questions associated with recommended changes to GOALS were harder to answer because CreateAbility had not yet developed a working GOALS prototype. Almost all participants cited the need to "play with GOALS" to establish sufficient context to offer feedback on details such as user interface design. As such, design feedback on GOALS was largely centered on desired features rather than details on how features should be implemented. The following subsections summarize the themes associated with each research question.

Themes – Background and Experience

Participants represented diverse roles within each group, revealing variability even within user categories. Though sample sizes were small, the variety helped highlight different needs and priorities. In the employee focus group, participants ranged in independence. ED1, ED4, and ED5 were more self-sufficient, needing minimal coaching, while ED2 and ED3 required consistent job coach support. Most held custodial/organizational roles, working 9–34 hours/week. In the job coach focus group, most participants were not full-time coaches; they balanced coaching with other responsibilities. JC1 focused on training other coaches; JC2 managed coaches; JC3 served as a benefits counselor. They supported 3–10 employees, though 4–6 was typical. All participants in the supervisor focus group had supervisory roles except SP4. SP3 managed a recycling business with 28 ED, who handled most operational tasks. SP1 (preschool) and SP2 (health club) oversaw 2–4 ED doing support tasks. All supervisors expressed interest in hiring more employees, but cited job-matching, availability, and managerial willingness as barriers.

Themes – Instruction Design and Provision

Job coaches typically began with demonstrations, using written lists or pictures. JC1 made customized notebooks (4+ hours), while JC3 used Avail, a DVR-funded prompting app, for faster video/picture-based support. Instructional updates took 30–120 minutes/week per employee. Fading supports started 2–3 months in, aiming for employee independence by 4–6 months. Avail offered efficient updates but wasn't widely used or accepted by employees or their families. Supervisors used verbal, written, and modeling-based instruction. SP1 preferred verbal due to time constraints; SP3 used peer training and written guides. SP2 emphasized adapting to employee preferences. Common challenges included communication, supervision levels, and over-involved parents.

Themes – Instruction Receival and Interpretation

Most of the employee participants cited receiving instructions from supervisors, other coworkers, or clients. ED2 and ED3 were more reliant on job coaches to receive instructions on a day-to-day basis, as well as to keep them on task. Most employees preferred learning new instructions via demonstration, followed by either verbal reminders or written notes (e.g., steps written on the back of their nametag/badge). None of the employees used picture-based instructions, although most indicated they would find them useful if they were available to them; ED5 did store some reference photos (e.g., layouts for table setting) on their phone. Additional supports some employees found helpful were having work "buddies" and (phone) timers to help keep them on task.

Themes – New Employees and Turnover

In the event of being matched with new supervisors or job coaches, employee participants cited that transitions were difficult, with new staff needing time to understand the job requirements and the employee's support needs, as well as to build trust. For ED1, the high turnover of managers at a fitness center was the reason they did not continue working there. According to the job coach participants, there are unique challenges in engaging new employees and new trained job coaches. At the IDD support center, onboarding new employees started with "getting to know you" forms, followed by direct contact with a job coach. New job coaches needed significant ramp-up time — 3 to 4 months to establish basic confidence — with learning tools like Open Future Learning and Quickbase aiding in job coach training. More experienced job coaches could fully understand a new job role for their employee by reviewing documents with supervisor support for 6 hours, as well as 6 hours of shadowing. According to supervisor participants, their primary challenge was assessing if new employees were a good fit for the job, which is often unclear until after a month of employment. Additionally, new supervisors needed to build comfort working with employees.

Themes – Perceptions of GOALS

For the employees, the GOALS approach was reasonably well-received, although the abstraction between the GOALS features presented on slides and the actual GOALS prototype was likely too difficult to elicit comprehensive responses. ED5 liked having a more centralized method of communicating with a job coach, and most EDs thought the clearer GOALS instructions could improve their independence. ED2's father also stated that too much text-based instruction could be detrimental to ED2, who could benefit from GOALS's picture-supplemented instructions based on ED2's history of workplace supports.

For the job coaches, the GOALS approach was received very positively. Interest was expressed in the GOALS skill assessments, particularly for the purposes of job placement. AI-generated steps and pictures were also viewed positively, although this was dependent on how well the AI is expected to perform. Having the option to provide instructions in both a PDF and an export file to a prompting app (e.g., Avail) was of high importance for the job coaches, as many of the employees were not allowed to use their phones at work sites or were too easily distracted by their mobile devices. The job coaches also stated that if GOALS had an interface with good usability, it

could help boost the confidence of newer job coaches who lacked experience with modeling-based instruction or working with employees.

For the supervisors/employers, the GOALS approach was received positively but with some reservations. Specifically, SP1 stated that using AI-generated steps for preschool tasks were not likely to be effective, given that the daily tasks are numerous and less well-defined, with regard to the various relevant contexts (e.g., which kid, their mood, staff presence). SP2 (health club) and SP3 (recycling center) stated that there could be utility of the AI-generated tasks at their employment sites given their more structured daily tasks. However, SP3 also deemed that GOALS would not be useful for their organization, given that they already have effective process, supports, and culture in place due to their majority employment of individuals with IDD. Collectively, all participants approved of the skill assessments (if a parent or job coach was filling it out for the employees), and were interested in using the assessments not only to determine the employee's suitable roles and required supports, but also to determine employment suitability in the first place.

Themes – Desired Changes to GOALS Design

Table 10 illustrates the desired changes or additions to the GOALS and which groups suggested these changes. The table entries are roughly ordered from the least to most development effort.

Resultant Recommendations

From a priority standpoint, the research team suggested addressing recommendations 1, 2, 8, 9, and 10 in Table 10. This suggestion stemmed from feasibility and impact considerations. Recommendations 1 and 2 add to the flexibility of existing/originally planned GOALS features. Recommendations 8, 9, and 10 collectively incorporate a highly desired joint feature of central communication, documentation of employee tasks and supports, and tracking employee progress to understand if the supports are working and/or the job roles are suitable.

Based on the collective findings of the focus groups, there are several important considerations associated with each user group. 1) GOALS is likely most impactful for employees who require more constant, in-person job coach support. 2) GOALS can serve as part of pre-vocational training for employees (e.g., at a co-op). 3) GOALS should be evaluated with more novice job coaches given the more likely use case and larger potential impact. 4) GOALS may demonstrate a better fit at work sites or for job roles that involve more structured everyday tasks.

Table 10: *Recommended Changes or Additions to GOALS (by user group)*

	Proposed Change or Addition	Employees with IDD	Job Coaches	Supervisors
1	Allow customization of skill assessments		X	X
2	Include option to also take and upload photos		X	
3	AI-generated images incorporating PECS		X	
4	Include option for multiple different languages		X	X
5	Add text-to-speech (for hands-free instructions)		X	X
6	Allow text-to-speech rate to be adjustable			X
7	Add image alt text option (for the vision impaired)			X
8	Add centralized communication with distinct login profiles for the employee's vocational stakeholders (supervisor, job coach, parent)	X	X	X
9	Add documentation of employee's history of employment, tasks, and supports		X	X
10	Allow summary reports on employee progress		X	
11	Ensure desktop and mobile versions match		X	
12	Add an interactive tool to debrief job coaches after shadowing sessions		X	
13	Add built-in task tracking and prompting capabilities (with timers)	X	X	
14	Enable training of the AI model to answer employee handbook questions or similar	X		X

Description of the GOALS Prototype

The focus groups were used by CreateAbility to help develop the GOALS prototype as a web-based system with a login portal, specifically implementing recommendations 2, 5, 9, and 13 from Table 10. Primary features included: 1) distinct "manager" and "employee" user accounts; 2) skill assessments for employees that compile responses from both employees and job coaches; 3) speech-to-text task steps generation with AI smoothing of phrasing; 4) edit mode to change or delete task steps; 5) option to supplement steps with images, either uploaded or AI-generated via text prompt (default prompt is the text instruction for the selected step); 6) export of job task instructions via PDF; 7) export of job task instructions to MeMinder (a complement app developed by CreateAbility) for step-by-step task prompting. Some of these features are depicted in Figures 1 and 2. Note that the left image in Figure 2 illustrates how step images that are uploaded (photos) and AI-generated images can be present in the same set of task instructions.

Figure 1: *GOALS Tasks Instruction Edit Mode (Left) and GOALS Sample Skill Assessment (Right)*

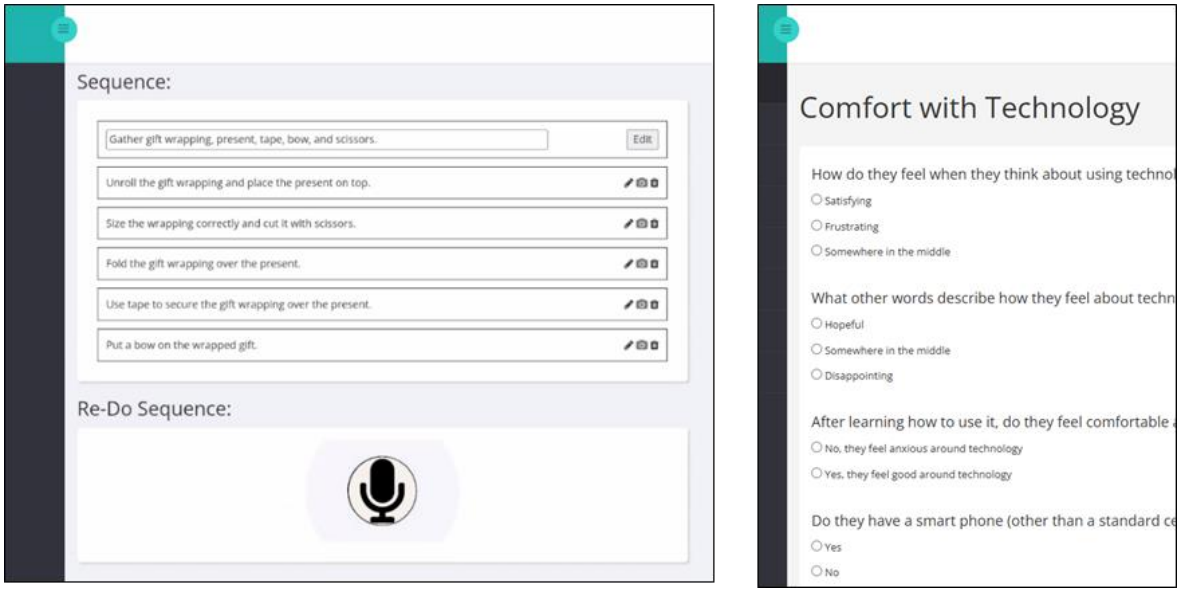
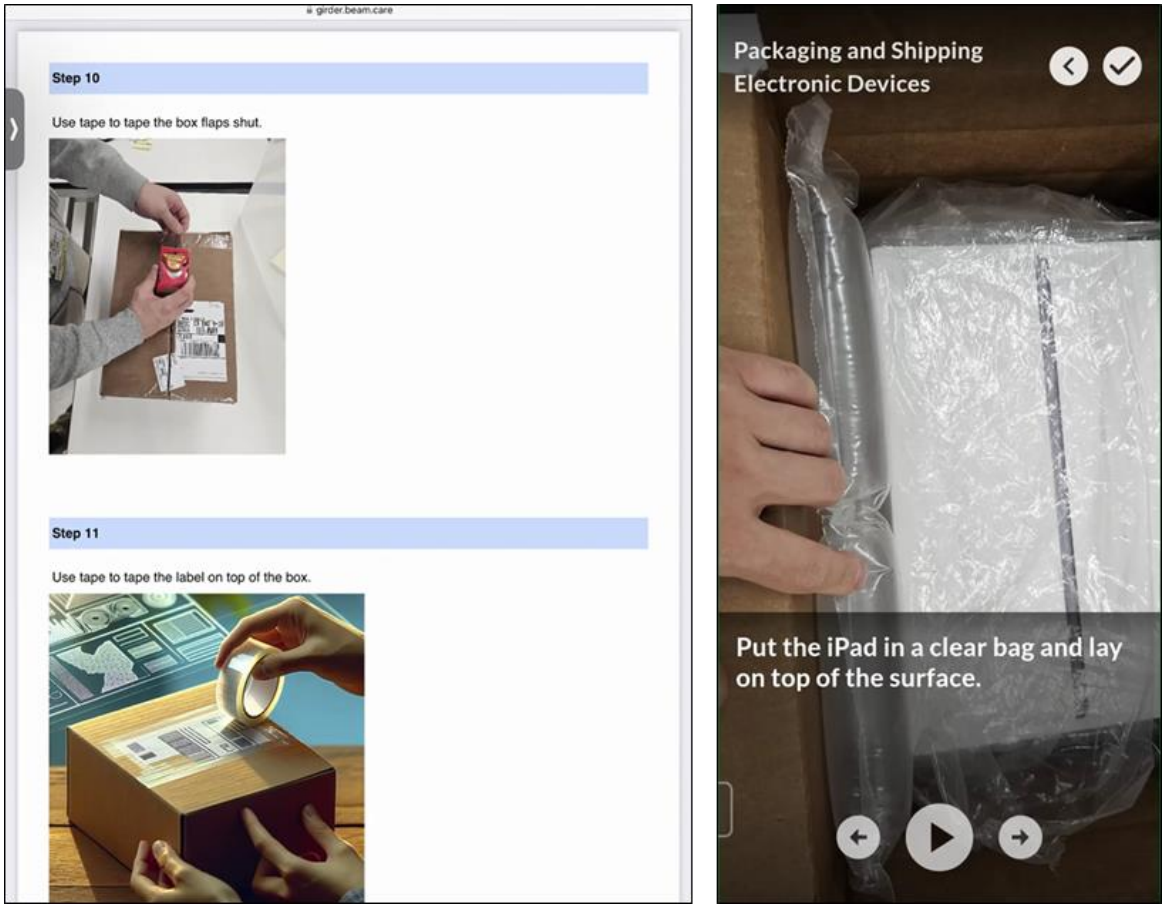


Figure 2: *GOALS PDF Format Task Instruction Export (Left) and MeMinder Task Instruction Export (Right)*



Usability Testing

PSSUQ Ratings

The PSSUQ is a 16-item standardized questionnaire widely used to measure users' perceived satisfaction of a website, software, system, or product at the end of a study. Each participant was asked to rate the questionnaire's 16 statements with respect to GOALS on a scale between 1 to 7, with 1 being strongly agree and 7 being strongly disagree, with lower ratings representing higher perceived satisfaction. The 16 statements can be split into four metrics of focus defined by the average of their associated statements: system usefulness (#1–6), information quality (#7–12), interface quality (#13–15), and overall (#1–16) rating. We reference Sauro and Lewis's 2016 benchmarks based on their analysis across 21 PSSUQ datasets for 210 participants, yielding "acceptable" averages of system usefulness at 2.80, information quality at 3.02, interface quality at 2.49, and overall at 2.82 (Sauro & Lewis, 2016). Given the differences in user population, these benchmarks may not generalize well to the IDD population but are the only PSSUQ benchmarks currently available. The PSSUQ data are summarized according to the four metrics in Tables 11 and 12. *(Full PSSUQ scores are available from the authors upon request)*

The employee group's overall PSSUQ score averaged at 3.6, indicating less user satisfaction relative to the 2.82 benchmark. All 3 submetrics underperformed their benchmarks, with system usefulness at 3.2 (>2.8), information quality at 3.9 (>3.02), and interface quality at 3.8 (>2.49). Having applied interval analysis to the PSSUQ data, we can attempt to infer that employees were most satisfied with the perceived system usefulness and least satisfied with perceived interface quality, based on the score differential versus the benchmarks. Most participants made comments about the difficulty in navigating GOALS, especially when trying to take the employee skills assessments, which may explain the underperformance in the information quality submetric.

Table 11: *PSSUQ Ratings – Employees with IDD (ED)*

PSSUQ Metrics*	Bench mark	ED1	ED2	ED3	ED4	ED5	AVG	SSD
System Usefulness (Avg #1 - #6)	**< 2.80**	4.0	4.8	2.7	2.8	1.7	**3.2**	**1.2**
Information Quality (Avg #7 - #12)	**< 3.02**	6.0	5.0	2.8	4.0	1.8	**3.9**	**1.7**
Interface Quality (Avg #13 - #15)	**< 2.49**	5.7	5.0	2.7	3.7	2.0	**3.8**	**1.5**
OVERALL (Avg #1 - #16)	**< 2.82**	5.1	4.9	2.6	3.4	1.7	**3.6**	**1.5**

** PSSUQ is rated on a scale of 1 (Strongly Agree) to 7 (Strongly Disagree)*

The coach/super group's overall PSSUQ score averaged at 3.0, indicating slightly less user satisfaction relative to the 2.82 benchmark. User satisfaction met the benchmark for system usefulness, which scored 2.6 (<2.8). User satisfaction underperformed the benchmarks for the other two submetrics, with information quality at 3.8 (>3.02), and interface quality at 2.6 (>2.49). Again, we can attempt to infer that job coaches and supervisors were most satisfied with the perceived system usefulness and least satisfied with perceived information quality, based on the score differential from the benchmarks. The most negative average rating was for question #7 found under the information

quality submetric, “the system gave error messages that clearly told me how to fix problems”. This indicates that job coaches and supervisors encountered problems with the system but were not given clear instructions by the system on how to fix them.

Table 12: *PSSUQ Ratings – Job Coach or Supervisor (JC/SP)*

PSSUQ Metrics*	Benchmark	JC/SP1	JC/SP2	JC/SP3	JC/SP4	JC/SP5	AVG	SSD
System Usefulness (Avg #1 - #6)	**< 2.80**	**5.2**	**1.8**	**2.0**	**1.3**	**2.5**	**2.6**	**1.5**
Information Quality (Avg #7 - #12)	**< 3.02**	**6.3**	**2.6**	**3.8**	**3.7**	**2.6**	**3.8**	**1.5**
Interface Quality (Avg #13 - #15)	**< 2.49**	**3.3**	**2.0**	**2.3**	**2.3**	**3.0**	**2.6**	**0.5**
OVERALL (Avg #1 - #16)	**< 2.82**	**5.3**	**2.1**	**2.7**	**2.4**	**2.6**	**3.0**	**1.3**

** PSSUQ is rated on a scale of 1 (Strongly Agree) to 7 (Strongly Disagree)*

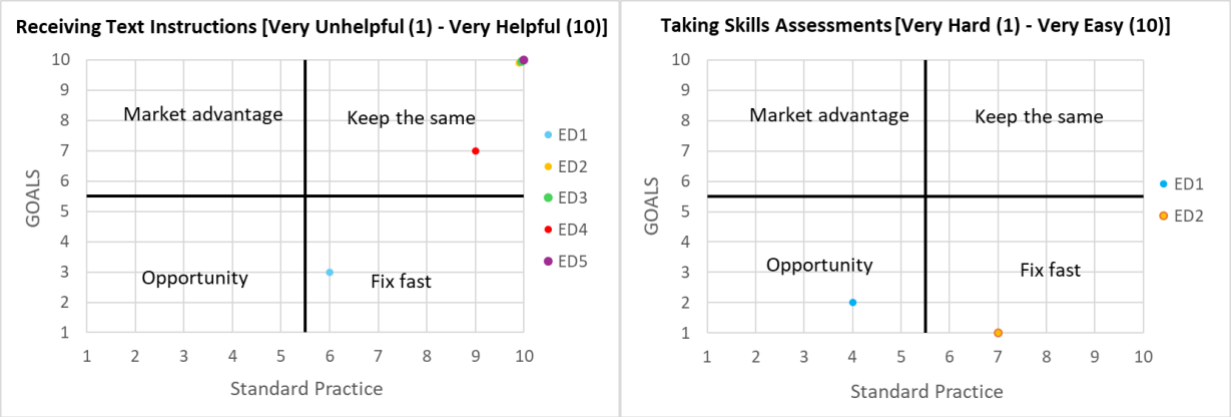
Standard Practice and GOALS Comparison

To provide an illustration comparing the participants’ expectations based on their standard practices to their experiences using GOALS or GOALS-created instructions, their respective pretest and posttest questionnaire ratings were plotted together, with each participant’s standard practice ratings on the horizontal axis and their corresponding GOALS rating on the vertical axis. The charts are separated into quadrants; based on which quadrant a data point is plotted in, a suggestion is provided for that feature:

- Upper right (expected easy, was easy) – keep this feature the same
- Upper left (expected hard, was easy) – market this feature
- Lower right (expected easy, was hard) – fix this feature fast
- Lower left (expected hard, was hard) – opportunity to improve this feature

For employee participants, the comparisons included the “helpfulness of the text instructions,” “helpfulness of step images,” “helpfulness of task prompting app,” and the “ease of completing skills assessments.” For coach/super participants, the comparisons included the “ease” and apparent “helpfulness” to the employee in “creating text instructions,” “creating step images,” “administering skill assessments,” and “replicating instructions in a prompting app.” Note that for “creating step images,” comparisons were made to both GOALS’s image upload and AI-generated image methods. Not all participants provided pretest questionnaire ratings for a standard practice if they did not apply or experience the method in real life (e.g. if an employee never received step images at their workplace), leading to not all participants being represented on each comparison chart. Note that most coach/super participants provided a pretest rating on their perceived helpfulness of instruction modalities, even if they did not apply it personally.

Figure 3: *ED Standard Practice vs GOALS for Receiving Text Instructions and for Taking Skills Assessments*



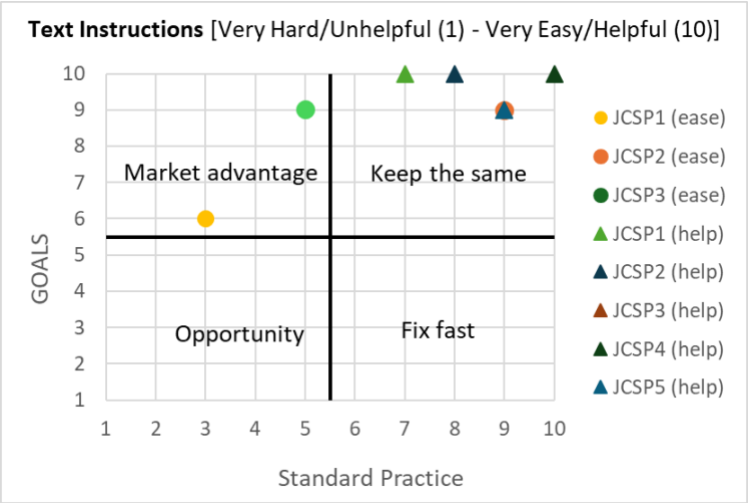
Most employees found the GOALS-created text instructions to be comparable to that of standard practices in their workplace, with ED1 finding the standard practice considerably more helpful than GOALS (Figure 3). This suggests that the format of GOALS-created text instructions could stay the same but may have some clear issues for a subset of ED users. Regarding the ease of taking skill assessments, data completeness only allowed for comparison data points from two employee participants (Figure 3). These data points indicate that skills assessments may be generally hard to complete, and the GOALS format for skills assessments needs to be fixed quickly to leverage this market opportunity.

No charts were created for employee participants on the "helpfulness of step images" due to no employees having received any supplemental images in the workplace instructions. Based on the posttest ratings, however, ED1 and ED2 found the GOALS-created pictures of little to no help, while the other three ED participants all rated the step images as being "very helpful." Similarly, there is no comparison chart for "helpfulness of task prompting app" as only ED1 had ever used such an app in the workplace. ED1 did find the GOALS-associated version of the task prompting app, MeMinder, to be much more helpful than their workplace app, and ED2 and ED3 rated MeMinder as "very helpful."

Comparison charts for coach/super data are shown in Figures 4 – 6, for "creating text instructions," "creating step images," and "administering skill assessments." Note that the ratings for "ease" of implementation and "helpfulness" of the output are plotted together on the charts with different datapoint shapes. Figure 5 further includes the GOALS "ease" rating for uploading images and AI-generating images separately. No chart was created for "replicating instructions in a prompting app" due to only JC/SP3 having used a prompting app in their workplace. JC/SP3 did rate GOALS as easier to implement (via the MeMinder app), but the GOALS output was rated as less useful to the employee versus standard practice (Avail). All other coach/super participants did rate the GOALS-associated prompting app MeMinder as easy to very easy to implement (because it transfers over directly from GOALS) and as useful to very useful.

For “creating text instructions,” two coach/super participants found the GOALS to be easier compared to their standard practices, while one found both approaches to be equivalent (Figure 4). All coach/super participants found GOALS to be equal or somewhat better than standard practices in being helpful to employees through text instruction. Based on these ratings, GOALS should retain the format of its text instructions while marketing it is easier to implement than standard practices.

Figure 4: *JC/SP Standard Practice vs GOALS for Creating Text Instructions – Ease and Helpfulness*



For “creating step images,” ratings from coach/super participants indicated that taking and uploading images with GOALS was easier than standard practice, although to varying degrees (Figure 5). The ease of AI-generating step images through GOALS was similar, although JC/SP2 did find this method notably harder than GOALS’s image upload method. All coach/super participants found the GOALS-created step images to be essentially equal in helpfulness compared to those produced by standard practices. Based on these ratings, the GOALS’s features for step image creation should be marketed for their ease of use while producing an output similar in helpfulness for employees to that of standard practices.

Figure 5: *JC/SP Standard Practice vs GOALS (AI & Upload) for Preparing Images – Ease and Helpfulness*

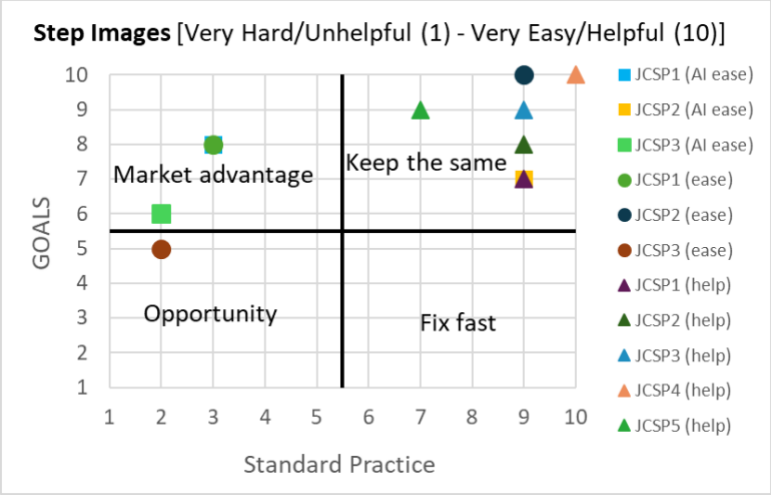
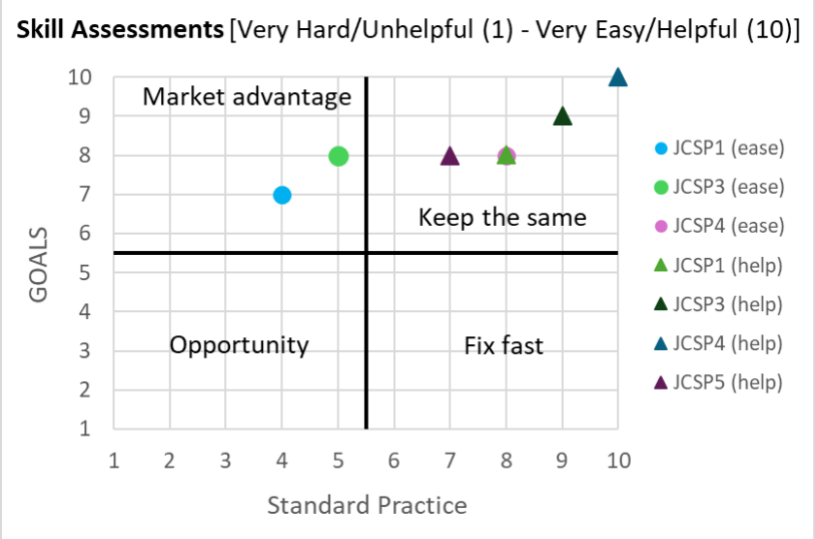


Figure 6: *JC/SP Standard Practice vs GOALS for Administering Skills Assessments – Ease and Helpfulness*



For "administering skill assessments," ratings from coach/super participants indicated administering skill assessment with GOALS was equal or considerably easier than standard practice (Figure 6). All coach/super participants also found the GOALS's skill assessment reports to be essentially equally helpful compared to those produced by standard practices. Based on these ratings, the GOALS's features for skill assessments should be marketed for their ease of implementation while producing an output similar in helpfulness for job coaches and supervisors to that of standard practices.

GOALS Design Feedback

From the posttest questionnaire, participants were asked to describe any design changes to GOALS, and to rate the helpfulness of a version of GOALS that implemented all of their suggestions. For employee participants, the majority of suggested changes (Table 13) involved: 1. improving accessibility of the skills assessments through simple language and text-to-speech; 2. increasing the intuitiveness of overall navigation. Rating on a scale of 1 (very unhelpful) to 10 (very helpful) the ideal version of GOALS with all suggested changes implemented, the individual ED responses were 6, 9, 9, 9, and 10, averaging to 8.6. Even if the software was perfect, some of the participants said it would not be helpful for their specific workplace, either due to electronic restrictions or not feeling they had a need for GOALS.

Table 13: *Participant-Suggested Changes to GOALS – Employees with IDD (ED)*

Category	Suggested Changes	# of ED
Skills assessments	Use simple language	3
Skills assessments	Add ability to hear questions/answers aloud	3
Skills assessments	Make the order of the answers more logical (i.e., "I never do x," "I sometimes do x," "I regularly do x," "I always do x")	2
Skills assessments	Increase size of answer bubbles to make an answer easier to select	1
Overall navigation	Make navigation simpler and more intuitive	3
PDF instructions	Increase the size of the text and pictures so that one instruction is on each page	1

For coaches/supers, the majority of suggested changes (Table 14) involved: 1. giving the user more edit control; 2. adding options for audio or video prompts; 3. changing the interface and interactions to reduce use error when editing task instructions. Rating the ideal version of GOALS with all suggestions implemented on a scale of 1 (very unhelpful) to 10 (very helpful), the individual coach/super responses were 9, 9, 10, 10, and 10, averaging to 9.6. A comment was made about GOALS being a great idea and helpful for everyone involved (employees with disabilities, job coaches, supervisors, and employers). Another participant explicitly stated that they gave a high rating after witnessing their employee successfully complete their test ("packaging") task using the GOALS-created instructions.

Table 14: *Participant-Suggested Changes to GOALS – Job Coach or Supervisor (JC/SP)*

Category	Suggested Changes	# of ED
GOALS task-create	Allow adding, editing, and changing the order of individual steps	3
GOALS task-create	Add ability to create audio and video prompts	2
GOALS task-create	Add ability to record your own voice instead of a generated voice	1
GOALS task-create	Add more spacing between the buttons	1
GOALS task-create	Require confirmation before step deletion to prevent accidents	1
GOALS task-create	Make the edit buttons clearer	1
MeMinder app	Add ability to check off completed steps	1

Usability Issues

The usability issues of GOALS are based on moderator observations of participant activities during their tasks and are reconciled with participant feedback to identify the potential root cause of participant use errors. For the employees, the most common complaint was related to the system's complex interface. They did not find it intuitive, both in terms of navigation and wording/phrasing. The participants were not sure where to find things or what the page labels meant. All five participants

expressed confusion over navigation and stated that they would not feel comfortable using the GOALS system without help. Other than interface/navigation struggles for all the GOALS components, most of the other issues mentioned were related to the skills assessments. These issues are listed in Table 15.

Table 15: *Usability Issues with GOALS – Employees with IDD (ED)*

Usability Issues for Employees with IDD (ED) Participants [**High** to **Low** Severity]
Employee confusion from third-person phrasing. Even when logged into an employee account, the default for the system was to provide skills assessments in third person point of view ("*They* prefer…") for a job coach instead of first person ("*I* prefer….") for an employee.
Wording too complex. The language used in the skills assessments questions was often complex and/or confusing. The questions would be easier to understand if written in simple language.
Many questions had answers in illogical order. For example, instead of ordering answers like "I never do this," "I sometimes do this," "I regularly do this," and "I always do this," the answers would be ordered randomly. This made it harder for the participants to find their desired answer. It also required more time to determine how the answer options related to each other.
Some of the questions were missing logical possible answers. Using the above example, a question might have the answers "I sometimes do this," "I regularly do this," and "I always do this" but lack the option for "I never do this."
Some of the questions need the ability to be marked as "not applicable." For example, one of the assessments asked about things like badges and lockers, which many of the participants do not use at their workplace.
Some interactive elements were too small. The answer bubbles were very small, and it was difficult for some of the participants to accurately select their desired answer. This was especially difficult for the participant with a vision impairment.

Notably, one participant had a vision impairment, and the GOALS system was difficult for them to use because the text and features were too small and not adjustable. They were not able to read the skills assessment questions/answers or accurately select their desired answer. They also were not able to read the task instructions on the PDF due to the small text, which was an issue mentioned by a couple of other participants as well. Additionally, there were several comments that the pictures in MeMinder were too big and zoomed in. Rather than the current default of having a picture take up the entire background of a task step (and therefore be zoomed in to fit the device's screen properly), the employee participants would prefer to have a smaller, more legible picture.

For coach/super participants, four primary usability issues impacted their user experience by introducing confusion and/or increasing the difficulty of using the GOALS features. These usability issues are listed in order of severity in Table 16, with the most severe issues pertaining to lack of error prevention or recovery and insufficient user control when editing task instructions. A few other issues observed or received as feedback included not knowing to tap on the employee name to

manage their profile (users tapped in the highlighted space), not having a feature to “generate AI images for” selected steps all at once, and having too subtle of an indicator that an image was already uploaded for a step (camera icon is darker). All participants found the AI-generated images “wonky” but three considered them serviceable. One participant explicitly stated actual pictures “are probably a lot more helpful.”

Table 16: *Usability Issues with GOALS – Job Coach or Supervisor (JC/SP)*

Usability Issues for Job coach or Supervisor (JC/SP) Participants [**High** to **Low** Severity]
In the task sequence steps, the “edit,” “add image,” and “delete” icons are placed too close together, and there is no error prevention for the “delete” function. Four participants made note of this issue, with two participants accidentally deleting steps as a result. One participant stated that they were “scared” after accidentally deleting a step, as they had to continue adding images while risking deleting a step again. While this issue may have been exacerbated by the use of GOALS via a touchscreen tablet rather than a laptop or desktop computer, it is still a realistic use case scenario for job coaches or supervisors, particularly because a tablet can be used to take photos for convenient uploading to sequence steps. This issue can be mitigated by improving icon spacing and adding a confirmation pop-up for the “delete” function (e.g. “Are you sure you want to delete this step?”).
There is a lack of freedom to add or change the order of steps, and the “redo sequence” function does not work. The two participants who accidentally deleted steps were quite frustrated with not being able to add a step. One participant continued without redoing the sequence and attributed the employee’s confusion on the predefined packaging task to this omission. The other participant tried to redo their sequence with the mic icon at the bottom of the generated step sequence page, only to see that the function did not work. The moderator had to assist this participant in deleting the old sequence and starting a new task sequence. This issue would require the addition and repair of the aforementioned features.
Repeat button labels cause user confusion. Three participants found the duplication of the “Upload image” and “Generate image” buttons to be confusing, particularly for the former as they did not recall which one was new after going through the image selection workflow. This issue can be remedied by disabling the first “option” button after it has been selected and distinctly showing that it is inactive (e.g. graying it out). Alternatively, consider changing the final action button to “Confirm” or “Apply” rather than “Upload image” or “Generate image.”
“Edit” not communicating apply or confirm text changes to the user. After tapping the “edit” icon for a sequence step, a button labeled “Edit” appears. Three users did not connect this button to saving their text edit changes, so once they finished typing parts of the step text, they just tried tapping outside the sentence space to apply changes. This issue can be avoided by simply changing the “Edit” button to “Confirm” or some equivalent.

Outcomes and Benefits

This paper showcases the user-centered design process for GOALS, a web-based tool intended to reduce job coach burden and enhance independence of employees with IDD through more efficient provision of employee-centered vocational task instructions. Additionally, the employee skills assessments offered by GOALS improves employee placement by informing supervisors (and new job coaches) of employees' vocational skills and necessary supports. Further development of GOALS by CreateAbility is planned, to enhance the usability of the prototype and implement a communication platform that centralizes correspondence among supervisors, job coaches, and employees.

More broadly, this study illustrates the importance of involving individuals with IDD and related stakeholders (e.g. job coaches) throughout the design of a new technological support product. Many user needs may have been overlooked without the focus groups, and judicious iteration and refinement of the GOALS prototype could not be attained without placing GOALS in the hands of the potential users via usability testing, as evidenced by the usability issues identified. Usability issue discovery can be near impossible without such methods, and missed issues could cause a commercialized product to be quickly abandoned or never adopted in the first place. Additional benefits yielded by this study can be drawn from the focus groups, with findings contributing to the body of knowledge regarding the communication barriers and challenges between employees, their job coaches, and their supervisors.

Discussion

The approach and findings of this paper demonstrate the critical need to apply user-centered design when developing technology for individuals with IDD, especially if involving newer and more complex technologies (e.g. AI). The accurate discovery of user needs through focus group themes, as well as the accurate discovery of user preferences and usability issues through usability testing, significantly improves the probability of technology development and commercialization success. Without this, GOALS is much less likely to be adopted to benefit employees with IDD and other involved stakeholders, and the developer of GOALS (CreateAbility) would lose their invested time, money, and effort. This finding is consistent with systematic reviews of user-centered design approaches with 3D-printed (Santos & Silveira, 2021) and visual impairment (Ortiz-Escobar et al., 2023) assistive technology, which conclude that the lack of early-stage user engagement correlates strongly with long-term design delays or failure.

The current iteration of the GOALS prototype, while potentially useful, appears to be best fit for employees who require more involved and constant support at worksites with more structured daily tasks. Additionally, the results indicate that job coaches and supervisors find it easier to use GOALS to create task instructions compared to their standard practices, although the quality of instructions appears to be comparable between the two approaches. Collectively, this suggests that leveraging AI-supplemented technology could reduce job coach burden significantly with employees who demand frequent in-person supervision, while maintaining task instruction quality. The GOALS

skills assessments are a key feature to supervisors, who want to better determine employee aptitude and fit without committing resources to “trial employ” various candidates. Overall, GOALS requires substantial refinement before user adoption, but it is well-positioned due to user-centered design and evaluation.

Notable limitations to this study include the small sample sizes, lack of a prototype during focus groups, and an incomplete early-stage prototype during usability testing. Smaller sample sizes per user group ($N \leq 5$) reduce the generalizability of findings, particularly with the heterogeneity of the IDD population’s support needs. Focus groups being conducted without a GOALS prototype limited the user feedback on how features should be implemented, thus requiring additional subsequent testing. Similarly, the early-stage prototype was incomplete since CreateAbility was unable to fully implement the recommendations derived from the focus groups prior to evaluation, leading to fewer features assessed during usability testing and thus more additional testing needed in future development.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. Funding for this study was provided via a subaward from CreateAbility, Inc. (Indianapolis, IN) through their Small Business Innovation Research (SBIR) Phase I grant, provided by the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90BISA0075), Administration for Community Living (ACL), Department of Health and Human Services (HHS). The contents of this paper do not necessarily represent the opinions and policies of NIDILRR, ACL, or HHS, and one should not assume endorsement by the Federal Government.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 86-105
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from Academia

Facilitating Independence through Automated Accessible Chart Creation

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Abstract

Data science is a multidisciplinary field that is used to discover insights and help understand trends. This can be in the form of statistics, charts, or written text describing a methodology or a result. For users with blindness or low vision working in data science, independence is paramount in the creation of complex data and in the interaction of the charts they have made themselves. We make two contributions in this work. First, we have created a fully automated, accessible, and open-source statistics and chart creation library for data scientists, emphasizing accessibility in both use and creation. Second, we conducted a small-scale randomized controlled trial with 10 individuals with blindness or low vision. Findings show that users can meaningfully extract information without assistance from charts as well or better than those with human-generated descriptions.

Keywords: human-centered design, blindness and low vision, data visualizations

Facilitating Independence Through Automated Accessible Chart Creation

Data science, a multi-disciplinary field blending computer science and statistics using scientific methods, processes, algorithms and systems to extract knowledge and insights from structured and unstructured data, plays a critical role in participation and success in science, technology, engineering, and mathematics (STEM) as well as economics, health care, and finance (Manyika et al., 2011). The National Science Board's 2018 Science and Engineering Indicators reports an estimate of total expenditures for the United States' research and development at $495.1 billion USD (National Science Board, 2018) and most of these fields utilize data science.

Individuals with disabilities should be able to meaningfully and independently participate in these courses and professions, but today significant barriers remain, such as the inaccessibility of data visualizations to individuals with blindness or low vision. A variety of recent work (Sharif et al., 2024; Zhang et al., 2024) has highlighted that it may be possible to use structure in visualizations like charts to help, but these approaches are not yet fully automated. For example, Sharif et al. (2024) interviewed 57 visualization creators on the barriers they face when making visualizations accessible, with many participants emphasizing the need for automation. One of their participants described a technology they would like as "A magic wand... a charting tool where a chart is just made accessible in the background without the chart author needing to do anything special." In this paper, our first contribution is that, while it is not a magic wand, we have built an accessible charting technology and open-sourced it under the Berkeley Source Distribution (BSD) license for the community to use in practice. Building on recent research (Godfrey, 2013; Gorlewicz et al., 2020; SAS Institute Inc., n.d.; Stefik et al., 2024; Tennison et al., 2023; Zong et al., 2022), we demonstrate a technical solution for automatically creating accessible charts that can be used by all users. We refer to our method for visualization as **Structured Charts**; meaning each piece of the chart has a generated screen reader cue which describes it along with an interaction model that connects these pieces to their related parts. Currently, we support a variety of chart types (e.g., bar charts, histograms, pie charts, doughnut charts, line charts, scatterplots, box plots, and violin plots). Each contains structured navigation automatically, many options for customization (e.g., colors, factors, facet grids), and accurate statistical information (e.g., *p*-values, effect sizes, inter-quartile range, etc.). For all visualizations, we use standard mathematical statistics, not approaches like large language models, to ensure that the information is exact and not approximated.

Second, charts do not exist in a vacuum, and while many audiences are important, one we found interesting to consider is data scientists with blindness or low vision. When creating charts, this system would provide the option to explore their data and verify the contents independently. The motivation for this work is rooted in our blind co-author's lived experience of needing to be able to create and interrogate his own data visualizations; this has made the co-design process an integral part of our development cycle. Our second contribution in this paper is one study from a series of studies, specifically a randomized controlled trial with 10 participants with blindness or low vision evaluating the structure of these generated charts with some limited data science information. This work lays a foundation for enabling independence for people with blindness or low vision using fully automated, accurate, and accessible charting technologies.

Target Audience and Relevance

There are several target audiences for this paper. Broadly, we are highlighting the importance of an automatic, accessible chart generation system for chart authors working in the field of data science and an attempt to facilitate their independence by removing the need for sighted assistance when creating data visualizations, particularly during steps in the data science workflow that require repetitive creation of charts of varying types to explore potential trends or discover patterns. However, the benefits of these tools are vast, as it also could help to alleviate the problem with chart authors in general leaving alternative descriptions blank. By making it an automatic tagging system based on the underlying data used to generate the chart, any chart created is born accessible. For chart authors, this removes the extra steps of writing an alternative description, and for chart readers, this ensures that the accurate tags are always available to dive in and retrieve the same information as anyone else, whether that means getting a quick summary at the top level or investigating the data further. This also has the potential to span beyond data science, as data visualizations have become an everyday tool used in many professional and academic fields when sharing information.

Literature Review

Alternative descriptions are an integral part of adding accessibility to purely visual content on the web. Unfortunately, it is common for images to be missing this information. Bigham et al. conducted a survey of images found on the 500 most high-traffic websites and found that only 39.6% had alternative descriptions assigned (Bigham et al., 2006). How to fix this issue is an open question. There are human-in-the-loop techniques that rely on volunteers, like friends or paid workers (Bigham et al., 2010) as well as computer vision technology (Fang et al., 2015), which can be used to generate missing text. These generated captions can be dynamically added as alternative descriptions through a transformation proxy, as was shown in Bigham et al. (2006). Each of these techniques has potential drawbacks, such as the cost and scalability. None of these techniques are the same as Structured Charts, because they provide only a non-interactive label.

Beyond the potential for alternative descriptions to be missing is the problem of writing thoughtful, all-encompassing descriptions. There is also a growing body of work in the area of automatically generating captions that can describe the trends and patterns found within the visualized data, such as Tang et al.'s work on applying language models for captioning, which uses a large dataset of visualizations alongside crowdsourced, human-generated captions to create a language model that attempts to automatically caption new visualizations with a human-like, natural sentence structure (Tang et al., 2023). They discuss four levels of semantic content developed by Lundgard and Satyanarayan (2022): L1 information about the construction of the chart, L2 summary statistics and relations, L3 perceptual and cognitive phenomena, such as trends, and L4 domain-specific insights. However, Tang et al. found that while they were able to auto-generate natural language captions, when evaluating a sample of the generated captions for descriptiveness and accuracy, approximately 52.9% of the L2 and L3 statements had some sort of error (Tang et al., 2023).

There has been recent work in making charts and graphs accessible to assistive technology. Godfrey described a plan to improve statistical software so that it is more accessible (Godfrey, 2013). Godfrey et al. also proposed a system built on top of the statistical packages in the R, a programming language commonly used to analyze and visualize data, to allow step-wise exploration of a diagram with relevant statistical information at the various levels of the chart (Godfrey et al., 2018). Several other implementations of accessible charts have started to arise, such as Vega-Lite (Satyanarayan et al., 2017) and Highcharts ("Highcharts," n.d.). These implementations tag visual elements with Accessible Rich Internet Application (ARIA) labels, text descriptions that help screen readers identify and describe elements in a web page, but often have arguably linear or difficult to use navigation and are limited to web-based contexts (Satyanarayan et al., 2017). Zong et al. have tested a set of high-fidelity prototypes built on top of Vega-Lite generated charts, which included a similar step-wise navigation to what Godfrey et al. describe, as well as spatial and landmark navigation (Zong et al., 2022). Question and answer (QA) systems are another option for chart accessibility which is gaining popularity in research (Kim et al., 2023; Sharif et al., 2022). Sharif et al. have developed a tool called VoxLens to add accessible interaction models to a few existing web-based visualization libraries (2022). VoxLens uses self-voicing navigation to provide several modes of navigation including sonification for summarization of trends and a QA system to allow for more direct feedback on pieces they may be interested in without having to fully explore the individual data points, such as minimums and maximums.

We created a design that was informed by prior findings on accessible charts and then conducted an empirical evaluation of Structured Charts compared to human-written alternative descriptions, the current status quo. While prior work has demonstrated promising accessibility techniques using high-fidelity prototypes, hand-authored ARIA tags, and automated approaches layered on top of existing visualizations, these solutions largely operate outside of the data science workflow itself. In contrast, our work targets accessibility as an intrinsic property of the data analysis process, enabling individuals to explore datasets, perform statistical analyses, and generate charts that are automatically accessible for independent work across the entire pipeline.

Contribution 1: Automatically Accessible Structured Charts

Historically, a chart being accessible has been focused on humans writing "good" alternative descriptions. We know this approach is problematic from prior work because 1) authors rarely write these descriptions and 2) a user with blindness or low vision needs sighted assistance to *make* their own chart and verify that the visuals are correct. Thus, we see the cornerstone of being "automatically" accessible as meaning that both conditions should be fixed. Users must be able to create and use the visualizations without third-party intervention or labeling. Because the charts might be used for real scientific work, the results in the charts must be exact and not approximated.

One might presume from existing literature on structure in charts that automating the procedures in creation is a simple affair. After all, the literature had provided good faith prototypes on structure (Godfrey, 2013; Gorlewicz et al., 2020; SAS Institute Inc., n.d.; Stefik et al., 2024; Tennison et al., 2023; Zong et al., 2022) with at least some amount of empirical guidance. In fact, we should admit that when we began this project, we expected the automation to be easier than it ultimately was. We begin this section with an explanation of what makes automation hard from the

lens of 1) data science and 2) accessibility. From there, we discuss how our automation layer works for charts.

The Data Science in Accessible Charts

Data scientists often do not need “just a chart.” They might need specific kinds of statistical tests, that provide specific kinds of information. They may want it presented in a bespoke way, whether visually or in text. For example, suppose an author is conducting a between-subjects repeated measure design and they want to represent a one-factor study with three levels. One way an author could present this for such an experiment might be a multi-factor box plot. Although prior work describes structure, exactly what aspects of the science should be embedded is less clear. For example, a chart could potentially include many aspects of the associated statistical tests (e.g., *p*-values, effect sizes, degrees of freedom) as summary, or not. Not everyone needs such information with a chart, but not all users are the same.

Exactly what information could or should go into a chart is not simple to decide. To help us pilot our system, we first made mini-versions and taught a course on data science using them at the University of Nevada, Las Vegas. This course was at the doctoral level and focused on methodology, statistics, and accessible visualization. The purpose of the piloting process was to obtain informal feedback and practical usage information, which we did over a three-year period. One key lesson learned was that what students seemed to need was a far more robust implementation than we imagined.

Through this iterative piloting process, our data science tools have grown to include multiple components. First, we created our own versions of statistical procedures for a wide variety of descriptive statistics (e.g., mean, median, standard deviation, etc.), in addition to many variations on parametric and non-parametric tests (e.g., Chi-square Goodness of Fit Test, Chi-square Test of Independence, Shapiro-Wilk Test, One-Sample T-Test, Paired T-Test, etc.). While time consuming to implement, this provided two essential outcomes. First, we wanted the data science course at the university to be fully accessible, and second, having the mathematical details of these tests available provided the option to experiment with the charting system.

There are many examples where having direct statistical calculations, from any programming language, can be helpful. For example, imagine conducting a factor analysis as a person with blindness or low vision and generating a scree plot. As a reminder, scree plots represent the eigenvalues and are often interpreted along with tests like Kaiser-Meyer-Olkin’s Measure of Sampling Adequacy (KMO) Test or many other approaches. A system that combines the statistical tests, not just their output but some aspects of their internal calculations, gives us a highly rigorous and methodical starting point that our accessible charts could start from. Thus, we could add structure, but we could also provide statistical semantics.

When users create a chart, they have considerable flexibility, and this grew from our extensive piloting. In our case, users write a code snippet describing the kind of chart they want to create. This includes 1) customizing titles or axes, 2) statistical information like the dependent and independent

variables, and 3) the type of chart to create. How they create the charts and what they can create is discussed next.

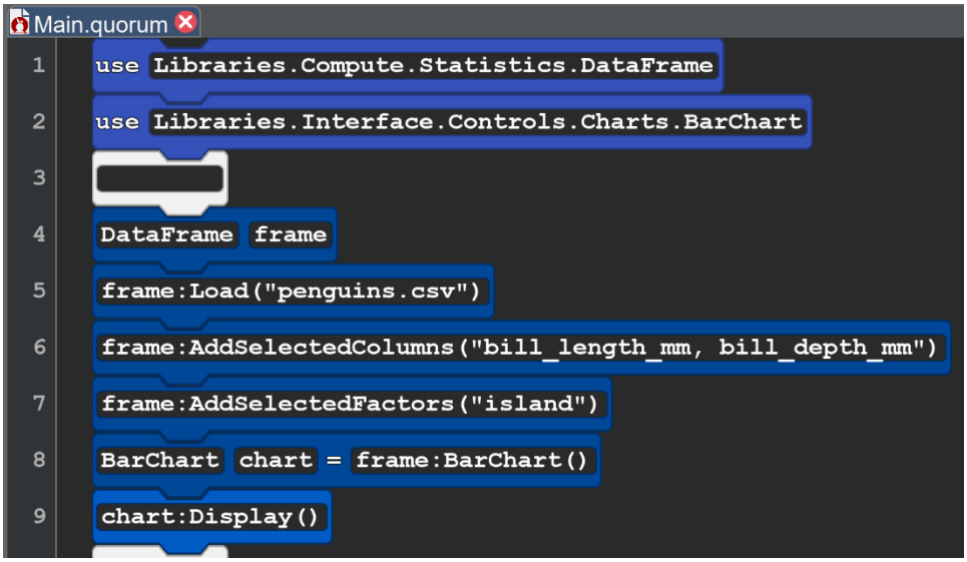
Creating a Chart

Our automatically accessible chart creation system was inspired to an extent by ggplot2 (Wickham, 2016), the popular chart library for the R programming language. This chart generator is metaphorically similar, based on a standard grammar of graphics (Wickham, 2010). Charts in our system are programmed, then auto-generated.

To construct a chart, you must create an object that is used for loading and saving data (e.g., from a comma separated file, in-line). The user then must: 1) select columns (dependent variables) and 2) select factors (independent variables). The metaphor is that, like ggplot2, the user is providing statistical information to the charting system and the generator uses this to make decisions on what information to embed.

Consider as an example that we wanted to investigate the palmerpenguins::penguins dataset (Horst et al., 2020), which consists of data collected about penguins in Palmer Archipelago, Antarctica. Using this dataset, a user could generate several forms of accessible charts. After loading the data, the user specifies in code the dependent and independent variables they would like the charting system to consider.

Figure 1: *Snippet of Code to Generate a Bar Chart*



For example, Figure 1 shows a script used to generate a chart in our system. The first two blocks specify the necessary libraries that need to be imported. The third and fourth blocks create a DataFrame and load it with the penguins.csv dataset. The next two blocks select the dependent variables “bill_length_mm” and “bill_depth_mm,” and then the independent variable “island.” Finally, the last two blocks create a BarChart from the DataFrame’s selected variables and generate the chart for the user. Obviously, tools could be created on top of the code that would have the same

effect, but programmatic access can be important for replicability in science, and thus, the system allows for both.

Since the system is generating the pieces of the chart, the underlying information is readily available to properly name and describe each element with exactly what it is, such as the value of a bar, which containing category it belongs to, the list of categories presented in the legend, or the range of an axis. The user does need to provide a title, which is true visually as well, and if they do, the visuals and accessibility are linked.

Further customizations are also supported. In this case, we made a bar chart, but there are many options of chart types such as histograms, pie charts, line charts, scatter plots, box plots, and violin plots. Each piece of the chart supports customization for visual elements like line thickness, font sizes, point sizes and major/minor grid lines. These options help support both personal aesthetic preferences and visual accessibility needs. User interactions are discussed next.

Charts User Interactions

Once a chart is generated, regardless of platform, a set of user interactions is also generated so a user can use it. The web and desktop make use of the keyboard, while tablets use gestures on Android and iOS. In this section, we will focus primarily on the keyboard interaction model; the gesture interaction model may be described in future work and is already open-source.

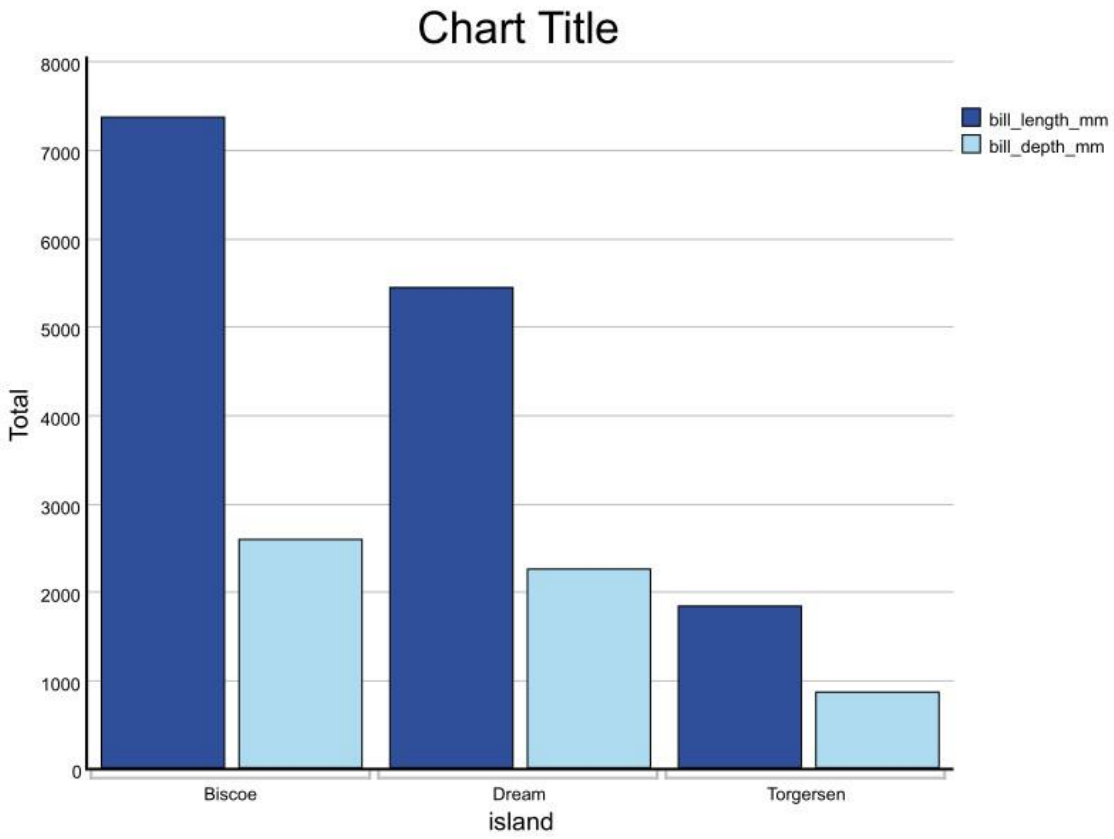
We describe here in detail exactly how a user interacts with the charts. Keyboard support works like a “drill-down” where the user can get increasingly detailed summaries about pieces of a chart. If the focus is on the chart itself, a templated summary is provided based on the type of chart, the title, and aggregate information about the contained chart elements. As interior pieces of the chart are focused, information about those pieces are provided to the user. This interaction model using the keyboard is not entirely unique to this implementation, as similar interaction models can be found in other recent works (Apple Inc. n.d.; “Highcharts,” n.d.; Godfrey et al., 2018; SAS Institute Inc., n.d.; Satyanarayan et al., 2017; Zong et al., 2022), each with its own pros and cons. Ours is fully automated and often embeds information related to data science.

Table 1 shows all the available keys used while navigating the chart. For our system, this consists primarily of using the arrow keys to move through lists of elements and ENTER / SHIFT + ENTER to move between parent-child relationships. The last set of key commands are PAGE UP and PAGE DOWN, which can be used with some of the bottom layer lists to traverse by value order.

Table 1: *Keyboard Commands Used in Structured Charts*

Key	Action
Right / Up Arrow	Move to the next element in the list.
Left / Down Arrow	Move to the previous element in the list.
Enter	Drill-down into the current element’s first child element.
Shift + Enter	Drill-up into the current element’s parent element.
Page Up	Move to the next element in value order.
Page Down	Move to the previous element in value order.

Figure 2: *Bar Chart with 6 Total Bars*



Next, consider the sample chart in Figure 2, which is produced with the code snippet in Figure 1. When navigating the Structured Chart, the focus starts on the root of the chart and the screen reader generates the phrase *"Chart Title, Bar Chart with 3 groups and 6 total bars. To navigate the chart, use Enter to move into the list of groups or use the arrow keys to navigate the chart information."* This element follows a template like:

- [Title], [Chart Type] with [Summary Counts of Interior Elements]. [Chart-Information-Level Instructions].

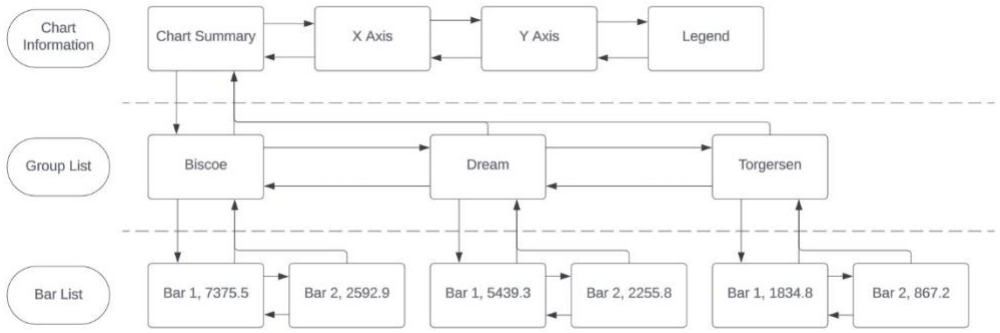
First, we have the title of our chart, the type of chart, a summary of the content of the chart and instructions on how to navigate. The first element in each list contains additional instructional text about what keys are currently available and what is in the layer above and below. Next, we will navigate through the chart information using the arrow keys where the X axis, Y axis, and Legend would tell us *"X axis shows island and has values Biscoe, Dream and Torgersen," "Y axis shows Total and ranges from 0 to 8000,"* and *"Legend has values bill_length_mm and bill_depth_mm"* respectively; these follow a template like:

- X axis shows [Axis Title] and has values [Factor-Level 1], [FactorLevel2] and [FactorLevel3].
- Y axis shows [Axis Title] and ranges from [Minimum] to [Maximum].
- Legend has values [LegendEntry1] and [LegendEntry2]

.

The structure of the sentence changes slightly depending on whether or not the values associated are a range of ordinal values or a list of categorical values. The elements in the chart information layer are generic between all chart types. If one of these pieces is not present (e.g., pie charts only use one axis and the legend can be optionally toggled on or off) then that element is skipped in the iterative list.

Figure 3: *Block Diagram of Structured Navigation for Figure 2*



Next, if we return focus to the root element by pressing LEFT or DOWN to move backwards through the list, we can choose to drill down into the structure contained under the Chart Summary. With the Chart Summary focused, we can press ENTER and the screen reader generates the phrase *"Biscoe group, 1 of 3 groups, has 2 bars. To navigate the list of groups, use the arrow keys to move between groups in list order, use Enter to move into the list of bars for that group, use Shift + Enter to return to the chart information."* The bar group element follows a template like:

- [Group Label] group, [Current Iterative] of [Total List Size] groups, has [Bar Count] bars. [Group-Level Instructions].

Currently, we are in the list of groups focusing on the Biscoe group. The description provides us with the group name, the current iteration and total number of groups, how many bars are in that group and a set of instructions for navigating the group list. From here, we can use RIGHT or UP to move to the next group in the list and LEFT or DOWN to move to the previous group. And we can press SHIFT + ENTER to return to the chart information or ENTER to drill down into the bar list.

Next, if we press ENTER on the Biscoe group, it will focus the first element in the Biscoe group's bar list. The screen reader generates *"Biscoe bill_length_mm bar, 7375.5, 1 of 2 bars inside Biscoe group. To navigate the list of bars, use the arrow keys to move between bars in list order, use Page Up or Page Down to move between bars by value order, use Shift + Enter to return to the group list."* The bar descriptions follow a template like:

- [Group Label] [Bar Label] bar, [Value], [Current Iterative] of [Total List Size] bars inside [Group Label] group. [Bar-Level Instructions].

We are provided the group name, bar name, current iteration and total count for the bar list, and some navigation instructions. If we press RIGHT or UP, we will move focus to the next bar in the list

and hear *"Biscoe bill_depth_mm bar, 2592.9, 2 of 2 bars inside Biscoe group."* From this point, if we want to fully explore the bars in another group, we will need to press SHIFT + ENTER to drill up to the group list and press RIGHT or UP to move to other groups.

Figure 3 shows a block diagram representation of the structured navigation that would be generated in this instance. The dotted lines separate the three: the chart information, group list, and bar lists. The horizontal arrows in the diagram show which elements in the chart can be navigated to and from using the arrow keys. The vertical arrows in the diagram show which elements in the chart can be drilled down into and up from.

While this work presents a big step forward in automated generation of accessible charts, we want to be clear that there is more work to do. Our system supports a variety of chart types and swaps terms (e.g., bar, point, slices) in the descriptions, but what all information should be provided by default for every single chart type is still an open question (e.g., clusters, trends, patterns).

Contribution 2: User Study on Accessible Charts

User-centered design is paramount to creating an equitable solution for everyone. It can be difficult, or nearly impossible, for a developer to encompass all the accessibility features necessary for a brand-new technology on their own. People's needs are not just a simple checklist, but a complex combination of unique perspectives that can only be evaluated by leveling the lab and reaching out to connect with people in the real world, observe how they interact with the tools, and have a conversation. As such, working with people from a variety of backgrounds and with a variety of disabilities has helped us to pinpoint areas of improvement that are difficult to ascertain without the help of the community. Over the years, we have gathered feedback through a series of structured experimental designs, observational classroom sessions, and focus group sessions. However, in this work, we will be focusing on the analysis and results of just one user study.

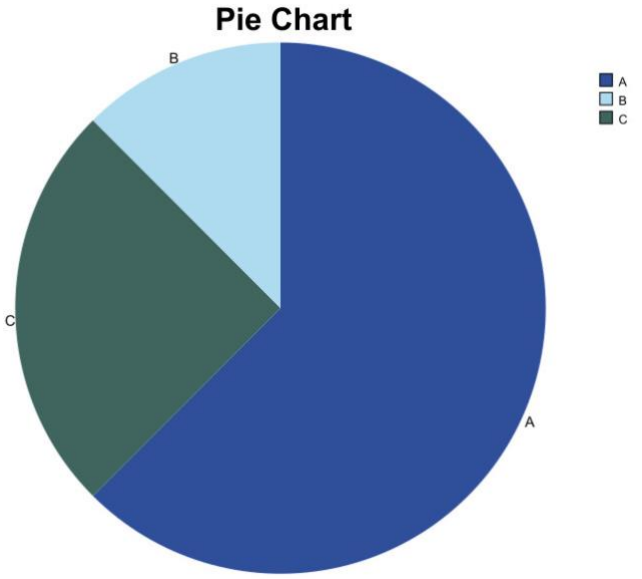
There are tradeoffs between a carefully written, human-generated Alternative Description and an automatically generated Structured Chart. Human authors can provide nuanced, context-specific information, but may omit details that an automated system can consistently supply. In contrast, automatically generated charts may better support independent exploration, particularly in scenarios involving rapid prototyping or iterative analysis.

While prior work has investigated structured navigation in accessible charts, those studies rely on handcrafted prototypes which can be tailored for a specific case rather than automated generation. In this study, we set out to make a comparison of a human-generated Alternative Descriptions and automatically generated Structured Charts to explore if the deliverables of our chart generator, without human curation, can provide an equal or better experience for users with blindness or low vision. We ran a small-scale randomized controlled trial ($N = 10$) to help understand the impact on using generated Structured Charts versus Alternative Descriptions for various chart types. This study was approved by the Institutional Review Board at the University of Maine.

Method

This experiment was a within-subjects design investigating 2 conditions (Alternative Description, Structured Charts). We used three chart types in our study (pie, scatter, and line). Participants were randomly assigned to be presented with either of the description conditions. All charts were presented in a fixed order to participants: 1) pie charts, 2) scatter plots, then 3) line charts. This order was instituted based upon the perceived complexity of the charts. Whether a user received Alternative Description or the Structured Chart first was randomized.

Figure 4: *Example Pie Chart from Materials*



Materials

Two accessible charting systems were evaluated in this study: 1) Alternative Description and 2) Structured Navigation. The Alternative Description condition provided textual information to the user, acting in general as a summary of the “important” elements of the chart. These descriptions were generated by human writers using current best practices for chart descriptions (Brown et al., 2023; Doore et al., 2021; Lundgard & Satyanarayan, 2022) in collaboration with experts in mathematics. First, descriptions begin with high level information about the chart, such as type, and some aggregate information to summarize the data (e.g., how many regions in the pie chart, how many points in the scatter plot, etc.), and finally, the specific information related to each point (e.g., the percentage for each region in the pie chart, whether a line segment increases or decreases). The description used as the alternative description for the image and a data table was provided alongside it. The Structured Charts were generated in our system and included the automatically accessible structured navigation.

Figure 5: *Example Scatter Plot from Materials*

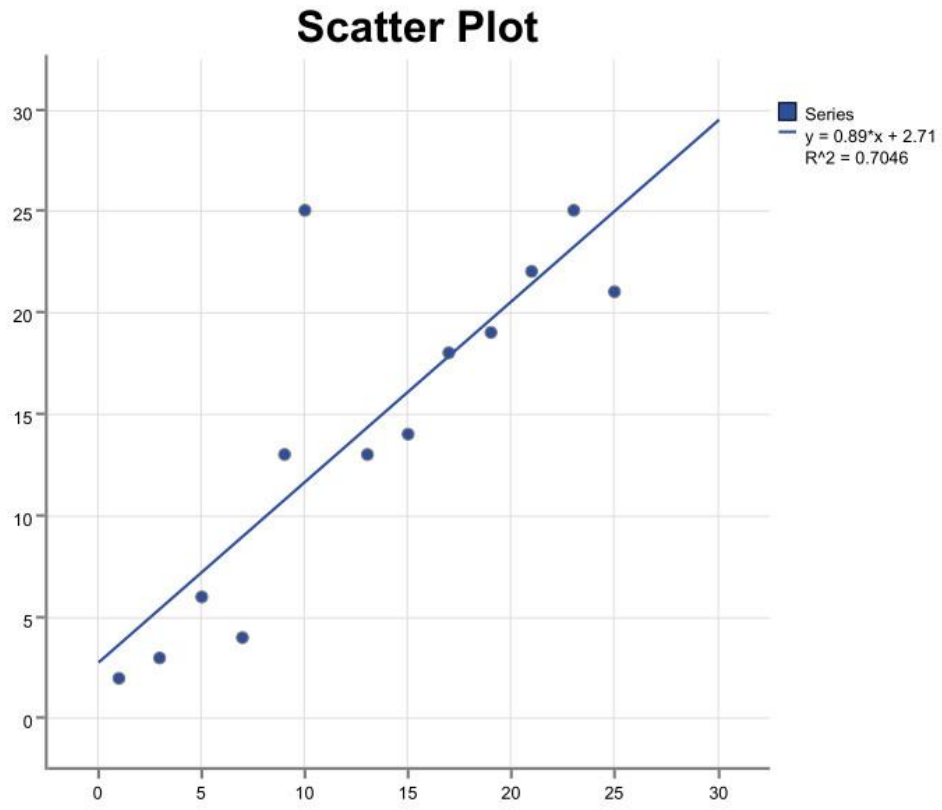
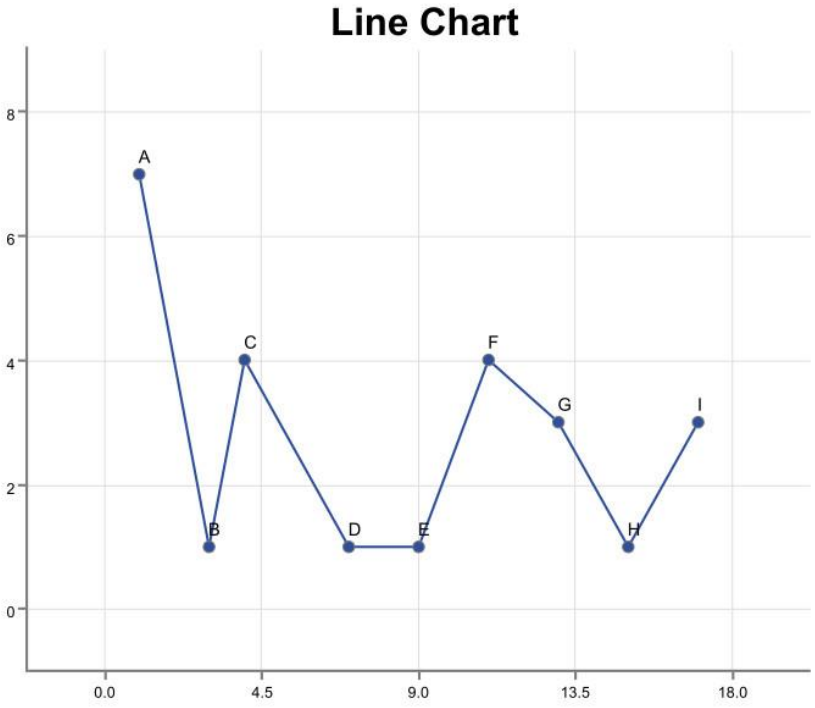


Figure 6: *Example Line Chart from Materials*



This study investigated 3 chart types: pie, scatter, and line charts. Participants received 12 charts in total, 4 charts for each of the 3 types. Examples of the pie, scatter, and line charts used can be found in Figures 4, 5, 6 respectively. Within a particular chart type, participants received 4 variants: a training chart for both the Alternative Description and Structured Chart conditions; an Alternative Description experimental chart; and a Structured Chart experimental chart. The pie charts had 3 regions, line charts had 8 line segments, and scatter plots had 13 points.

Participants

Ten participants (18–63 years; *M* = 42.90 years; *SD* = 16.11) were recruited for the study at the 2022 National Federation of the Blind (NFB) conference. Seven participants were female and three were male. Participants ranged from completely blind to having the ability to perceive light and movement (see Table 2 for reported diagnoses). A majority (*N* = 7) of the participants had an undergraduate or graduate degree, one had some college, and two had a high school degree/GED.

Table 2: *Participant Summary*

#	Age	Sex	Diagnosis
1	57	F	Retinitis Pigmentosa
2	57	F	Completely blind
3	18	F	No lens right eye
4	55	M	Retinitis Pigmentosa
5	63	F	Retinitis Pigmentosa
6	40	F	Axenfeld Rieger Syndrome
7	20	M	Retinoblastoma
8	28	F	Multiple Sclerosis
9	46	F	Glaucoma
10	45	M	Glaucoma

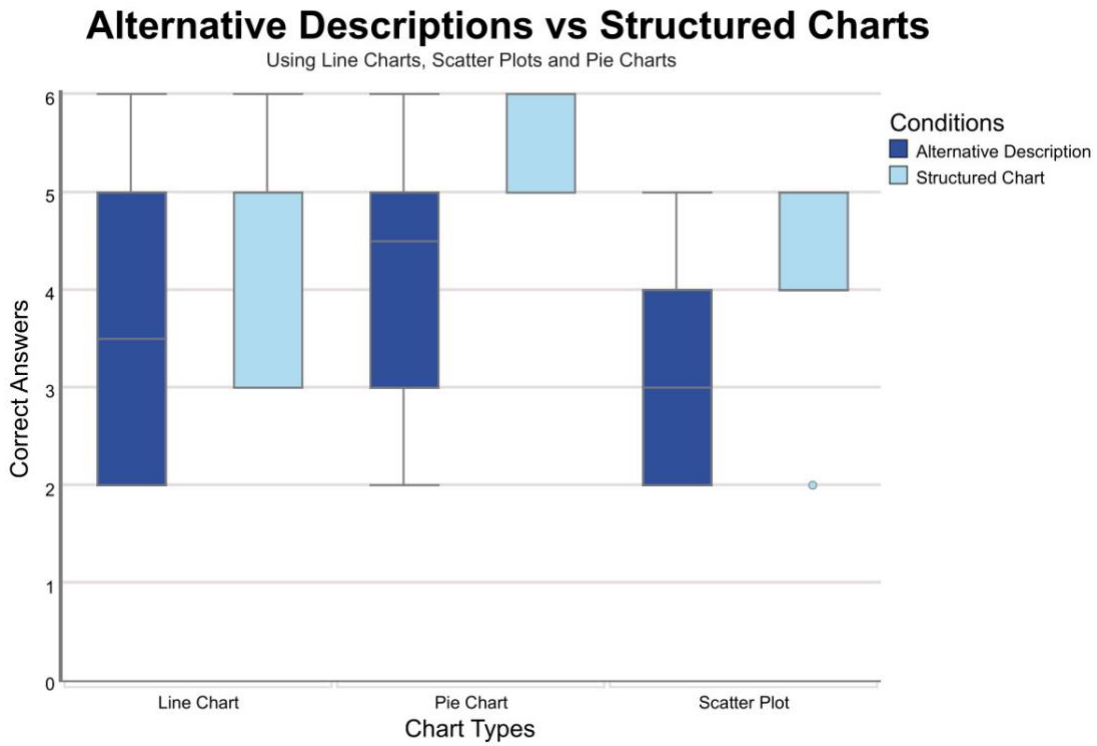
Procedure

Participants first completed an intake survey with demographics questions, followed by a brief training phase before each condition to verify baseline familiarity with NVDA. Each session lasted approximately one hour and included both conditions (Structured Charts, Alternative Description) in randomized order. For each chart type, participants completed a training phase and experimental phase. In the training phase, participants explored a chart and answered a few criterion questions (e.g., “What type of chart is this?”). During training, experiment proctors were available to aid with technical aspects of interaction, such as answering questions about NVDA key commands, and to verify that participants had enough familiarity to progress through the tasks. In the experimental phase, participants were given five minutes when each chart was first presented to explore its contents before they were asked to answer six questions. We ensured that all alternative descriptions and accompanying data tables provided sufficient information to answer the questions. Participants were allowed to consult with the charts during and between questions. Context, such as chart type and aggregate summaries of the internal elements (e.g., how many slices, line segments, or points), was given for each category of charts as internal.

Results

In the Alternative Description condition, participants, on average, correctly answered 4.1 (*SD* = 1.37) out of 6 questions for the pie charts, 3.2 (*SD* = 1.22) out of 6 questions for the scatter plots, and 3.8 (*SD* = 1.61) out of 6 questions for the line charts. In the Structured Chart condition, participants on average correctly answered 5.7 (*SD* = .48) out of 6 questions for the pie charts, 4.1 (*SD* = .87) out of 6 questions for the scatter plots, and 4.3 (*SD* = 1.12) out of 6 questions for the line charts. A paired-samples *t*-test suggested that participants performed significantly better in the Structured Chart condition than the Alternative Description for the pie charts ($t(9) = 4.31$, $p = .002$, 95% CI (.47, 2.21), $d = 1.17$) and the scatter plots ($t(9) = 2.58$, $p = .02$, 95% CI (.44, 2.12), $d = 1.10$). However, there was no difference in performance for line chart between description categories ($t(8) = 1.07$, $p = .31$, 95% CI (-.33, .97), $d = 1.23$). Figure 7 shows a boxplot comparing total correct answers for each chart type per participant for the Alternative Description and Structured Chart conditions.

Figure 7: *Correct Answers for Alternative Descriptions versus Structured Charts*



Outcomes and Benefits

Chart accessibility is a complex problem with a variety of solutions being investigated in the literature, such as sonification, tactile feedback, generative AI captions, QA systems, and structured navigation. Each has potential benefits, but in this work, we explore the implementation of a chart creation tool that allows the automatic generation of accessible charts that can be navigated very similarly to a user interface. While much of the prior work in this area has explored the interaction

model and made use of high-fidelity prototypes, which involve a human-in-the-loop manually tagging example charts, we investigate the efficacy of a chart creation tool that implements accessibility automatically. The results of our study show that the deliverables of our system, automatically accessible charts, worked as well or better than charts that had sighted assistance with creating an alternative description.

In addition to the study, arguably the more crucial innovation is that because our approach uses standard mathematical formulas to calculate all relevant accessibility information from first principles, our results are not the same as a Large Language Model trying to estimate accessibility information—the accessibility information is based on mathematical guarantees. While not discussed at length in this paper, for many chart types, the types of mathematical models used behind the scenes are typical (e.g., regression, ANOVA models, factor analysis, descriptive statistics), so that the accessibility information is not simply a guess. As a tangible example, if a blind user generated a regression model in n-dimensions, statistically appropriate information (e.g., trends, *p*-values, effect sizes) is embedded strategically into the descriptions to provide relevant information at the relevant time. This is true regardless of the visualization type.

The benefits of this technology are thus difficult to pin down with an exhaustive list. Our primary focus in this paper has been on facilitating the independence of data scientists with blindness or low vision. Data visualizations are a central component of the data science workflow, supporting both rapid exploratory analysis and the clear communication of findings in reports. However, charts are used by a much larger population for a variety of reasons, and automatically accessible charts could have benefits for those authoring charts in their given field and anyone reading charts in their day-to-day lives.

Through a series of studies, we have worked with individuals with a wide range of lived experiences and accessibility needs beyond those with blindness and low vision. While getting the interaction model and proper screen reader and braille device support is an essential step, there are other insights that we have been able to gather by working with the community in our development process. For example, although we used the literature to support an evidence-based decision about the color palette using Colorgorical, a system for generating perceptually discriminable and aesthetically pleasing color palettes (Gramazio et al., 2017), we received significant negative feedback in focus groups, almost universally disliking Colorgorical's limitations on color hue. After investigating, we observed that the Colorgorical approach has other issues, notably that it tends to do a poor job ensuring that all colors have sufficient contrast against the background and adjacency in tandem. While we do not discuss it here, we have created our own approach in later versions of the charts based on a different mathematical model. And, while we work with these technologies daily and rigorously test our software with a range of assistive tools, important gaps can still be missed and only become apparent to someone who relies on them for everyday tasks. We have found that this is often the case for individuals with low vision, an often-overlooked group in the literature.

Lastly, designing an interaction model for structure navigation is important, but ensuring consistent implementation across varying platforms, browsers, and assistive technologies adds a lot of complexity. One of the major strengths of our charting system is that it is open-source, free, and

publicly available. It runs on multiple operating systems (Windows, Mac) and has been tested with many of the popular screen readers (e.g., JAWS, NVDA, VoiceOver) and browsers (e.g., Chrome, Firefox, Safari). The system also supports a diverse set of use-cases: generating charts in an integrated development environment locally with OpenGL, running a code editor in the browser using WebGL, or exporting charts to SVG so share or host on the web.

From a data science perspective, the system supports a range of visualization tasks, including exploratory data analysis, verification of content within a chart, and reviewing visualizations created by collaborators. Analysts with blindness or low vision can independently explore trends, outliers, and individual data points before incorporating figures into reports, dashboard, or publications. While Structured Charts provide rich, interactive navigation on platforms such as the web, publication-ready PDFs cannot support the additional technologies necessary to add an interaction model, to our knowledge. As a result, the system is best suited for verification and analysis prior to PDF publication; once a chart is embedded in a PDF, readers rely on an alternative description.

Discussion, Limitations and Future Works

One reasonable interpretation of our study is that we were testing whether Structured Charts were easy to use for simple charts and whether it gave sufficient information automatically. This is an important point to remember compared to prior work. Our system fully automates generation of the structure, without any human intervention. We were careful to ensure that all questions were answerable with alternative description and, thus, were arguably generous to the description group. For example, the human-generated descriptions had the benefit of sighted assistance pointing out specific points of interest, such as which quadrant an outlier or cluster of points is in. While both things could be features included automatically, we feel that taking a more precise approach to inclusion of statistics, points of interest and features like additional hotkeys, layers, or navigation modes will help to meet the needs of the users while not overloading the system with so much information by default that overloads the user. Furthermore, it is important to remember that the goal is to provide independence for all data scientists, from novice learners to professionals. So, there likely will be some variance in what individuals want to know, and future work will be required to investigate these topics. We think that an approach to those topics similar to that of Sharif et al. (2024) might be a good path for this type of research; interviewing professionals in the data science space, likely ranging from teachers of novice learners to professionals in the field, and to better understand what questions they run into and what information would be necessary for each chart type to fully scope out what the minimum details should be at different experience levels and what broader set of details would be necessary. And then use that information to create feature improvements and test the chart generation tool again.

Lastly, while we do discuss our study results and what they may suggest, it is important to keep in mind that this was a small-scale randomized controlled trial, and the results may not generalize. This can be a difficult sample to find, as individuals with blindness or low vision come from varying backgrounds, age ranges, and experience levels with mathematics, data science, programming, and assistive technologies. Our goal in this work was to build and describe a system for making automatically accessible charts, as well as include some degree of user validation testing in the initial development cycle as a litmus test before expanding to larger scale testing.

Overall, to understand what we believe is the core lesson from our study requires remembering two key facts: 1) in practice, alternative descriptions are almost always missing or poorly done in academic papers and on the web (Bigham et al., 2006), and 2) even under conditions generous to alternative descriptions, we still observe better results with Structured Charts. Prior work by Emerson and Anderson (2018) highlights that different STEM images require different levels of descriptive granularity to be understandable, and this relies heavily on the content creator selecting a granularity and authoring a description that meets this requirement. Structured Charts enable users to start with high-level summaries and interactively drill down through multiple levels of detail to find the information they need. Previously, we pondered whether Structured Charts were truly accessible; however, our findings suggest that the question may be better reversed: Are alternative descriptions actually accessible? For charts, our study seems to favor structure and interaction over reliance on static, human-authored descriptions that must anticipate users' diverse information needs.

Conclusions

In this paper, we make two contributions. First, we created a chart generator that automatically makes accessible charts. Our charting library is free, open-source, and publicly available for use, modification, or improvement, and can be found at https://github.com/qorf/quorum-language. Second, we tested our tool in a user study with 10 users with blindness or low vision. Results from our study show that we can generate accessible charts that are at least as, and in some cases more, accessible compared to human-created alternative descriptions. While there is still room for improvement in the details of what is included in an automatic generation tool, this is a step forward in validating that it may be possible to remove the human-in-the-loop necessary in the current status quo. This may significantly improve accessibility in data science and open the door for data scientists with blindness or low vision to regain some autonomy in their work.

Given that alternative descriptions are often missing anyway, this provides a potential shift into what it means to be accessible. Instead of relying on humans to label charts, it might be feasible to move to automatically generated Structured Charts or visualizations. This may significantly improve accessibility in data science and beyond, as well as move us closer to the independent experiences that are desired by all.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No non-financial disclosures were reported by the author(s) of this paper. The work is supported by the National Science Foundation under Grant Nos. 2048356, 2106392, 2048428, 2106394, 2048605, 2048394, 2106393 and 1822800. We extend our sincere appreciation to the participants of the user study.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 106-131
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Industry

Engaging Learners with Disabilities in Design of Online Request Processes for Testing Accommodations

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Abstract

This article details a multi-year, multi-project research collaboration between Microsoft and the Accessibility User Research Collective (AURC) to update the organization and information on the Microsoft Learn website and the requirements for requesting testing accommodations for Microsoft's technical certifications in order to facilitate the process of requesting and receiving testing accommodations. The AURC is a user experience research program at Shepherd Center, a not-for-profit hospital for people with disabling neurologic conditions and diseases. Accessibility in online learning, spanning the entire experience, including requesting and using testing accommodations, is critical to promoting social, professional and economic inclusion of people with disabilities. Microsoft and the AURC have collaborated on 19 discrete user needs and usability research projects since 2021, investigating diverse aspects of certification training and examination interfaces. This article summarizes four of these collaborative research projects across three phases of product development (needs discovery, prototype testing, and final validation) aimed at enhancing the accessibility and usability of the Microsoft accommodations resources. This includes updating policies and procedures for requesting testing accommodations and making it easier to understand and follow Microsoft's process for requesting accommodations for examinations. This collaborative effort illustrates the importance of a sustained user experience research program when planning and implementing system-wide changes for people with all types of disabilities.

Keywords: user experience, usability, accessibility, test accommodations, online learning, industry collaboration

Engaging Learners with Disabilities in Design of Online Request Processes for Testing Accommodations

This article describes a multi-year, multi-project collaborative research and development effort to enhance the process for requesting and receiving testing accommodations for certification exams provided by Microsoft's technical training and certification division, Microsoft Learning. To gather user insights from learners with disabilities, Microsoft partnered with the Accessibility User Research Collective (AURC), a disability-focused user experience research program based at Shepherd Center, a rehabilitation hospital for people with chronic disabling neurological diseases and conditions in Atlanta, Georgia.

Career and technical education (CTE) – acquisition of new professional knowledge and skills – is closely intertwined with expanded employment opportunities, career advancement, and enhanced personal self-actualization and well-being. CTE in turn contributes to the smooth functioning and growth of the overall economy, enabling the workforce to adapt to new technologies, job roles, and organizational structures. Ongoing economic transformation and innovation across all fields, especially scientific and technical fields, makes CTE ever more critical to continued employment and professional advancement, as well as to microeconomic business adaptation and macroeconomic growth (Kirsch & Braun, 2016). CTE is often delivered via certificate-based training programs either through colleges and universities in parallel to their regular degree programs or through certifying private and corporate training programs. Science, technology, and business management certificate programs are the most common. Microsoft is a leading provider of CTE and certification programs, offering 78 distinct credentials and 4,379 separate courses, modules, and learning paths that cover Microsoft's extensive portfolio of software products and services.

Beginning in 2021, Microsoft began to explore updates to its documentation policies for disability verification to simplify without risking exam security as well as to the Microsoft Learn website to facilitate discovery of accommodations documentation requirements and streamline the process for learners to request testing accommodations. Microsoft engaged the AURC to co-design a series of user experience research studies to inform and guide those updates. From 2021 to the present, Microsoft and the AURC collaborated on a total of 11 research studies on user needs and experiences related to Microsoft's accommodations documentation requirements and the accommodations request process. These user experience research studies utilized a mix of methods, including surveys, in-depth interviews, and user-testing of prototype webpages. In this article, we summarize four of these research studies, highlighting the arc of user experience research across three core phases: 1. discovery of needs, 2. evaluation of solutions and prototypes (content, webpages, and process flow, in this case), and 3. validation of near final solutions before deployment.

Personal Statements and Disclaimer

Delaney Cowart is a biomedical engineer, user experience researcher and the program manager for the Accessibility User Research Collective (AURC). She has 5 years of experience designing and leading user experience research projects for the AURC's commercial partners and

for other technology development grants funded by the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR). John Morris is a senior research scientist and the director of the AURC. He has 18 years of experience designing and conducting user-centered research for commercial partners and NIDILRR funded grants on technology development. The AURC operates on a work-for-hire contract model with private industry. It has conducted research for Fortune 500 companies and smaller vendors, including startups and grant-funded product development and evaluation projects. The AURC is committed to rigorous and non-partial research that provides valid user insights to inform the development of accessible and usable products and services.

Kathy Dixon is Principal Customer Experience Program Manager in Global Skilling at Microsoft, responsible for the development, testing, and implementation of accessibility and accommodations policies and processes. Her 25-year career at Microsoft has included senior-level roles in user experience, accessibility, accommodations, and inclusive experiences. She led revisions to Microsoft's soft-skills curriculum to reflect the needs of neurodiverse learners, improving the learning experiences for over 65,000 employees. She is a member of the disability community and is committed to developing evidence-based solutions derived from rigorous user research to promote inclusion.

Target Audience and Relevance

The target audience for this article includes people with various professional and user backgrounds: 1. user experience and academic researchers; 2. product designers/developers; 3. educators and corporate learning and development (L&D) professionals; 4. organizations that develop and deploy online training and certification programs; 5. advocacy organizations; and 6. people with disabilities.

For user experience and academic researchers and product designers/developers, this article provides insights into how to establish and conduct a durable partnership between product and service vendors and external user-centered research organizations to engage communities of people with disabilities. Critical to the success of user experience research projects are active engagement and interaction between both the client company and the research organization. The client company has detailed knowledge of its product and service offerings and the specific questions that need to be answered to inform the work of designers and engineers. This article describes the development of a research program comprising multiple individual user-centered projects that are implemented over time and that build on the insights gained from previous projects.

External disability-focused research organizations have unique insights on how to engage and recruit people from communities of people with disabilities, expertise with research design and effective data collection techniques for specific disability populations, familiarity with human subjects research protections processes, and agility in developing and conducting user-centered research projects with target disability populations. Advocacy organizations and people with disabilities will gain insights into mechanisms and processes for participating in accessibility-focused user experience research. These include insights into the development and execution of user-centered research for product and service development, user needs research, and the outcomes and benefits

of user-centered research. This article is relevant for all these target audiences as it provides information on the regulatory background and best practices for processing requests and ultimately providing testing accommodations.

Background and Literature Review

Testing Accommodations Requirements

Testing accommodations are changes to the regular testing environment and auxiliary aids and services so that "the examination results accurately reflect the individual's aptitude or achievement level or whatever other factor the examination purports to measure, rather than reflecting the individual's impaired sensory, manual, or speaking skills." (U.S. CFR 36.309 (b)(1)(i)) Testing accommodations cover a wide range of changes to the testing environment, including extended time, breaks, screen reading technology, scribes, distraction-free rooms, and wheelchair-accessible testing spaces, among other accommodations. The Americans with Disabilities Act (ADA) requires that accommodations be available for tests administered by any private, state, or local government entity for "applications, licensing, certification, or credentialing for secondary or postsecondary education, professional, or trade purposes." (U.S. CFR 36.309 (a)). The most common testing accommodations requested and granted for high-stakes exams in the U.S., according to a recent study by U.S. Government Accountability Office (GAO) are: extra time (55% of requests), adjustments to the testing environment (22%), auditory or visual assistance (6%), alternate test format (6%), time-stop breaks (4%), and other accommodations (8%; U.S. Government Accountability Office, 2022).

Disabilities covered by the ADA's testing accommodations rules include physical or cognitive impairment that substantially limit a major life activity (e.g., learning, reading, walking, sitting, writing, typing) or a major bodily function (e.g., musculoskeletal, neurological systems). Determining whether an individual has a disability should not require extensive analysis or place repeated or extensive burdens on the individual (i.e., requiring excessive documentation from a healthcare provider). Accommodations must address specific barriers created by the interaction of the testing methods and environment with the examinee's specific disabilities. Section 309 of the ADA requires any entity that provides examinations for educational or employment applications, licensing, certification or credentialing to offer them "in a place and manner accessible to persons with disabilities or offer alternative accessible arrangements for such individuals" (42 U.S.C. § 12189). Accommodations must not provide an unfair advantage to the examinee with disabilities. They must ensure access, not success (Balasa & Case, 2019).

Documentation

Any documentation of disability required by a testing entity must be reasonable and limited to supporting the specific requested testing accommodations. Appropriate documentation varies depending on the disability and the requested accommodations. Examples of documentation include: proof of past testing accommodations, history of disability diagnosis, results of professional evaluations, recommendations of qualified professionals (including educators), and an applicant's statement of their history of testing accommodations. Depending on the nature of the disability and requested accommodations, a testing entity may require only one or two forms of documentation.

Documentation of disabilities to support accommodations requests and the process for review varies across credentialing organizations, resulting in uneven administration of testing accommodations. The U.S. Government Accountability Office (GAO) highlighted this variability in a 2022 report, noting that for seven of the most widely taken high-stakes exam programs — ACT, Advanced Placement (AP) exams, Graduate Management Admission Test (GMAT), Graduate Record Examination (GRE), Law School Admission Test (LSAT), Medical College Admission Test (MCAT), and Preliminary SAT (PSAT) — the rate of approval of accommodations requests varied from 39% to 98% (U.S. Government Accountability Office, 2022). Furthermore, accommodations documentation requirements varied based on the disability or diagnosis of the requestor.

Request Process and Timeliness of Review

The process for requesting a testing accommodation should not be burdensome. It should be easy to understand what documentation is required, how to submit the request for accommodations, the timeframe for a response, and the opportunity for appeal of any denial or limited approval. The review and response process for accommodations requests should ensure that the applicant has sufficient time to register and prepare for the test. Also, the process should allow for a reasonable opportunity to respond to any requests for additional information or documentation from the testing entity.

Social, Economic, and Technology Trends and Career and Technical Education

An estimated 39% of worker skills are expected to be “disrupted” — requiring additional training for existing or new jobs — between 2025 and 2030, according to the annual Future Jobs Report, 2025, published by the World Economic Forum (WEF; Leopold et al., 2025). Total job creation and destruction caused by structural labor market transformation, according to the WEF report, will be equal to 22% of current total employment, including creation of 170 million new jobs globally (14% of current total employment) and displacement of 92 million jobs (8% of current employment). Though the disruption of skills is expected to impact 59% of the current global workforce, adequate training programs are available to only half of the workers impacted, according to companies surveyed for the WEF report.

CTE encompasses a broad range of programs that include secondary and post-secondary institutions, providers of massive open online courses (MOOCs) and non-academic institutions such as occupational licenses, industry-recognized certifications, military certifications, and apprenticeships, among others. It is estimated that 738,428 unique credentials were offered by CTE programs in the United States in 2021, including 370,020 credentials offered by postsecondary institutions (colleges and universities recognized by the U.S. Department of Education under Title IV of the Higher Education Act as meeting academic and operational standards) and 315,067 by non-academic organizations (Credential Engine, 2021).

Reliable data for the number of learners earning non-academic credentials (certificates) in the United States are not available due to the large number and heterogeneity of conferring organizations and programs. However, the number of certifications completed at academic

institutions in the U.S. has continued to grow in recent years after declining slightly in the 2020–2021 period, most likely due to the COVID-19 pandemic. In the 2021–2022, 2022–2023, and 2023–2024 periods, the number of certificates conferred annually by academic institutions grew by 4.9%, 5.5%, and 11.2%. Meanwhile, the number of associate and bachelor's degrees declined, though at a slowing rate, -3.4%, -1.9%, and -1.3%, over the same 3 years (National Student Clearinghouse Research Center, 2024), a pattern that may be related to the gradual recovery from the COVID-19 pandemic.

Importance of CTE to Employees, Employers, and People with Disabilities

The growing numbers of certificate programs and certificate completions in the U.S. in recent years reflects the increasing importance of these credentials for career advancement and workforce development. Employees generally value CTE opportunities for keeping their knowledge and skills current and for professional advancement. In a recent survey research study of adult members of the workforce in the U.S. sponsored by Amazon and conducted by Gallup, 57% of respondents said they were "extremely interested" or "very interested" in participating in an upskilling program to learn new skills or upgrade their skills to advance their careers (Gallup & Amazon, 2021). Specific reasons motivating interest in upskilling by these respondents were advancement in current careers (59%), finding a new career with higher pay (17%), finding a more fulfilling job (11%), and seeking a new job with greater potential for growth (10%). Higher percentages of respondents from racial/ethnic minority groups were extremely or very interested in upskilling programs than White people, underscoring the perceived socioeconomic benefits of upskilling by people from lower-resource communities. Similar results, including the positive perceptions and impact of CTE on people from low-resource and minority communities, are reported from other surveys (Daugherty, et al., 2023; Lin, et al., 2024; McKinsey and Company, 2024).

People with disabilities also generally have lower socio-economic resources. Compared to the population of people aged 18–64 without disabilities, people with disabilities in the same age range have substantially lower completion rates for high school and 4-year college programs, employment rates, and earnings from work. Meanwhile, they have much higher poverty rates (Houtenville & Bach, 2025). Consequently, they are likely to share many of the same challenges to postsecondary education as individuals from lower resource communities and racial and ethnic minorities: limited financial resources, time, access, and family/community support. But they are not generally included as a demographic group in large surveys on attitudes and perceptions of CTE and skills acquisition, a critical "troublesome" gap in existing research (Lombardi et al., 2018).

Impact of Testing Accommodations on Test Results and Learner Experience

In general, research shows that testing accommodations contribute to the success of test takers with disabilities, without providing unfair advantage (Sireci et al., 2003). However, the literature is not uniformly consistent about the impact of accommodations because of the wide variety of possible accommodations, disability types studied, testing context and type of tests, and design of the research protocols (Sireci & O'Riordan, 2020). Additionally, the high variability in the quality of research design, especially insufficient sampling power, contributes to variability in results and for

some studies the inability to establish causal relationships between variables (Römhild & Hollederer, 2024).

The most robust studies compare test takers with disabilities who use approved accommodations with other control groups: either 1) students with disabilities who do not use approved accommodations; 2) students with disabilities who were not approved for accommodations; or 3) students without disabilities who do not use accommodations. One study that analyzed performance, process, and posttest survey data of eighth graders with learning disabilities (LDs) showed that students with LDs who used extended time accommodations (ETAs) performed statistically significantly better than their peers with LDs who were not granted ETAs and those who received ETAs but did not use them. They also engaged more with the test, as indicated by more frequent revisits to test items and greater use of features like drawing and text-to-speech functionalities. Post-exam survey data showed that students who were given extra time, regardless of whether they used it, reported feeling less time pressure and greater interest and enjoyment of the content (Wei & Zhang, 2024).

Another study comparing silent reading and comprehension test results of students with and without attention deficit hyperactivity disorder (ADHD) in both regular classroom and private proctored settings showed that separate room accommodations may be beneficial to some students with ADHD (Lovett et al., 2019). The relatively small samples in this study make results less reliable. A sufficiently powered study of results from Israel's national Psychometric Entrance Test (PET) confirmed the positive effects of extended time and breaks on test performance of students with ADHD (Saka et al., 2025). In contrast, a study of the impact of common testing accommodations on results from standardized math exams taken by grade school students with ADHD showed no improvement on test outcomes (Pritchard et al., 2016).

Methods

The Accessibility, Accommodations, and Inclusive Experiences team within the Microsoft Customer and Partner Solutions (MCAPS) division first engaged the AURC in September 2021 to gather user feedback about the Microsoft Learn website and platform to evaluate its content, usability, and accessibility. Over the subsequent four years, the AURC collaborated with the team at Microsoft on a series of 19 discrete user experience research studies that engaged disabled learners to discover and explore current needs related to online learning and testing. Eleven of these studies focused on exam accommodations (Table 1), including the evaluation of Microsoft's accommodations policies, offerings, and webpage design.

The goals of these studies were to 1) identify areas for improvement, 2) test several iterations of the proposed new webpage for reviewing accommodations requirements and request processes, and 3) validate the improvements through user-testing of the prototype and final iterations of the accommodations webpage. Protocols for each study were reviewed for Human Subjects Research Protection and approved by Shepherd Center's Institutional Review Board (IRB).

This article summarizes four (4) of these user experience studies spanning three (3) phases of the accommodations content and webpage development:

- **Phase 1**: Exploration of disabled learners' user needs regarding content offered on the accommodations webpage, as well as its usability and accessibility.
- **Phase 2**: Gathering user feedback on proposed content and usability and accessibility of prototypes of the accommodations webpage.
- **Phase 3**: User validation of prototype and final accommodations webpages.

Table 1: *Accommodations Research Projects Conducted by the AURC and Microsoft*

Date	Study Method	Disability Population	*N*	Study Description
November 2021*	In-Depth Interview	Blind, low vision, dexterity, mobility, learning disability	8	User history of requesting accommodations; exploration of old webpage: what is missing or unclear and layout design
April 2022	User Testing	Neurodivergent, blind, low vision, mobility	10	Task completion on old Microsoft Learn website: finding exam information and scheduling exams with Pearson Vue
June 2022*	In-Depth Interview	Blind, low vision, neurodivergent, hearing, mobility	6	Asynchronous content review for Accommodations website; followed by 30 min In-depth interviews (IDIs)
September 2022	User Testing	Blind, neuro-divergent, mobility, Deaf	8	Completed tasks on finding accommodations info on MSFT Learn website and requesting accommodations
November 2022	Survey	Any disability	50	Survey gathering feedback about MSFT's policies for documentation requirements for accommodations
December 2022	In-Depth Interviews	Any disability	8	IDIs focusing on those who need accommodations, but who do not have documentation
March 2023	In-Depth interviews and user testing	Any disability	8	IDIs and task analysis on Figma prototype of new website
June 2023*	In-depth interviews and User testing – Part 1	Neurodivergent or learning disability	4	IDIs and task analysis of Figma website prototype. Finding documentation requirements, request process and support
September 2023*	In-depth interviews and user testing – Part 2	Low vision, blind	8	Testing accommodations request webpage prototype; IDIs finding accommodations and associated required documents

December 2023	In-depth interviews and User testing	Low vision, blind, neurodivergent, low dexterity	8	Testing accommodations request webpage prototype; finding accommodations and uploading the required documents
June 2024*	Survey and User Testing	Blind, low vision, cognitive, neurodivergent, dexterity	45	How to find information on accommodations on near-final webpage design; history with requesting accommodations

The first study broadly evaluated the needs of disabled learners related to the Microsoft Learn accommodations webpage, the accommodations offered, and the process of requesting and using those accommodations. The design of each subsequent study was informed by user needs identified and feedback collected in the preceding studies. Upon conclusion of data collection for each study, researchers identified common themes and critical barriers from the feedback and developed recommendations to improve the content and webpage's accessibility. Designers and developers at Microsoft incorporated those recommendations into iterative prototype designs of the webpage. The prototypes were then tested with target end users to evaluate their format, content, discoverability of content, and accessibility to ensure that user needs were met.

Each study varied in its target population and data collection methods. However, every study utilized the same sampling and recruitment methods developed and refined by the AURC over many years of operation. The AURC maintains a national network of more than 1,400 people with diverse disabilities who are interested in testing products and sharing their lived experiences with researchers and product developers. When they join the network, members complete an "intake" or "member" form that records their contact information, demographics, disability, assistive technology use, and general technology use. The AURC's panel includes members in all 50 states of the United States of America, as well as all ages (over the age of 18), races, socioeconomic, and educational backgrounds. Once the disability population for a study was identified, researchers compiled a geographically and demographically diverse list of potential participants from the AURC members who matched the inclusion criteria.

For each study with Microsoft, researchers from the company and the AURC jointly designed a short screener survey on the SurveyMonkey platform to identify potential participants. Respondents answered questions about their disability, accessibility needs and tools, experience with online courses, and history of testing accommodations. The research team reviewed the data collected from the screener survey to: 1) identify eligible participants, 2) gather a high-level understanding of the participants' accessibility and accommodations needs, and 3) prepare follow-up questions to ask during the interview or main phase of data collection.

Survey data were collected asynchronously by sending links to study questionnaires to invited AURC members who had met the study inclusion criteria. Data collection usually lasted 2–3 weeks for each study, with periodic checks to ensure high data quality and completeness. Some survey studies required participants to visit live or prototype Microsoft Learn webpages to explore content and layout. Survey studies were closed when sampling targets were achieved. After closing each survey, AURC researchers cleaned the data by removing mostly incomplete responses and "straight-

liners" who speed through the survey and answer every question the same. Survey analyses in this series of studies relied mainly on descriptive analyses, such as overall percentages and frequencies, and subgroup analysis by disability groups to identify trends in task completion and barriers by disability. Results were then shared with Microsoft partners, along with executive summaries of key findings.

Interviews were conducted using moderator guides jointly developed by staff from Microsoft and the AURC, who identified questions about topics of interest and their sequence during the interviews. The moderator of the interview followed these guides, asking the participant the outlined questions. The interviews always started with introductory questions, building rapport between researcher and participant and establishing context before the core questions. Researchers also asked follow-up, probing, and exploratory questions to further expand upon participants' responses. These probing prompts make participants think more deeply about and explain the reasoning behind their answers and allow researchers to identify the root causes of problems or successes.

For interviews and user testing, participants were asked to "think aloud" as they attempted to complete the assigned tasks, so that the research team could better understand their decision-making process and identify which features and elements of the webpage stood out. Researchers conducted thematic analysis by first taking notes during the interview and identifying the most important results by participant. We noted if a participant took a long time or could not complete a task, if a participant particularly liked or disliked a website component, or if a process was very intuitive or unintuitive. Additionally, user comments expressing affect (pleasure, frustration, etc.) related to tasks or user interface items were noted and analyzed. After taking notes for each participant, all results were compared across tasks and questions to identify the themes of the study, including the biggest barriers, the best facilitators, and overall recommendations by the participants.

In addition to qualitative analysis, when testing the accommodations webpage prototypes, participants were asked to rate the ease/difficulty and satisfaction/dissatisfaction with tasks or experiences on 5-point Likert scales. Researchers averaged these ratings and compared them across studies to identify whether the ease of a task improved after a change in the webpages was implemented. All interviews and user testing sessions were conducted remotely on either Microsoft Teams or Zoom. Interview recordings and transcripts were captured by the AURC team and de-identified before sharing by secure file transfer with Microsoft. All participants were compensated upon completion of each study at a rate of $50 per hour.

Results

The three user experience research phases were carried out across four studies from 2021 to 2024, utilizing surveys, interviews, and user testing of prototypes and final designs for the Microsoft Learn accommodations web subsite.

Phase 1: Exploration of User Needs

Study 1: Discovery of User Needs for Accommodations – Interviews

The multiyear series of user experience studies commenced with an exploration study of user needs for accommodations. Study 1 was collaboratively designed by the AURC and Microsoft, utilizing in-depth interviews (IDIs) to uncover needs and gather feedback from learners with disabilities. The goals of the study were to 1) learn about and understand the barriers and facilitators that disabled learners had encountered when requesting and using accommodations for testing in the past and 2) evaluate the discoverability, accessibility, usability, and content of the existing Microsoft Learn webpage for accommodations. Feedback gathered from interviews informed the new design of the process for requesting accommodations and its presentation on the webpage.

To broadly gather the needs of people with disabilities in this initial exploratory study, the AURC recruited 8 participants for this study, with two participants recruited for each of 4 disability subgroups: blindness, dexterity- or mobility-related disability, d/Deafness, and neurodivergence. The four main groups were included to ensure the representation of various needs when evaluating the accommodations process and to identify at a high level the barriers within each group. To be eligible for this study, in addition to having a disability, participants must have relied on accommodations to engage in a learning activity or exam. A group of participants with a mix of disabilities was used so that a broad set of accommodations were represented in the study.

Researchers engaged participants in an hour-long in-depth interview on Zoom. The interview questions were organized into four sections: introduction, experience with accommodation eligibility and registration, experience with accommodation delivery, and website discovery and feedback. In the introduction section, the participants were asked about their disability, occupational background, and typical accommodations or assistive technology used on their desktop or laptop computers, so that researchers could understand the context in which these disabled learners request accommodations.

When discussing accommodation eligibility and registration, researchers inquired about participants' experiences with the accommodations process leading up to delivery of their accommodations. The line of questioning focused on how participants identified their needs and expectations for learning about and requesting accommodations. Most learners reported expecting a detailed timeline on the webpage, from application to delivery, ranging from one week to several, but usually no longer than a month. For learners requesting accommodations through that entity for the first time, they expected that the request might require more documentation, effort, and time for approval. However, after their first request for accommodations, any subsequent request should be faster, as individual profiles should be saved for future requests. This was an important factor, as it saves time and effort for repeat test takers.

Regarding the delivery of accommodations, researchers sought to understand the participants' experiences with the process following their accommodations requests. Participants were asked about their preferences with preparation materials and instructions ahead of the exam, testing environment (e.g., in-person versus online), available technologies, and interactions with exam proctors. They emphasized the importance of confirmation of approval or denial of their accommodations as soon as possible, with preference towards email communications for their record keeping. The email should contain the instructions for next steps regarding how to schedule their exam and how to obtain their accommodations.

Finally, the last section of the interview focused on reviewing the Microsoft Learn accommodations website. The researcher guided the participant to the webpage with more information about specific exams and requested that they share their screen. Participants were asked where they would expect to find information on exam accommodations and what type of information they would expect to be included. On the original website, the label for the link to accommodations content on the exam webpage was ambiguous to participants. It read “Support for certifications and exams.” Many participants believed that this meant they would be directed to information for support, not necessarily for accommodations. Learners preferred the most commonly used term among the disability community, which is “accommodations.”

After exploring the exam webpage, participants then navigated to the webpage with more information on accommodations. The clearest theme that emerged was that the original webpage for accommodations was presented as a long “wall of text” without much visual separation between sections. This made finding specific information very difficult and time-consuming. These findings allowed Microsoft managers and designers to begin shaping the content and prototypes of the new Microsoft Accommodations webpage.

Phase 2: Gathering User Feedback on Prototypes and Proposed Content

Study 2: Content Review and Feedback – Interviews

Following the incorporation of feedback from Study 1 into an outline for the future accommodations request process, Microsoft and the AURC conducted a study in June 2022 in which participants reviewed the proposed content for the updated accommodations request process and participated in interviews to discuss their first impressions and preferences. To ensure a representation of different needs, the AURC recruited six participants with a mix of disabilities to review the content and give feedback: two blind participants, one neurodivergent participant, one deaf participant, one with mobility and dexterity impairments, and one with low vision. Because a primary focus of this study was to review the policies regarding required documentation for the accommodations request, a broad set of disability groups was needed. This way, we were able to capture a wide range of ways that documentation is acquired across disabilities, such as doctors’ notes, individualized educational programs (IEPs), or workplace accommodations.

Participants were provided with a Word document to review independently at their convenience within a 3- to 4-day window. The document contained the unreleased text for the proposed accommodations process and its instructions. The major changes that had been made to the content were clarifying which accommodations required documentation and, if needed, what documentation is needed. Participants were instructed to take notes on their first impressions and on anything positive or negative that stood out to them. Then, researchers followed up with a 30-minute interview via Zoom. The goal of the interview was to understand participants’ first impressions of the material. Could they easily understand the information and instructions? Were they clear, concise, and relevant to participants’ needs? After discussing the content, participants were asked, “If you had to explain Microsoft’s certification exam accommodations process to a friend, what would you say about it, in your own words?”

Participants reported that from the content regarding documentation requirements, it can be difficult to gather the required documents in the updated list, especially medical documentation, to support their accommodations requests. It can be a lengthy process, in which a requestor may need to schedule an appointment with their medical provider and wait for an official note. For frequent test takers, this means it is important to keep a copy of various documentation and have it readily available to circumvent delays. Additionally, requestors then need to share their personal and confidential health information with the testing centers, which is not ideal for them.

Study 3: User Testing of Prototype Webpage (2 parts)

After the initial studies in the series, in which users evaluated content, identified improvements in the webpage, and tested new prototype webpages, Microsoft had developed a static Figma-based prototype and live webpage prototype for the new accommodations webpage, allowing more direct interaction by target users with the new content and webpage designs.

Study 3 was organized into two parts. In Part 1, the static prototype webpage was tested with disabled learners who do *not* use screen readers or magnification tools, to evaluate its visual layout and organization. Then, Microsoft developers incorporated the user feedback on the Figma prototype from Part 1 into a functioning webpage, navigable and usable by users of assistive technology. In Part 2 of the study, researchers collected feedback only from learners who were blind or had low vision, and who also use screen readers, screen magnifiers, or increased text sizes.

For Part 1, because researchers were evaluating the visual layout of the website, and not yet its compatibility with assistive technology, researchers recruited four (N = 4) participants who were neurodivergent or had learning disabilities who did not use assistive technologies to access webpages. Disabilities represented in Part 1 of the study included ADHD, dyslexia, autism, PTSD, and auditory processing disorder.

Each participant was asked to open the Figma prototype of the new accommodations webpage on their own laptop or desktop computer and attempt to complete several tasks while sharing their screen with the researchers. The participant attempted to 1) locate documentation requirements within the exam webpage, 2) learn about and initiate the process to request accommodations, and 3) identify where on the webpage one could get support if they had questions about any of the content. The participant's success in these tasks was measured by researcher observation of several factors, including overall completion, degree of confusion by the participant, the amount of time taken to attempt/complete the task, and the pathway taken to attempt/complete the task (e.g., direct vs indirect navigation path). After the participant attempted all tasks, they were asked questions by the researcher about the layout, format, and content.

For Part 2, with the visual and organizational feedback from Part 1 implemented into a working prototype website, researchers next wanted to ensure that it was compatible with and usable by assistive technologies. Researchers recruited eight (N = 8) participants with visual impairment for the second part of the study. Four (n = 4) participants had low vision and used screen magnifiers or enlarged text to navigate webpages, and four (n = 4) participants were blind and exclusively used screen readers to navigate and read webpages.

With their respective assistive technology, each participant attempted to complete the same tasks as in Part 1. The researchers recorded the same measures of success as in Part 1, while additionally examining how the user interacted with the webpage through their assistive technology and noted whether any issues with access arose. Specifically, for screen reader users, researchers monitored for properly labeled buttons, sequential presentation of content, navigable headings, and working links. For screen or text magnifier users, researchers observed the reflow (wrapping to a new line) of enlarged text on the webpage, the amount of "white space" on the page, and contrast of text and background.

A number of participants noted that the link to the accommodations webpage was "buried" in the exam webpage. Many expected it to be at the bottom of the page, as that tends to be the location for any information about accessibility-related items, but it was about three-quarters of the way down the page and presented in a long list of unrelated links. For screen reader users, this meant they would need to explore the page thoroughly, item by item or link by link, to find the accommodations webpage. For sighted users, researchers identified a common preference for visual separators and indicators, like bullets, lines between links, and bolded links or important phrases.

When they clicked into and explored the proposed accommodations landing webpage, participants were generally content with the new layout of the information, which will be described in the Outcomes and Benefits section. Participants had a much easier time navigating the webpage and finding what they were looking for quickly, compared to their experience in Study 1.

With these findings, the researchers were able to validate that they were on the right track with the webpage redesign, while still needing to adjust a few items to continue to improve the webpage. Microsoft designers incorporated the feedback from Studies 2 and 3 to produce a final webpage, to be validated by a larger number of people in the next phase through a survey.

Phase 3: User Validation

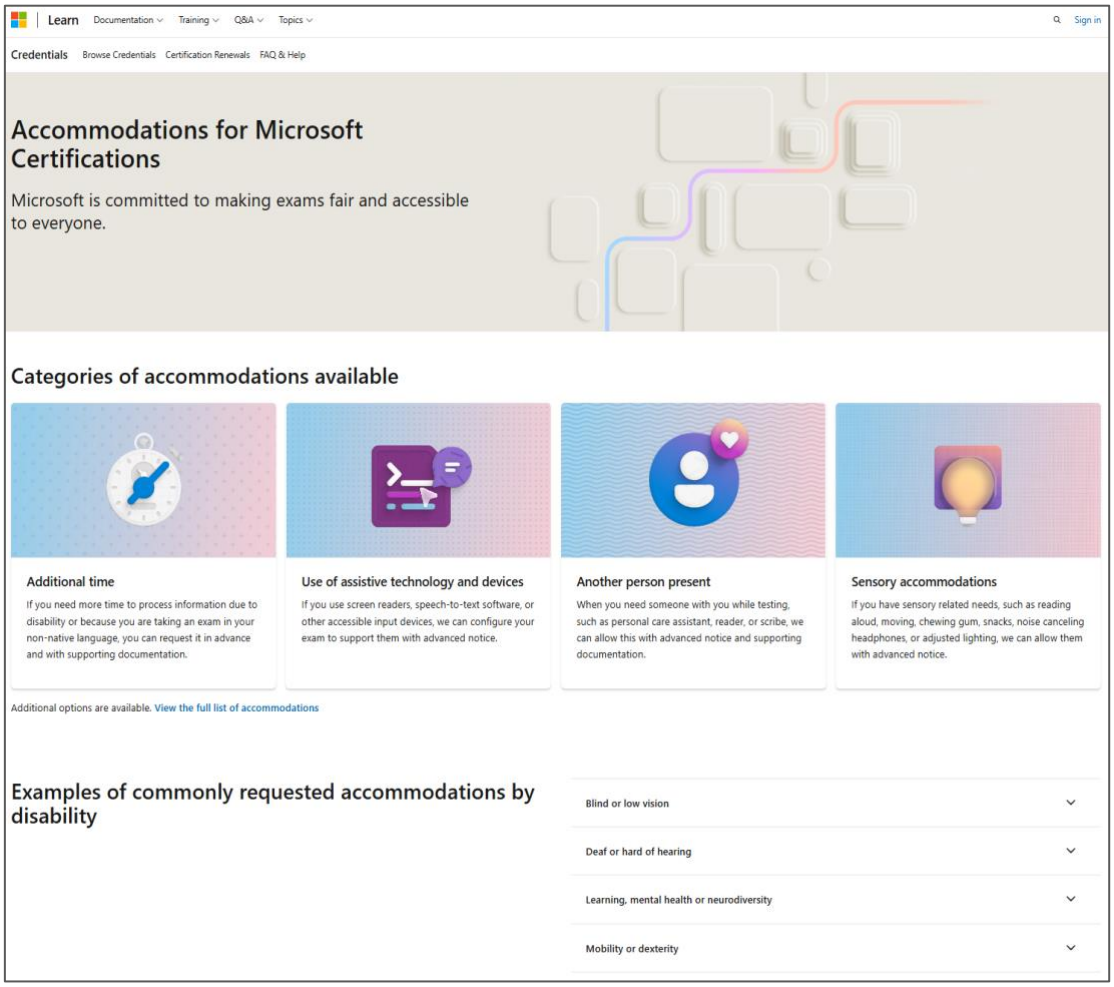
Study 4: Survey of Users Validating Published Webpage

In June 2024, the Microsoft Learn website and content (Figure 1) had reached a level of maturity at which researchers could seek final user validation. To reach a broader disability audience, a survey research questionnaire was developed and shared with 45 individuals representing various disability groups including those with visual impairments, mobility and dexterity-related disabilities, neurodivergence, learning disabilities, d/Deafness, and those who are hard of hearing. The representation of these various disability groups across a larger total number of participants ensured that people with various needs and assistive technologies would be able to give feedback on the website.

Within the survey, respondents answered questions about their disability, demographics, and history with requesting accommodations for exams. The survey included the link to a Microsoft Learn exam webpage, and respondents were instructed to open the link, find the accommodations webpage, read through the information, and return to the survey to answer the last set of questions. Respondents were asked to rate the level of difficulty of finding the information on accommodations

on a 5-point Likert scale of “Very easy” to “Very difficult,” with an additional option: “could not find any information or reference to accommodations without using the search feature.” This last option was included because the accommodations information had been rated as difficult to find by users of the previous version of the webpage before any updates. Microsoft updated its website so that users should be able to easily find this information without resorting to using the search feature. Respondents were then asked to explain in an open-ended response why they chose the level of difficulty, or why they used the search bar. In the survey, 77.3% of respondents reported that finding the information was either “Very easy” or “Easy” on the exam webpage.

Figure 1: *Final Microsoft Accommodations Subsite Landing Page*



The survey also assessed if the information on accommodations was where the respondents expected it to be, what could be done to make it easier to find (if anything), if the content was clear about what to expect during the request process, and if any issues arose while using their assistive technology on the webpage. On the new accommodations landing page (Figure 1), 93.1% of respondents reported that finding the general categories of accommodations was either “Very easy” or “Easy,” and 90.1% agreed that their preferred accommodations for test taking were accounted for in those categories. Over 95% of all respondents found the full list of accommodations, which was a link on the main landing page, with 84.1% identifying the task of finding them either “Very easy” or “Easy.” For finding what documentation is accepted for their accommodation request, 81.4%

reported that it was “Very easy” or “Easy” to locate on the webpage. In open-ended responses about the usability of the new webpage, a common suggestion was to include a filter function to reduce the amount of information shown on the page, allowing the requestor to find details relevant to their needs more quickly.

Compared to the results from Study 1, in which only 37.8% of participants thought that finding information about accommodations was “Easy” or “Very easy,” these results suggest improvements in the webpage’s content, formatting, and organization.

Outcomes and Benefits

Overall, the research projects presented here have supported Microsoft’s intention to reduce requirements for documenting learners’ disabilities to support their testing accommodations requests and improve the discoverability and user experience for Microsoft’s accommodations request process. This research program also informed the development of specific documentation policies and the design of the user interface of the Microsoft Learn accommodations subsite. Broader system-wide outcomes include reduction in barriers to CTE and testing for thousands of professionals with disabilities who seek to enhance their knowledge and skills in Microsoft technology products, expand their career opportunities and enhance their economic condition.

From the user needs exploration in Study 1, researchers identified a common theme that learners need clear expectations for the accommodations request and fulfillment timeline, which resulted in the addition of a new disclosure message on the Microsoft accommodations webpage (Figure 2). This disclosure appears at the top of the webpage that provides more information regarding accommodations, so that learners are informed immediately that 1. they need to request accommodations before scheduling the exam, and 2. it may take up to 20 days to process their request. This definitive maximum timeline allows learners to plan and reduces uncertainty about what to expect.

In Study 1, researchers also noted that a substantial cause of anxiety surrounding the accommodations process is silence from the entity following the request. Microsoft aimed to minimize this anxiety by providing **two** confirmation emails: one for confirmation of request receipt and another for approval or denial of the request, as seen in the section of the webpage on the instructions on how to request accommodations (Figure 3).

Figure 2: *Notice About Timeline for Accommodations*

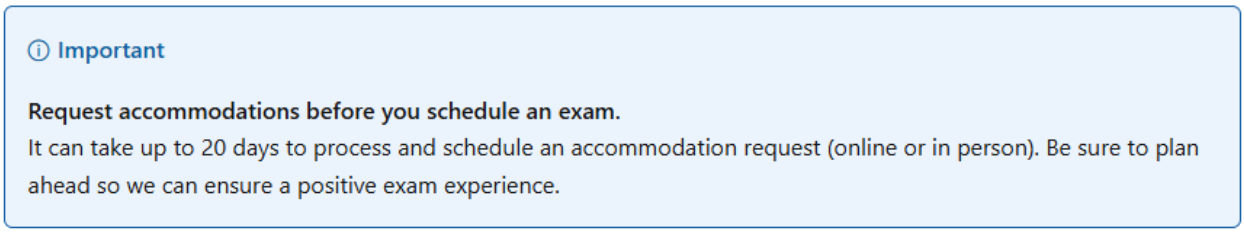
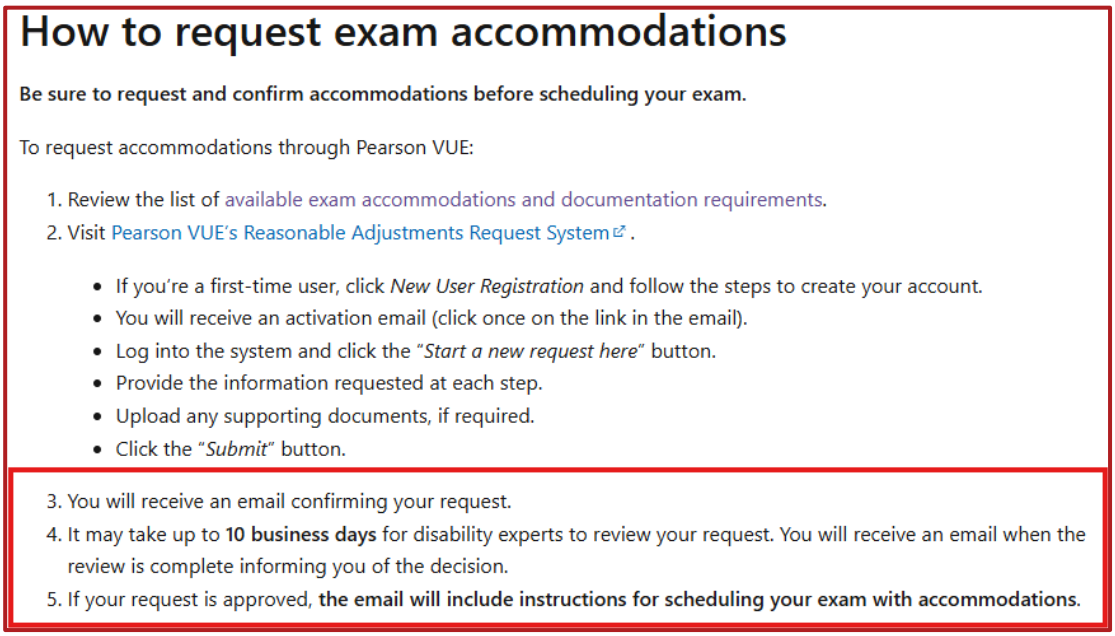


Figure 3: *The Explicit Mention for Confirmation Emails (Highlighted in Red)*



Based on Study 2 findings, Microsoft reviewed the insights, with consideration to maintaining the integrity of the exam, and changed its documentation policies regarding which accommodations require documentation and what types of documents are accepted (while also maintaining exam security), as listed on its accommodations website (Table 2). For many accommodations, Microsoft does not require any documentation, although a request for those accommodations still needs to be submitted.

With the goal of maintaining exam security while reducing the effort from requestors in gathering documentation for accommodations, Microsoft also changed policies that required medical documentation, which can be difficult to obtain. The requestor can now provide proof of previous accommodations instead. This information is relayed in an answer in the FAQ section of Microsoft's accommodations website (Figure 4), as well as during the request process. It should be noted that Microsoft Learn still requires documentation to support requests for extra time, the most frequently requested testing accommodation.

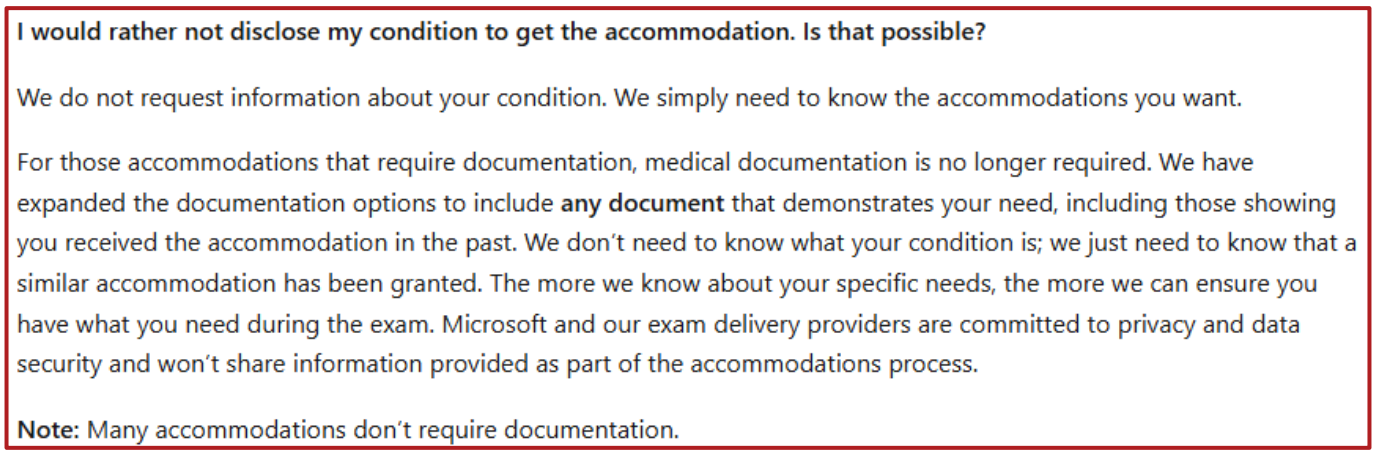
Based on results from both Studies 1 and 3, the Microsoft team rearranged the exam webpage to include the link to the accommodation content toward the bottom of the webpage under the header "Exam Resources" (see Figure 5), this time renaming the link to match the preferred term of "Accommodations" rather than the original vague language of "Support." Now organized in "tiles," each item under Exam Resources is now visually distinguished from the other items. Within each tile, the link has a one-sentence description for further clarification. In this layout, the header and tile structure provide easy navigation for screen reader users, while the visual separation of the bolded links allows for efficient scanning for sighted users.

Table 2: *Current List of Accommodations and Documentation Requirements*

Accommodation	Verification Documentation required for test center	Verification Documentation required for online proctoring	Why do you need to request this accommodation in advance?
Extra time	Yes	Yes	Adding extra time requires a reconfiguration of the exam. Note: Microsoft has added **5 minutes** to exam time for unscheduled breaks. You do not need to request an accommodation for this time to be added. Visit Unscheduled breaks on exams.
Reader and Reader/Recorder	Yes	Yes	**Extra time will be provided**. For test center deliveries, you'll test in a separate room. For online deliveries, the proctors need to know that another adult will be in the room.
Personal Care Assistant (PCA)	No	Yes	For test center deliveries, you'll test in a separate room. For online deliveries, the proctors need to know that another adult may enter the room.
Ability to read aloud	No	No	In test centers, this is a distraction to others, so you'll be given a separate room. For online deliveries, the proctors need to know you'll be reading aloud.
Moving during the exam, including fidgeting	No	N/A. No advance notice is required.	In test centers, this may be a distraction to others, so you'll test in a separate room. For online deliveries, you may move around within your work area if your face stays in view of the camera and all prohibited items remain out of arm's reach. If you need to leave your work area (the view of the camera), initiate a break.
Noise cancelling headphones	No	No	Proctors will inspect the headphones to ensure Bluetooth has been disabled.
Screen Reader Software (i.e., Dragon Speak (STT), JAWS, or NVDA)	No	No	The exam must be configured to allow this software to run. At test centers, you'll be provided with a separate room. For online deliveries, the proctor must be aware that audio will occur during the exam. NOTE the availability of the screen reading software varies by modality: - **Test Centers:** JAWS may be available depending on the test center location. - **Online Exams:** JAWS, NVDA, ZoomText Reader, and Windows Narrator
Sign Language Interpreter	No	No	For test center deliveries, you'll test in a separate room if the sign language interpreter is needed during the exam. If they are only needed for the check-in and exit process, you may test in the primary testing area. For online deliveries, the proctors need to know that another adult may be in the room with you.
ZoomText (Screen Mag Only)	No	No	The exam must be configured to allow this software to run.

Wheelchair Accessible Test Center	No	N/A. No advance notice is required.	Not all test centers are wheelchair accessible.
Adjustable Workstation	No	N/A. No advance notice is required.	Not all test centers have adjustable workstations.
Sit/Stand	No	N/A. No advance notice is required.	Not all test centers have a sit/stand desk, and this requires a separate room.
Additional lighting	No	N/A. No advance notice is required.	At test centers, you may require a separate room.
Chewing gum	No	N/A. No advance notice is required.	In test centers, this is a distraction to others, so you'll test in a separate room.
Other	Yes	Yes	Anything not expected under typical exam conditions requires an accommodation so the proctor is aware something will be different, so others are not distracted, and to ensure any changes to the exam configuration are available during delivery.
Extra time	Yes	Yes	Adding extra time requires a reconfiguration of the exam. Note: Microsoft has added **5 minutes** to exam time for unscheduled breaks. You do not need to request an accommodation for this time to be added. Visit Unscheduled breaks on exams.

Figure 4: *FAQ Regarding Documentation for Requesting Accommodations*



I would rather not disclose my condition to get the accommodation. Is that possible?

We do not request information about your condition. We simply need to know the accommodations you want.

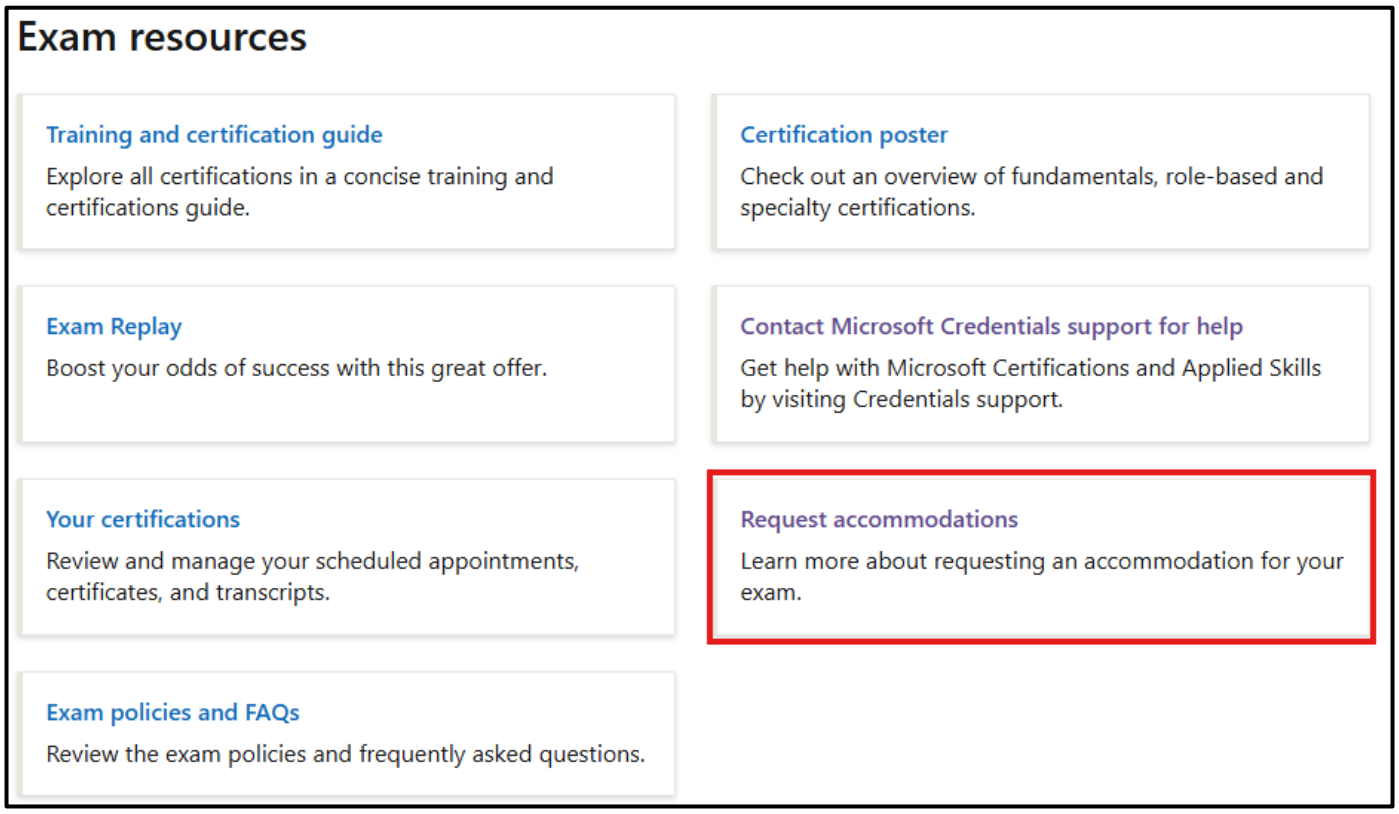
For those accommodations that require documentation, medical documentation is no longer required. We have expanded the documentation options to include **any document** that demonstrates your need, including those showing you received the accommodation in the past. We don't need to know what your condition is; we just need to know that a similar accommodation has been granted. The more we know about your specific needs, the more we can ensure you have what you need during the exam. Microsoft and our exam delivery providers are committed to privacy and data security and won't share information provided as part of the accommodations process.

Note: Many accommodations don't require documentation.

One of the purposes of Studies 3 and 4 was to ensure that the layout and formatting of the webpage itself was designed accessibly. Based on participant feedback across the several studies, the team at Microsoft decided to develop a landing webpage which included icons, widgets, and clear sections with bold headers in a large font (Figure 1). The specific details about each topic were removed, and only the high-level overview text remained. Participants preferred this setup over the

previous one, as it allowed easier scanning to find the section they need, aided by the graphical icons. Each section had links to the more detailed, relevant information on a separate page. The inclusion of headers and paring down of text within the webpage also allowed blind screen reader users to navigate by headers and skip to the section that is pertinent to their needs. In summary, instead of having one page that contains all the information for accommodations, there is now a landing page that presents the high-level categories and instructions and allows the user to navigate directly to the information they need on subsites.

Figure 5: *Current Label and Location for Accommodations Content (Highlighted in Red)*



Summary of Major Research Recommendations

The series of research projects on testing accommodations policies, processes and website design described in this article can be summarized by several critical recommendations. These recommendations guided Microsoft to continue to develop upon their previous policies and content for their accommodations process and webpage:

- Broaden the types of documentation required as much as possible: It is important to ensure that accommodations are approved for the people who need them. From this series of studies, Microsoft expanded the set of acceptable documents to any documents that demonstrate a person's need for accommodations, including accommodations given in the past. Examples include IEPs (individualized educational programs), records of disability benefits received,

and workplace accommodations. These may be easier to gather than a doctor's note or a prescription, especially if the learner has not received a medical diagnosis.

- Require verification documentation only when necessary: Reading out loud, using assistive technology such as screen readers and screen magnifiers, and standing during testing are examples of accommodations from this series that were determined to not need verification documentation. If they are requested, the accommodation is provided.
- Make the link to the accommodations webpage easily findable and identifiable on the education/training homepage: In the research reported here, most people expected to see information about accessibility and disability at the end of the page. Expecting information regarding accessibility to be at the bottom of the page is also applicable to links for disability-specific information for any website. Also, they preferred the use of the word "accommodations" rather than the more ambiguous term "support."
- Explicitly and plainly state the expected timeline and avenues for communication: Having a timeline and contact information for the accommodation process alleviates anxiety and allows requestors to plan for and ask questions about their exam.
- Avoid text-heavy webpages: Accommodations address a wide range of disabilities, assistive technologies, and needs. Instead of providing a long comprehensive list of accommodations, it is helpful to organize accommodations by disability, with drop-down menus providing more examples. Also, provide visual cues and graphics to help decrease cognitive burden and promote easy visual skimming.

Key Takeaways for Industry-Research Collaborations

For UX researchers, product designers, and developers in any field, this series of research studies revealed several important insights into engaging people with disabilities throughout the design process of products and services:

- Start with discovery of user insights: Discovering user needs, experiences, and exploring other user insights can help inform the design of subsequent user experience research projects in the larger R&D program. This approach can also prevent many common problems that need to be fixed later in the development cycle, which can be costly and delay timelines for product launch or delivery.
- Incorporate feedback in all stages of product development: Gathering feedback about iterative prototypes allows users to give actionable feedback on functionality and appearance. Incorporating that feedback into future iterations ensures that the product *continues* to evolve to more effectively meet the needs of its users. As outlined in this article, this process *should* be distributed over time, even over years, in order to identify and address user needs sufficiently.
- Partner with disability and accessibility experts: User experience research with disability populations can be daunting. It is important to partner with organizations that have deep knowledge and engagement with the disability community and their needs. Such a partnership still requires that the industry sponsor remain involved as an active collaborator in the research to ensure that product expertise helps guide the research.

Limitations

Industry-sponsored user experience research projects tend to be highly customized to address specific challenges or goals of the sponsor. For large multinational corporations, those challenges and goals may even partly reflect the expertise, insights and perspectives of the managers of individual work units leading the research and development project. Consequently, the context under which the R&D effort is informed and conducted can substantially impact the overall design and impact of industry sponsored user experience research efforts. These variables may limit the generalizability of the research described here. Indeed, many of the user experience research efforts conducted by the AURC do not comprise multiple discrete projects spanning multiple years. That sort of continuity over an extended period of time is not typical. Furthermore, the research focus on accommodations request processes for high-stakes exams is highly specialized, thereby limiting generalizability of the industry-sponsored research described here to user experience research on other types of products and services.

Other limitations include possible sampling bias due to the purposive convenience sampling and self-selection by participants. Participants who have experienced disappointment or frustration when requesting accommodations might be more motivated to participate than those who have experienced minimal or no difficulty requesting and receiving accommodations. Additionally, the focus on the experience of learners in the United States, within the national regulatory system may limit generalizability to other countries. This last limitation might be attenuated somewhat by the global nature of Microsoft's CTE program.

Conclusion

The studies detailed here show that user engagement is critical to the success of product and process design. It also shows that for complex systems like online CTE and testing accommodations, user experience research ideally takes the form of an iterative *program* that comprises multiple research projects conducted over time. Additionally, partnerships between technology vendors and independent research organizations specializing in user experience research with people with disabilities can be critical to ensuring smooth and efficient design and execution of research projects and high-quality data collection and analysis. The AURC's use of the "network" or "panel" research model also supports efficiency and high data quality by ensuring that sampling targets and timelines are met and that participants are pre-verified. Improving accessibility of user interfaces, website content, and business processes (e.g., for accommodations requests and fulfillment) also relies on the commitment of the owners of those assets (e.g., Microsoft). This article demonstrates how numerous positive advances in access and accessibility can derive from the commitment to a multiyear, multi-project research program that goes beyond regulatory compliance requirements.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. Delaney Cowart and John Morris received salary support from Shepherd

Center to conduct the research reported here. Shepherd Center received payment from Microsoft to conduct all of the studies referenced in this paper. Kathy Dixon is a full-time received salary support

The authors are deeply grateful to all the learners with diverse disabilities (also members of the AURC national network) who participated in the research projects described in this manuscript. They have helped make high-stakes career and technical education and test taking more accessible, more accommodating, and less stressful for the thousands of individuals with disabilities who pursue Microsoft certifications. We also thank the research, design, and engineering teams at Microsoft for working through multiple iterations of the accommodations subsite. Finally, we thank AURC researchers Ben Lippincott, Raeda Anderson, Nicole Thompson, Sarah Mosley, and Kelsey Koupal for their contributions to some of the several studies conducted with Microsoft.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 132-146
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Industry

Initial User Feedback on a Novel Indoor Navigation Application for People Who are Blind or Have Low Vision and People with Mobility Impairments

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Abstract

Indoor wayfinding within the blind or low vision (BLV) and mobility impairment (MI) communities, especially in larger indoor spaces, continues to be a concern. A novel application called Mapping for Accessible Built Environments (MABLE) aims to assist both these groups in overcoming those challenges. The purpose of this manuscript is to highlight the initial reactions to MABLE from those intended to benefit from it (people with BLV and MI). Data were analyzed using a thematic analysis of the qualitative data and a Chi-Square test of the quantitative data. The qualitative results highlight an overall positive reaction toward MABLE, with participants identifying specific features they would like to see added to MABLE. The quantitative results identified environments in which the participants would use MABLE, which included airports, hotels, and shopping malls, with shopping malls being the highest indicated environment. Both disability groups indicated that they would likely utilize MABLE in a variety of familiar and unfamiliar environments. Technology developers need to consider users' lived experiences when designing assistive technologies, including both the similarities and differences between disability groups, to create a product that meets users' needs.

Keywords: MABLE, Wayfinding, Navigation, Blindness and Low Vision, Mobility Impairment, Assistive Technology

Initial User Feedback on a Novel Indoor Navigation Application for People Who are Blind or Have Low Vision and People with Mobility Impairments

Indoor wayfinding and navigation remain a persistent challenge for individuals with disabilities, particularly in large public environments such as airports, office buildings, and shopping centers. While outdoor navigation tools (e.g., GPS) have improved mobility and independence for many, indoor spaces often lack accessible, dynamic navigation solutions. MABLE (Mapping for Accessible Built Environments) is an emerging concept that aims to fill this gap using AI-powered mapping tailored to user needs. By filling this gap, MABLE can offer those with disabilities a solution for increased access and wayfinding navigation within indoor environments.

This study explores initial reactions to the MABLE concept among two distinct disability groups: individuals who are blind or have low vision (BLV) and individuals with mobility impairments (MI). Participants were shown an overview of the MABLE system and asked to provide feedback on its usability, value, and potential feature needs. Through a mixed-methods approach involving thematic coding and chi-square analyses, this study identifies areas of shared enthusiasm as well as differences in desired functionality across disability groups.

These findings offer important implications for user-centered design in assistive technology and highlight opportunities to improve inclusivity in indoor wayfinding tools. The initial user responses from this study were utilized to update the design of MABLE through a feedback-driven approach. This demonstrates in practice how to promote inclusive design and implementation of assistive technology by centering user perspectives in the early evaluation of an emerging indoor wayfinding solution. The MABLE concept, which leverages artificial intelligence (AI) to support wayfinding in complex indoor environments, was presented to people who are blind or have low vision and individuals with mobility impairments. The research also contributes to broader conversations within the Assistive Technology Outcomes & Benefits (ATOB) community about the integration of AI into assistive solutions, ensuring that address the diverse needs of end users. This study demonstrates an inclusive, user-driven approach to assistive technology evaluation by collecting rich feedback directly from end users before the tool is fully developed or deployed. In doing so, it provides a case example of how user experience data can guide co-design, prioritize feature development, and ultimately support equitable implementation of high-tech assistive technology solutions.

Target Audience and Relevance

This article is intended for multiple audiences engaged in the design, evaluation, and deployment of assistive technologies. Assistive technology developers and engineers will benefit from insights into feature preferences from two disability groups, providing guidance on inclusive design practices for indoor navigation systems. The alignment of user groups is only discoverable when each group's preferences are explored individually. Rehabilitation professionals, including orientation and mobility specialists, low vision therapists, vocational rehabilitation teachers, and assistive technology instructional specialists – as well as other allied health professionals such as occupational therapists and physical therapists – will learn about how future tools like MABLE might

support functional mobility in their client populations. Committing to evaluate whether new tools that come to market included authentic user input positions rehabilitation professionals to promote tools that are likely to be the most effective, while also supporting ethical design practices. Disability advocates and policy makers may use this research to advocate for more inclusive technology standards and funding priorities that support accessible indoor environments. Researchers and academics in the fields of human-centered computing, rehabilitation engineering, and disability studies will find value in the methodological approach and the cross-disability comparisons.

Literature Review

Indoor wayfinding and navigation present unique challenges for people with BLV and MI. People with BLV experience difficulty navigating indoor spaces and locating destinations without the aid of maps and signs, which are almost always presented in a visual-only format. Although accessible GPS applications (both mainstream systems and those specifically built for BLV users) can provide nonvisual information about landmarks and points of interest during outdoor navigation, these systems have little to no functionality in most indoor spaces (Cheraghi et al., 2019). In particular, BLV individuals have reported difficulty navigating airports, sports arenas, and other complex buildings (Guerreiro et al., 2019; Ponchilia et al., 2020).

In the past decade, researchers have developed and tested a variety of applications to assist BLV users with indoor navigation. Examples include CityGuide (Cheraghi et al., 2019), NavCog (Sato et al., 2017), and ASSIST (Nair et al., 2022). Many of these applications rely upon Bluetooth Low Energy (BLE) beacons, pre-installed within indoor spaces, to denote points of interest (e.g., Guerreiro et al., 2019; Kim et al., 2016). Other applications use infrared tags, computer vision, and/or Augmented Reality (AR) technology (e.g., Legge et al., 2013; Nair et al., 2022). Many of these technologies require specific building configurations for use of the apps, limiting the type and number of buildings in which these apps can be accessed. Computer vision can also make errors, both false negatives (missing landmarks) and false positives (flagging a landmark where none exists) as well as other significant mistakes like misinterpreting the gender on restroom signs (Abdolrahmani et al., 2016). Although several assistive navigation systems have been designed for people with BLV, adoption remains limited due to usability constraints, costs, and a lack of alignment with real user preferences and needs. Based on targeted feedback from the BLV community, Soltani et al. (2025) recommend that assistive navigation technologies for BLV users combine navigational guidance with high-level mapping of spaces, offer multimodal feedback (auditory, tactile, and haptic), and come at an affordable price point (Soltani et al., 2025).

People with MI, in contrast, have less difficulty accessing signage and other visual landmarks. However, indoor spaces frequently present physical barriers, particularly entrances with steps, narrow doors, and stairwells (Imrie, 2012). People with MI have expressed interest in improved indoor maps that highlight accessible entrances, ramps, and elevators. In fact, Muller et al. (2022) found that both individuals with BLV and MI experienced a lack of accessible indoor maps as a barrier to independent navigation. People with MI have also articulated a need for up-to-date information when the accessibility of a space changes, such as notification of elevator outages or construction, which will necessitate route modification (Chen et al., 2024).

Compared with the BLV user population, there has been far less research on or development of indoor navigation technologies for people with MI. Some systems, such as Project Sidewalk (Saha et al., 2019), aid navigation in outdoor environments by crowd-sourcing accessibility information and providing warnings of barriers like sidewalk obstructions and missing ramps. Chen et al. (2024) developed a process for mapping physical accessibility barriers and facilitators on university campuses, which include both indoor and outdoor elements. Other systems, such as “robot guides” employed in some museums, are designed to aid people with a variety of disabilities in wayfinding and barrier avoidance (Cazini & Frasson, 2013).

Focused on the user-feedback aspect of applications, those with disabilities make up a small portion of mobile application users and those without disabilities make up the majority of ratings or reviews (Alshayban et al., 2020; Chen et al., 2021). This results in feedback from users with disabilities having a limited influence on the overall application ratings and reviews. Consequently, due to the lower amount of feedback, accessibility-related concerns can potentially become overlooked. Individuals with disabilities who are looking for an application cannot fully rely on the application’s ratings to make informed decisions (Alshayban et al., 2020). Incorporating feedback from users with disabilities helps identify accessibility concerns that could otherwise go unnoticed by users without disabilities (Seixas Pereira et al., 2024).

It is vital for indoor navigation application designers to actively incorporate feedback from people with BLV and MI into all phases of the design process. People with both BLV and MI may benefit from some similar features, such as comprehensive mapping of indoor spaces. At the same time, they have differing access needs and priorities. In fact, amenities that may act as an access aid for one group may act as an access barrier for another; for example, an elevator without braille signage may be essential for building visitors with MI, but visitors with BLV may prefer to use the stairs (Han et al., 2020). Usability studies have been conducted to evaluate many of the indoor navigation applications reviewed above, but generally, usability studies have been small and limited to contrived laboratory settings.

Furthermore, some researchers have used blindfolded sighted participants to test the efficacy of indoor navigation apps intended to assist BLV people (e.g., Legge et al., 2013; Li et al., 2018; Nair et al., 2022). Blindfolded sighted people do not travel like BLV people, since they have not yet adjusted to vision loss or mastered effective orientation and mobility techniques. Blindfolded participants often travel more slowly and cautiously than BLV individuals (Nair et al., 2022) and they may not engage with nonvisual feedback (tactile, haptic, or audio) in the same ways as people who have been BLV for many years. It is essential for designers and developers to understand how people with BLV and MI orient themselves and move through indoor environments. For example, sighted individuals often misunderstand how BLV individuals who use white canes utilize tactile feedback from walls, doors, and other landmarks, which often act as orientation aids rather than hazards to be avoided (Williams et al., 2014). The voices of potential users with a variety of disabilities, including BLV and MI, must be incorporated into technology design to maximize technology adoption and user satisfaction. Therefore, the purpose of this study was to illustrate a process by which user-centered design and interactive feedback from potential users can be implemented into a more universally useful wayfinding and navigation tool.

Method

MABLE Concept

MABLE (Mapping for Accessible Built Environments) is being developed through a community-based participatory research approach, in which engineers with lived experience of blindness, low vision, and mobility impairment collaborate closely with organizations serving the BLV and MI communities. MABLE was developed as a scalable and cost-effective universal accessibility wayfinding option for those with BLV or MI to work with their assistive technologies, or those without disabilities who could benefit from wayfinding solutions. Preferences can be customized for the user's identified maps and routes to meet their needs. The product development process prioritizes user-centered design by integrating iterative feedback from users at every stage, from initial concept and ideation to prototyping and refinement. This feedback encompasses a range of aspects, including app usability, interface design, navigation experiences, and overall functionality, ensuring that MABLE evolves in direct response to the needs and preferences of its intended users.

The MABLE interface presents a clear and streamlined landing page designed to support flexible exploration and routing in indoor environments. Upon opening the app, users encounter a building-selection screen that allows them to choose from a list of supported buildings, each displayed in a simple, high-contrast card layout. Once a building is selected, the interface offers two distinct modes of exploration: on-site exploration and navigation, which provides real-time guidance for users physically present in the building, and remote exploration, which enables users to preview routes, examine accessibility information, and familiarize themselves with the environment ahead of time. This dual-mode structure supports both active navigation and offline planning, making the system useful for a wide range of mobility-related needs.

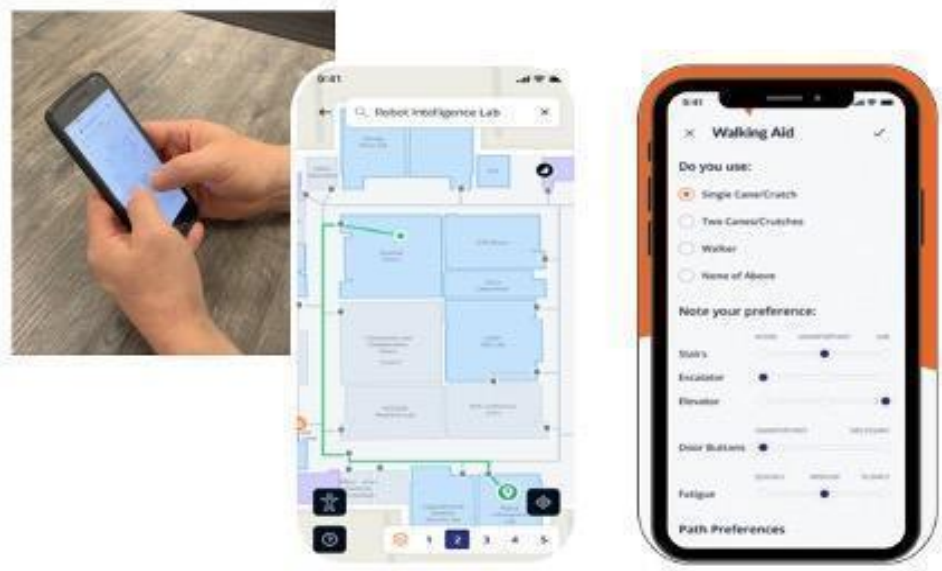
A personalization screen in MABLE provides a clear and structured way for users to specify their accessibility needs before navigating a building. The interface presents multiple accessibility profiles such as Wheelchair, Walkers/Crutches/Cane, Vision, with each represented as large, color-coded selection cards. Each card includes an option to "Set up preferences," allowing users to further refine their mobility or sensory requirements within the chosen category. An additional toggle labeled "I don't have any accessibility needs" appears beneath the profile list, allowing users without specific requirements to bypass the personalization process. Currently, MABLE can be accessed via an application format on an iPhone (with an Android operating system under development) or through a web browser.

MABLE has the long-term goal of improving accessibility for people with disabilities (PWDs) within and around indoor built environments. MABLE consists of two components: a) digital accessibility maps for indoor environments with an interface for assessing, planning, and navigating within them based on the affordances and capabilities of the user, and b) an indoor localization and navigation system that uses information from created digital maps to provide fine-grained, customized, turn-by-turn navigation within or across indoor and outdoor spaces. Expected users include BLV and MI communities plus other categories of PWDs desiring planning and navigation assistance. While the creation of the MABLE system is motivated to benefit PWDs, the general population is expected to greatly benefit based on the applications and their needs. The various

applications of the MABLE system include emergency management, remote assistance, transit, wayfinding, tourism in large indoor public spaces such as shopping centers, convention centers, stadiums, airports, hospitals and private or access-controlled indoor spaces such as company campuses and commercial multi-story buildings. MABLE is being developed to be as universally useful as possible, capable of interfacing with various assistive technologies.

The key distinguishing features of the MABLE concept are accessibility-enriched indoor maps, personalized routing, real-time localization, and usable and accessible interfaces, all tuned to the user's own preferences and mobility profile. MABLE leverages AI-driven mapping, localization, and navigation features to provide real-time, user-friendly wayfinding assistance tailored to the needs of BLV and MI users, among others. By enabling seamless navigation within complex-built environments, MABLE aims to enhance independence, safety, and confidence for PWDs.

Figure 1: *MABLE Systems*



Note. A figure that shows the MABLE system being used on a smartphone.

Participants

Two different disability groups were surveyed for this study: people who were blind or had low vision (BLV participants) and people with mobility impairments (MI participants). Participants who were in the BLV group were recruited from the American Foundation for the Blind's participant pool and various email listservs. The MI participants were recruited from numerous listservs and organizations including The Cerebral Palsy Foundation, FSHD society, AIChE society, Easterseals, and the Emerging Researchers Network Working Group for Students and Professionals with Disabilities. Blind and low vision participants were surveyed in October 2024, and MI participants were surveyed from January through April 2025. The total number of participants who completed the BLV survey was 109, while 190 completed the MI survey.

Survey Measures

An accessible online survey was administered to both groups using Qualtrics. The survey consisted of about 40 questions organized into 10 sections. The questions were a mix of open-ended questions, where participants were given the option to type or dictate their responses; and questions conducive to quantitative analysis, such as Likert scale questions. Skip logic was used to ensure a tailored experience for the participants.

For the purpose of this paper, the researchers focused on questions about the participants' reactions to the MABLE concept. All participants were shown a short paragraph and a video describing the MABLE concept. They then answered one open-ended question asking about their "first gut reaction" to MABLE, including what they liked and did not like, along with suggested improvements. Then, the participants answered a multiple select question asking participants to select all of the specific indoor environments (airports, conference centers, hotels, office buildings, and shopping malls) in which they would likely use MABLE to navigate; and two Likert scale questions asking participants how likely they would be to use MABLE in a building that they frequent and a building that is less familiar to them.

Data Analysis

The researchers used thematic analysis to analyze qualitative responses to the question about participants' gut reaction to MABLE. In total, seven codes (e.g., *positive response*, *negative response*, *neutral response*, *requiring/requesting more information*, *asked question(s)*, *requested features*, and *other*) were identified between both the MI and BLV groups. After coding the responses, themes were identified and analyzed between the two groups.

The researchers used Chi-Square tests to compare the two groups' responses to the Likert questions. Chi-Square tests tested the null hypothesis that both groups would report the same levels of interest in using the MABLE application in familiar and unfamiliar environments as well as in specific settings.

Results

Qualitative Results

Ninety-two respondents in the BLV group responded to the question asking about their initial reaction to the MABLE software. Of the 92 responses, 70% (n = 64) indicated positive comments toward their initial reactions to MABLE. One participant stated, "I think it sounds great! I particularly like that it was designed by a person with low vision who likely better understands the needs to potential users." Another participant indicated, "It seems promising and I would definitely use it in professional environments. I would like it to include retail spaces like malls as well as healthcare facilities like hospitals (it seems as if the product will cover spaces like clinics that are laid out like office buildings). Twenty-three percent (n = 21) of participants indicated a neutral response, with one stating, "It sounds like it has significant potential. I don't understand why you would need to combine it with another way-finding app and how that would work indoors." Similar to the above response, a subtheme containing a positive comment with the participant not wanting to use MABLE was indicated, with one participant stating, "MABLE sounds like it could be useful for certain

circumstances, but could be a pain sometimes. I don't think it would help me," and another stating, "It sounds OK, but not like an app that I would want it to be. It sounds like it relies on maps a lot and not as much AI. It would take a lot of time to use." Four percent (*n* = 4) indicated a negative response, commenting:

> Initial reaction - so this requires I have the time and plan to learn the interior map in advance and remember that info, which is what I already do and wish I didn't have to as it reduces my ability to just go places and into spaces. It also isn't helpful when traveling and you don't know which train platform in advance or which airport hangar, or which conference room, etc. It also depends on user feedback, which requires a certain number of users and certain number of people willing to provide this info and keep it up to date, which often is a challenge with other apps.

Of the additional themes uncovered, 15% (*n* = 14) of participants requested that MABLE add features, with one participant requesting,

> I think it is a great idea. I just wonder if there would be a way for me to request that a certain building be mapped, a building that is not as popular. It would be neat if I could walk [into] a building with sighted help and for me to have the app on and I could map this newer building.

Additional requested features indicated by the participants included emergency preparedness, color and line thickness adaptations, customizable directional/positional concepts (e.g., clock face notation), and the announcement of points of interest updating in real time as the user walks by. Seven percent (*n* = 6) asked questions related to the cost, availability, and features of MABLE. Seven percent (*n* = 6) indicated miscellaneous statements that were categorized as Other, which included comments such as, "This would be too similar to Goodmaps, and the presence of both would make both less useful[.] Please work together!" Finally, 5% (*n* = 5) of participants requested additional information on the MABLE system.

From the 190 participants within the MI group, 167 responded to the question asking about their initial responses to the MABLE software. When focusing on the 167 responses, 63% (*n* = 105) of participants indicated a positive response to their initial views on MABLE. One participant stated, "I think that the app has a lot of good benefits to it. And I can't wait to try it out! I do think that with AI, it would be able to keep up with any changes to buildings and their accessibility," with another indicating, "Love it!! This is amazing, and it would help me a lot!" Twenty-four percent (*n* = 40) of participants stated neutral responses toward their initial views on MABLE, with statements such as, "It seems good enough" and "Not sure whether or not I would use it." It was also observed that while some participants stated a positive comment about MABLE, they were unsure about their usage of MABLE with one participant stating, "I like the concept; however, depending upon how detailed the app is designed I may not use it if it doesn't address my needs as previously discussed." Four percent (*n* = 7) of participants indicated negative responses regarding their initial views on MABLE, with statements including, "I think it's way over thought and not necessary. I have never had enough trouble to warrant such technology" as well as "I currently do not need and cannot see needed." Finally, 9% (*n* = 15) of participants provided statements that were not tied to the question, such as "I'd need to practically utilize it to give a well-informed assessment." Six percent (*n* = 9) requested

for MABLE to have additional features with statements such as, “I like the concept. For me, I would need to be able to customise [customize] it with my walking speed to get an estimate of how long it would take me to get to my destination.” Other individuals requested features such as having large print and audio feedback, dynamic updates (e.g., unavailable vertical transportation such as escalators and elevators), and area preview abilities (ability to preview a location before accessing). 5% (n = 8) of participants asked specific questions pertaining to cost and MABLE features (e.g., “Will it open the doors for us, so we do not need to have a caregiver with us to go into any office?”). Three percent (n = 5) of participants requested additional information on the MABLE system, with one participant indicating, “I still need more information with scaled displays.”

When comparing both groups, there was an overall positive response regarding their initial reaction to the MABLE software. Both groups felt the MABLE software offered promising solutions for the BLV and MI communities. That said, those within both groups like the ability to preview environments before accessing them. Continuing with the similarities, both groups asked questions related to the cost and specific features associated with MABLE as well as requested additional information on the MABLE system. Examining the differences among the groups, it was observed that each respective demographic generally requested features related to their needs. Respondents in the BLV group requested features more closely aligned with concepts related to their orientation and mobility needs in conjunction with their visual abilities (e.g., directional/positional concepts, color/contrast customization), whereas respondents in the MI group indicated additional features related to their ability to navigate areas (e.g., unavailable indoor supports – elevator). The specific features requested by both groups, while different, can assist any and all users of the MABLE software. Each requested feature offers insight by potential users with disabilities to create a product tailored to their common needs.

Quantitative Results

All 190 participants within the MI group responded to the quantitative questions asking about proposed environmental use of MABLE and whether it would be used in familiar or unfamiliar environments. The BLV group had varied participation across these questions: 97 responded to the question about using MABLE in familiar environments, 101 responded to the question about using MABLE in unfamiliar environments, and 106 responded to the question regarding proposed environmental use. The researchers conducted Chi-Square tests on every environment that respondents from both the BLV and MI groups indicated that they would likely use MABLE. The examined environments were airports, conference centers, hotels, office buildings, and shopping malls. All environments ranked above 75% across both disability groups. The null hypothesis for all of these tests was that there is no difference in likelihood to use MABLE in the specified environment between the two disability groups. The only environment that showed statistical difference was shopping malls, X^2 (1, N = 264) = 6.1505, p = 0.01314. MI respondents indicated that they are more likely to use MABLE in shopping malls than BLV respondents, 90.4% (n = 141) and 80.2% (n = 85), respectively. None of the other tests showed a significant statistical difference between the two disability groups (all p-values were > 0.05). The researchers advise that these results be interpreted with caution due to the number of tests conducted.

Table 1: *Comparison of Specific Environmental Preferences*

Environment	Group	Yes	No	Total	% Yes
Airports	BLV	88	12	100	83.02
Airports	MI	149	18	167	89.22
Conference Centers	BLV	90	16	106	84.91
Conference Centers	MI	139	20	159	87.42
Hotels	BLV	94	18	112	88.68
Hotels	MI	139	19	158	87.97
Office Buildings	BLV	83	21	104	78.30
Office Buildings	MI	141	17	158	89.24
Shopping Malls*	BLV	85	23	108	80.19
Shopping Malls*	MI	141	15	156	90.38

Note. A table that shows the numbers of both BLV and MI participants reporting they were at least somewhat likely to use the MABLE application in specific environments. And * denotes a statistically significant difference between the BLV and MI groups.

The BLV and MI participants were asked to indicate whether they would use MABLE in unfamiliar and familiar environments. Of the BLV participants, 82.5% (n = 80) indicated that they would use MABLE in a familiar environment, while 92.3% (n = 156) of MI participants indicated that they would use MABLE in a familiar environment. In response to the question regarding use of MABLE in unfamiliar environments, 93.1% (n = 94) of the BLV participants indicated that they would, compared to the 93.4% (n = 170) of MI participants. In both the familiar (X^2 (1, N = 266) = 3.8317, p = 0.05029) and the unfamiliar (X^2 (1, N = 283) = 8.0156e-30, p = 1) environments, the researchers failed to reject the null hypothesis; in this sample, there is no difference between the two disability groups when using MABLE in either familiar or unfamiliar environments.

Outcomes and Benefits

This study examined survey responses from two disability groups, one with blindness and low vision and one with mobility impairments. The survey elicited both qualitative and quantitative information encompassing the MABLE software application. Both groups indicated positive initial reactions toward MABLE; however, each group requested different features they wanted in MABLE.

Table 2: *Comparison of Familiar and Unfamiliar Environmental Preferences*

Environment Type	Group	Yes	No	Total	% Yes
Familiar Environments	BLV	80	17	97	82.47
Familiar Environments	MI	156	13	169	92.31
Unfamiliar Environments	BLV	94	7	101	93.07
Unfamiliar Environments	MI	170	12	182	93.41

Note. A table that shows the numbers of both BLV and MI participants reporting the likelihood of using MABLE within familiar and unfamiliar environments.

Respondents in the BLV group requested features related to visual accommodations adjustments (e.g., color/contrast) and orientation and mobility-related support (e.g., directional indicators) whereas respondents in the MI group requested features to assist with identifying specific navigation supports (e.g., elevator). Notwithstanding the positive reaction toward MABLE, the features requested from both groups indicate the needs of users based on their personal lived experiences of inaccessible environments or technology with limiting features. It is recommended that technology designers and developers consider the requested features of potential users and, when possible, incorporate these features to assist in creating a user-friendly application focused on increased mobility, navigation, and independence.

Alternatively, from the quantitative findings, shopping malls were identified as the environment that differed most between the BLV and MI groups. Respondents in the MI group indicated a greater willingness to use MABLE in a shopping mall compared to the BLV group. When examining the layout of a shopping mall, there are usually various levels, multiple stores, different entrances and exits, stairways, elevators, and escalators, as well as potential hazardous situations (e.g., wet floors), resulting in an environment that may be especially difficult for people with MI to navigate. Implementation of MABLE in high traffic areas, such as the environments mentioned throughout the paper (e.g., shopping malls, airports), and familiar or unfamiliar environments can facilitate efficient travel while increasing the safety and independence of MI and BLV users.

Based on the initial user feedback indicated by the BLV and MI groups, the MABLE developers have integrated additional visual accessibility settings. These settings include improved screen reader experiences, visual accessibility compliance and updates (e.g., contrast adjustments), improved interaction clarity, and proper focus management specific to the MABLE application. Additionally, multiple modalities for input (e.g., voice and keyboard) and output (visual, auditory, and tactile) were integrated into MABLE. The feedback largely aligned with what the MABLE developers anticipated. Participants' comments on the application's functionality, features, and overall usefulness were consistent with the expectations established during the design phase. However, the responses were more insightful and nuanced than predicted, offering specific and detailed observations that highlighted subtle aspects of the user experience. This level of depth provided

valuable direction for refining the system and enabled more focused, targeted improvements to the application.

Discussion and Conclusion

The purpose of this study was to demonstrate how user-centered design with iterative feedback from potential users can be integrated to develop a more universally accessible wayfinding and navigation tool. MABLE will contribute to further assistive technology development as a planned inexpensive, user-centered, and user-friendly alternative to current indoor wayfinding applications. While a wayfinding app is unlikely to fulfill all the wants and needs of the intended users, MABLE is an effort to achieve success in making a helpful difference to the lives of PWDs.

A vital finding of this study highlighted the importance of obtaining ongoing user feedback for assistive technology development or when conducting software/hardware updates. This feedback can be used to initially include features that meet a majority of the user's needs. After the design process is complete, the feedback can continuously be utilized to make updates as needed. Focusing broadly on the design aspect, technology developers and engineers should consider the feedback from their intended users, as their feedback is invaluable to creating a device that addresses a broader spectrum of wants and needs. Focusing on the rehabilitation sector, primarily orientation and mobility instructors with National Orientation and Mobility Certifications and Certified Orientation and Mobility Specialists, the findings from this study validate the importance of orientation and mobility instruction with the additional incorporation of assistive technology utilization.

As highlighted by respondents in the BLV group, orientation and mobility skills go beyond the use of cane techniques (such as two-point touch), non-cane specific techniques (such as room familiarization and crossing strategies), and move into the need for assistive technology for orientation and wayfinding support. Teachers of orientation and mobility should encourage the usage of assistive technology, not as a replacement for foundational skills, but rather an additional tool in the user's toolbox to increase safety and independence. Practitioners should continue to develop their knowledge of orientation and mobility assistive technology to assist in the prescription process that best meets the specific needs of each client. The same can be said for other rehabilitation practitioners (e.g., physical therapists) who work specifically with MI clients. Developing knowledge of assistive technology to enhance mobility amongst rehabilitation practitioners can help them to increase the safety and independence of their clients.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of the Assistive Technology Industry Association (ATIA). No non-financial disclosures were reported by the author(s) of this paper. This work was funded in part by the U.S. National Science Foundation under award #2345057.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 147-163
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Field

"It Has to Fit Right": Customization in Assistive Technology

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Abstract

The role of assistive technology (AT) is to improve or increase an individual's functional capabilities to support well-being. Cami Smith is a lifetime AT consumer and co-author of this article. She relies on AT for communication and mobility. Our story is one that highlights the importance of using a person-centered team approach to AT service provision and underscores the function of AT customization to ensure fit and usability of AT equipment. Our goal is to bring the reader on an AT service journey that begins with assessment, moves to design and fabrication of a custom-built lap tray to house a new speech generating device, and finishes with a satisfied AT consumer. Our team includes Cami and three AT specialists. We share our process and the lessons we learned. We conclude with recommendations for key AT stakeholders including AT professionals, consumers and family members, administrators, and vendors.

Keywords: assistive technology, augmentative and alternative communication, person-centered, assistive technology customization

“It Has to Fit Right”: Customization in Assistive Technology

The purpose of assistive technology (AT) is to help make the inaccessible accessible for individuals with disabilities. AT enables individuals to perform activities and increase participation. Augmentative and alternative communication (AAC) includes the strategies and tools that individuals use to help make the activity of communicating accessible, thereby increasing participation in all aspects of life. It has been estimated that nearly 97 million individuals in the world may benefit from access to AAC (Beukelman & Light, 2020). Despite the numerous benefits that AAC tools can bring to individuals with communication disabilities, AAC device abandonment continues to be problematic (Moorcroft et al., 2019; Smidt & Pebdani, 2023; Waller, 2019).

Many factors have been linked in the literature to device abandonment. These include but are not limited to poor usability of devices and the social context with which the AAC device is being implemented. Attitudes and the knowledge and skills of those who support individuals with communication disabilities have been found to influence those who use AAC (Boot et al., 2019; Johnson et al., 2006). One critical factor has been ensuring that the fit of the AAC device is commensurate with the consumer’s needs, preferences, and individual abilities (Johnson et al., 2006). Imperative to ensuring an ideal fit is access to a multi-disciplinary team of knowledgeable AT specialists and the concept of customization. While customization is not always possible when considering AT for those with disabilities, it can often be necessary. When it is possible it can positively influence and support use by AT consumers (Boot et al., 2019; Waller, 2019). When paired with person-centered team-based services, the prospect of device adoption increases.

In the following article, Cami Smith, co-author, and an AT assessment team (first, second, and third authors) present their story as a case study that highlights adherence to a multidisciplinary team-based approach to AT assessment and implementation. The services are person-centered and guided by the Human Activity – Assistive Technology (HAAT) Model (Cook et al., 2020). It is a story of incorporating teamwork and AT consumer input into every aspect of customization of AT to ensure a good fit, so that the AT will not only work to meet the needs, preferences, and objectives of the AT consumer, but that it will also increase AAC device acceptance and use and thwart device abandonment. An outline of the service delivery model is provided along with a series of lessons that were learned and recommendations garnered from those lessons learned. Our aim is to highlight the importance of teamwork, person-centered services, the role of customization in AT service provision, and the critical value of ensuring that AT services are driven by the AT consumer to influence the future of AT and AAC services.

Target Audience and Relevance

Professionals working in AAC and AT would have a particular interest in this case study as it pertains to AT service provision, with the focus being on benefits of a multidisciplinary team approach that is person-centered and incorporates design and fabrication to generate customized AT solutions for AAC systems. Additionally, this paper highlights some of the limitations to current service delivery models that do not necessarily create landscapes that facilitate multidisciplinary collaboration and the resources to customize AT. Therefore, it is our hope that AT policy makers and administrators

within the health care and special education arenas, two primary environments for which AT services are provided in the United States, have access to the overall impact that a team approach and custom-built equipment can have for AT consumers. Finally, AT vendors will learn some of the limitations that can occur for AT consumers, particularly consumers who rely on specific speech-generating devices when products are discontinued and unavailable.

Personal Statement

The Assistive Technology Unit (ATU) at the University of Illinois Chicago is a transdisciplinary clinic aimed at providing comprehensive AT services. Services are in the form of client and community advocacy as it relates to access to AT and AT services, clinical research, AT assessment, and design and fabrication of customized AT solutions. Services are guided by the Human Activity-Assistive Technology (HAAT) Model (Cook et al., 2020) and the Participation Model (Beukelman & Light, 2020). Both frameworks place an emphasis on the individual and their own unique physical, sensory, emotional, and cognitive/linguistic abilities and intrapersonal factors such as motivation, experience, and resilience; the activity or task and its demands that are inaccessible; the context with which the AT will be used; and the complex interplay among all aspects. Clinicians within the ATU work collaboratively with consumers and their families/carers to identify AT solutions.

This past year the ATU AAC team had an opportunity to work with a community member in need of a new speech-generating device to support her communication and subsequently her safety, independence, and participation in all aspects of life. This community member was co-author Cami Smith, and this is our story.

Meet the Team

Our story centers around Cami Smith. She is a 58-year-old woman born with cerebral palsy. Due to her disability, she does not talk, walk, or feed herself. She is no stranger to AT. All her life she has had some kind of communication device and an electric wheelchair. She uses her communication device in many ways. She uses it to communicate with family and friends, participate in groups, write articles for the *Ray Graham Association Newsletter*, go on social media, and for pleasure in fun activities like playing solitaire or browsing the internet. Cami notes, “Without my *[Communication Device],* I could not share serious thoughts and feelings of my heart.”

Stephanie Bay is a speech-language pathologist, assistive technology professional, and disability studies scholar. She has over 18 years of experience working in AT specializing in AAC. Her role on the team was to evaluate Cami’s needs and preferences as they related to language and communication as well as to discuss various options with Cami regarding current available AAC devices and funding considerations that best matched the features identified as necessary in the AT assessment.

Kathryn “Kathy” Waldera is an occupational therapist, assistive technology professional, and rehabilitation engineer. She has over 35 years of experience working in AT specializing in both assessment for AT needs as well as design and fabrication of customized AT solutions. Her role on the team was to evaluate Cami’s needs and preferences as they relate to physically accessing and

transporting the desired AAC device and assist in the design of a custom solution to support access and transport of the new speech-generating device.

Adrian Tabungar is the equipment specialist for the ATU. In this role he makes AT for clients with disabilities by collaborating with ATU teams to design custom or modified equipment that better serves the needs of users with disabilities in the community. His role on the team was to collaborate with Cami and the clinicians to design and fabricate the customized equipment to ensure the accessibility of Cami's preferred AAC device.

Our Story

Augmentative and Alternative Communication

As noted, Cami has relied on a variety of AAC strategies and tools throughout her lifetime. Stephanie initially met Cami approximately seven years prior to the current story when Cami's previous speech-generating device (SGD) stopped working. At that time, Cami had been using a Dynavox VMax Plus for several years with a heavily personalized vocabulary page-set that was built into the device's speech-generating software. Cami accessed the device's touchscreen using a custom-built wooden stylus, and the device was housed in a custom-built lap tray to support her physical access needs and transportation of the AAC device.

Originally, when Cami and Stephanie met, Cami was looking to simply replace her SGD with a new (working) version of her previous device. Unfortunately, things in AAC manufacturing had shifted, making a simple replacement impossible. The previous device was no longer being manufactured. The software that ran her personalized vocabulary was no longer available to run her page-set. There was no fabrication lab in the outpatient medical clinic she was being seen at to design and fabricate a customized lap tray. New SGDs were being built with capacitive touchscreens, something not familiar to Cami, and not compatible with her custom-built stylus. Because Cami relied so heavily on her lap tray to access and transport her SGD, and because there was no way to design and fabricate a new lap tray, Stephanie's job became one of finding a device that would physically fit in the custom-built lap tray and rebuild her personalized vocabulary in a new speech-generating software system. Cami's choices were constrained by the use of the custom-built lap tray, but a traditional wheelchair mount was not going to work to support Cami's access needs or her transportation of the AAC device preferences. She was adamant in maintaining use of her custom-built lap tray.

Stephanie found an SGD that had dimensions like Cami's previous device, allowing it to fit into the custom-built lap tray. Cami's father found a commercially available stylus that Cami could use to activate the capacitive touchscreen. We were essentially able to fit the square peg into the round hole! Unfortunately, the device could not run the original speech-generating software. Therefore, Stephanie spent nearly 20 hours programming the speech-generating software to personalize the vocabulary to match the layout and structure Cami was familiar with in her previous device. Per Cami, ensuring access to the vocabulary she needed, wanted, and was familiar with was essential, as it avoided the need for learning new motor patterns, which would ultimately slow down her communication efficiency.

For nearly six years, the SGD and custom accessories worked well for Cami in supporting her communication needs and goals. She even used the device to develop new skills in computing and socially participating within the digital communication environment. She reported, “I need my email, Facebook, and Solitaire,” which were features that were not available in her original SGD. However, as with all computers, the SGD only worked for so long. The AAC device began to malfunction, and Cami sought assistance through the AAC vendor in locating an AT team that could help her in procuring a new AAC system.

This brings us to our current story and when Stephanie met Cami for a second time. Only this time, services were available through the ATU, which differs from a traditional medical outpatient clinic. This time a team of professionals was available to work with Cami. When Stephanie and Cami met again, Cami learned that the SGD vendor Cami had worked with had stopped manufacturing Cami’s current device. Additionally, neither she nor Stephanie could find another SGD vendor that had a device that would meet the physical size requirements to maintain use of the custom-built lap tray. However, Cami and Stephanie realized that the speech-generating software Cami had been using was still available. The need to reprogram Cami’s personalized vocabulary could be avoided. After six years of using the speech-generating software and accessibility features built into the AAC device that allowed her to use digital communication and engage in entertainment activities, Cami stated, “I want to keep this program and make a new tray.” As the SLP on Cami’s AT team, Stephanie realized quickly that to support Cami’s needs, her goals, and her preferences for the AT she was seeking, they needed to explore other avenues with occupational therapy, rehab engineering, and design and fabrication.

History of the Custom-Built Lap Tray and the Role of the Occupational Therapist and Rehab Engineer

Kathy met Cami in 2006. At the time, Kathy was a clinical rehabilitation engineer at a large urban rehabilitation hospital. She was working as part of an interdisciplinary team with OTs, PTs, SLPs, engineers, and technicians to design, build, and modify custom equipment for both inpatients and outpatients of the rehabilitation hospital. This was during a time when adaptive equipment was not generally commercially available. Rehabilitation engineering was a special service offered by the hospital with the goals of improving accessibility, participation, and quality of life.

Cami was receiving services from an OT and SLP who were working to get her an SGD. To use the device fully, Cami, a wheelchair user, needed a way to transport it with her in all environments. Spasticity caused Cami to have limited fine motor control. She needed to rest her right arm on a surface that was level with the screen to make accurate selections on the touchscreen. The surface that supported her arm needed to be padded to increase comfort and prevent Cami’s skin from getting sore or breaking down.

Cami needed to use the one tray on both her power wheelchair and her manual wheelchair. She drives her power wheelchair using a right-side joystick. Because of this, the right side of the lap tray needed a cutout so that it did not interfere with the motion of the joystick (see Figure 1). Luckily, Cami’s two wheelchairs had similar widths. The same lap tray hardware was installed on both wheelchairs, and the tray could be easily changed between chairs (see Figure 2).

Figure 1: *Cutout for Joystick*

Note. In Kathy's original design, she ensured continued access to mobility and independence with driving by creating a cut out on the custom-built lap tray to support the joy stick to control the wheelchair.

With input from Cami, her parents, and the team, the team designed and fabricated a custom lap tray in the Rehab Engineering department's workshop. The tray had a cutout in the center and a compartment that suspended her SGD so that its screen was level with the tray surface. This was attached to Cami's wheelchair using commercially available lap tray hardware and Velcro straps. A covered pad was attached to the top surface, the inside edge, and the bottom surface of the tray to protect her arms during use of the device and her legs in case they came into contact with the bottom of the tray. Cami used this custom lap tray successfully until we could no longer find a device that could fit within the tray and support her personalized vocabulary profile.

In the following years, Kathy returned to school to earn a degree in occupational therapy (OT) and combined her skills as both a rehabilitation engineer and OT as a member of the AAC team at the ATU. This is when she met Cami again and our current story continues.

Figure 2: *Lap Tray Hardware on Manual Wheelchair*

Note. Photograph depicting the hardware that was available to procure the lap tray to both of Cami's wheelchairs.

Cami was still using the custom lap tray Kathy had designed for her in 2006. Over the years, Cami was fortunate to get new communication devices that fit into that lap tray. She was also fortunate that her family made repairs as needed. Cami's father reported, "I found a seamstress that could make new covers for the protective padding when it wore out, and I used a hot glue gun to reattach Velcro straps when they came loose." Cami's father also noted how he drilled holes in the bottom of the tray to provide ventilation and to increase the volume of the device, which had a speaker on the back. But now Cami was getting a new SGD that would not fit into her existing tray. Since the new SGD would have a very different size and shape from her original device, a brand new custom lap tray was necessary.

Several things had changed since Kathy last saw Cami. For one, Kathy was now an OT. She was able to use her therapeutic OT knowledge and skills to be involved in the problem-solving and design process in a different way. Also, since it had been nearly 20 years, Kathy had to reassess Cami's upper body strength, range of motion, and positioning in her wheelchair while working on the new tray shape and dimensions.

Another big change since 2006 was the clinical climate. AT specialists had been steadily moving away from making custom-built equipment for AT consumers. Due to funding constraints and a decreased emphasis on the role of rehabilitation engineers and design specialists in healthcare, many therapists are now limited to ordering commercially available equipment, which in this situation would be standard SGD mounts and wheelchair lap trays, neither of which would support Cami's physical access and transportation needs of her SGD. Cami's health insurance would not cover a custom-built lap tray. However, standard equipment does not meet Cami's needs. Evidence shows that when the match between the user and AT equipment is poor, this contributes to frustration and device abandonment (Boot et al., 2019; Johnson et al., 2006; Smith et al., 2018; Waller, 2019). The UIC ATU is one of the only local places that continues to make custom equipment. Fortunately, Cami was able to pay for the new lap tray out of pocket.

When Cami and her parents came to the ATU for an evaluation appointment, they brought the old tray, which was used as a starting point. Cami and her family directed our team by telling us what worked and what could be improved. Cami's tray needed to suspend her new communication device below the tray's surface. During discussion, Cami reminded the team, "but what about eating?" The tray would also be used as a surface for Cami to place her plates and bowls during meals for self-feeding. This was accomplished by the family putting a firm surface over the tray cutout and a towel over the padding. After evaluating Cami's strength, range of motion, seated position, and size of the device, Kathy worked with the ATU's design specialist, Adrian, to modify the tray shape. New foam padding was ordered. Moisture-resistant fabric that was found to be beneficial in the old lap tray was used to make new protective covers.

The team was able to successfully get one part of the custom-built lap tray covered by Cami's health insurance. Cami's lap tray was supported distal to the armrests by commercially available lap tray hardware. Fortunately, this hardware is still able to be purchased, and Cami and her family worked with Cami's wheelchair supplier to get new lap tray hardware as a repair covered by her health insurance to help offset the out-of-pocket costs to Cami.

Process for Designing and Fabricating the Custom-Built Lap Tray

The process for designing and fabricating the custom tray began with understanding constraints and establishing goals at the outset. We knew that Cami was upgrading her SGD, which needed to fit into the tray in a similar fashion as the previous device, and that she required an updated lap tray due to the wear and tear that occurred over the years. Knowing this, we established that the tray's overall dimensions should remain consistent with the previous version to maximize the available space without affecting her daily activities like eating or working. This design choice also ensured that she maintained a safe distance when navigating entryways/ thresholds, preventing the tray from sticking out too far in all directions.

One feature we were mindful of was to pad the edge of the tray. This part of the tray rested against her torso. It was important for us to make sure the tray was comfortable for her so that it protected her skin when she came in contact with it, specifically at times when she would lean forward and when she would rest her arms on the edge to make selections on the SGD screen, preserving her functional ability and continuity from one piece of equipment to the next.

We thought carefully about the use of materials, especially in terms of contact and durability. For example, when it came to the Velcro, Cami alerted us to the need for placing the soft-loop side against the tray's surface so that even when the rougher hook side wasn't fastened, it wouldn't irritate her skin. If we had done it the other way, using the hook side, it would have been abrasive against her touch, causing high sensitivity and discomfort. As for the tray body, we decided to use ⅜-inch polycarbonate for its durability and its high impact resistance, and again to remain consistent with the previous version. Also, during our initial evaluation with Cami, she requested that we keep certain features, such as the metal spring stylus holder and the use of Kydex, a plastic material with strong thermal and impact resistant properties, for creating the supportive compartment for the device.

The overall dimension of the device was a key constraint in this project because the slot designed to house the device needed to be snug enough to secure it without taking up too much surface area, and the new device was wider than the previous device. This meant the slot needed to be just wide enough to allow Cami's Personal Care Attendants (PCAs) to effortlessly slide their fingers in and between the device to operate the equipment and remove it for charging and maintenance. Additionally, we had to ensure that the Kydex material on the underside of the tray had ample clearance along the edges for stability and to be able to affix it to the tray, as well as to avoid any potential for cracking when installing the hardware.

Methods and Making

Once the team had established the criteria from the first evaluation, Adrian and Kathy began developing the new tray. First, they laid down the previous tray on brown kraft paper to create a stencil. They traced the overall dimensions and noted the side contours and radii. They approximated the center cutout for the new device and marked the existing location of features like the stylus holder and padded lining. The resulting stencil became the guiding template for the new design.

After applying the stencil to the 3/8-inch polycarbonate, it was time to cut into the material. First, Adrian began making rough cuts to outline the overall shape. Using a band saw, he made several passes, each time getting closer to the edge while leaving about 1/8- to ¼-inch of clearance for finishing. Once the overall shape was cut, Adrian moved to the drill press to cut out 1-inch diameter holes using a Forstner bit for the device holder at the center of the tray. He cut 1-inch diameter holes at the corners of the rectangular shape that was marked as the space for the communication device. This made it easier to remove material from the center of the material while also rounding out the corners. Then, he used a router bit in each hole and followed a straight path connected by tangent points from corner to corner. This technique allowed Adrian to rout the remaining interior edges more effectively to achieve a cleaner look as shown in Figure 3.

Once the center hole was cleared and the interior walls were routed, Adrian and Kathy began working on the Kydex device holder. Kydex is an acrylic-PVC hybrid that provides rigidity and is both impact- and chemical-resistant. Its durability makes it ideal for holding a heavy device for extended periods of time, even at high temperatures, as well as for ease of maintenance.

The new SGD was larger than the previous model, which required adjustments to the shape of the plastic holder. Adrian needed to modify the angle at which the device sits so that it did not protrude too far or sit too low from the top surface of the tray, which was imperative to supporting Cami's physical access to make selections on the SGD screen. The team's goal was to make sure that the device's surface sat flush with the top surface of the holder when placed inside (see Figure 4).

Figure 3: *Creating the Lap Tray*

Note. Adrian used a stencil created from the original lap tray to re-create the novel lap tray, however needed to use a band saw to ensure the overall shape worked with the new SGD.

To create the plastic holder, Adrian used thermoforming rods. The process begins with transferring an approximate sketch from brown kraft paper onto Kydex and carefully outlining the design. Next, the material is cut to size to fit the center cutout. Once the starting material is cut, corners are marked, and excess edges are trimmed to allow for an easy bend once heated. In this step, it's important to leave a clearance of about one to two inches from the top edge to accommodate the hardware during installation. Finally, the material is placed between the heating rods and gently bent along the guidelines to achieve the desired shape (see Figure 4).

This part of the process involves some trial and error. When using thermoforming rods to shape the plastic, the accuracy of the bend's radius can vary based on the thickness of the material. Specifically, as the plastic is heated and bent, the curvature of the bend affects the overall dimensions of the molded area. Therefore, it's important to account for this thickness to achieve more exact results.

Figure 4a: *SGD Sitting Flush Within the Kydex Compartment*

Figure 4b: *Underside of the Kydex Compartment*

Figure 4c: *Side View of Kydex Compartment Mounted Under the Lap Tray*

Note. The new compartment to hold the new SGD was made from Kydex. The SGD needed to sit flush with the lap tray to ensure Cami's ability to physically access the touch screen as well as support self-feeding.

The tray and plastic holder were presented to Cami, who noted, "This is too tight" when attempting to generate a message on the new SGD. Additionally, the team all noted that the holder was not deep enough to ensure that the device was flush with the tray. This created increased effort for Cami when accessing the device with her stylus, and she reminded the team of the need for the device to be flush so she can use the tray for other activities, such as support during meals. The team took notes and brought the tray back to the shop where adjustments could be made to ensure that comfort and access needs were being met.

Next, Kathy and Adrian worked on the softer materials that lined the edge of the rigid tray. This portion of the project was essential for ensuring both the comfort and protection for Cami that she sought out at the outset. We selected several 3 mm and 1.5 mm neoprene fabric options, as well as a viscoelastic cushion, commonly known as Pudgee orthopedic foam, for the overall

materials. We wanted to recreate a soft, fabric-covered foam pad that would prevent any potential damage to the tray's surface while also providing Cami a cushioned touch and skin protection.

To begin, Adrian and Kathy made a template based on the previous padding on brown kraft paper. They outlined a general shape with some clearance, offsetting the material by about two inches (see Figure 5). This allowed them to ensure an accurate fit by giving room to adjust the consistency along the edge of the tray as needed. After cutting out the new pieces, Adrian moved on to sewing them together. He decided on a standard topstitch seam, which is a reinforced stitching technique to enhance the durability of the seam, since it would be stretching over the foam. This technique makes a clean seam without exposing any cut edges. Throughout the sewing process, Adrian ran into some issues with the material thicknesses causing fabric bunching, but he learned to adjust the tension on the machine to resolve this.

Figure 5: *Creating a Template for the Foam Padding Lining the Lap Tray*

Note. Adrian and Kathy created a template for the padding that would protect Cami's torso from the roughness of the lap tray.

After some trial and error and several test pieces later, Adrian had sewn the pieces together as shown in Figure 6 and moved on to attaching them to the tray. In keeping with the previous tray, Adrian adhered Velcro to interface with the edge of the lap tray. This involved reinforced stitching onto the back of the sewn pieces, so that the entire back of the pad created a secure edge-to-edge attachment to the tray and would then be stronger to withstand frequent removal for washing.

Finally, the team adhered Velcro to the bottom of the tray using fabric adhesive and hot glue so that a flange piece from the pad could wrap around the edge that comes in contact with Cami's torso and hook onto the bottom Velcro for a firm closure. The result was a clean, water-resistant covering that redefined the edge of the tray closest to the body, that would provide protection and comfort for Cami (see Figure 7).

Figure 6: *Sewn Edge of the Foam Padding*

Note. Adrian completed the foam padding using a standard top stitch to secure the material. Adrian completed the foam padding using a standard top stitch to secure the material.

Outcomes and Benefits

While working towards a novel AAC system, the team identified several key lessons along the way, and from these lessons we have developed recommendations for AT vendors, AT professionals, family members/carers of those with disabilities, and AT consumers. These lessons revolve around the incorporation of multidisciplinary teams that focus on person-centered care that is guided by a HA-AT framework, the importance of customization in ensuring fit and usability of AT, as well as the need for AT to remain available and consistent from device vendors.

For professionals working in AT and AAC and organizations providing these services, we want to strongly encourage an environment that supports collaboration with a multidisciplinary team of professionals that specialize in AT. At the helm of the team should be the individual seeking AT services and their family or carers as applicable. The clinicians on this team have met countless AT consumers through our work at the ATU where professionals have recommended a piece of equipment without the input from the consumer. This is inclusive of children who are receiving services within the public education system. The literature tells us of the importance of person-centered services (Smith et al., 2018), and anecdotally, we at the ATU witness what can happen when the consumer is not placed at the center of the team. Inclusion of the AT consumer increases the likelihood that the equipment will be suitable for use, increasing the likelihood of equipment adoption and decreasing the likelihood of abandonment. If the goal is for the AT to make an activity accessible and to increase participation, then the consumer must be driving the decisions based on their preferences, goals, abilities, and needs every step of the way. Cami remarked, "They [ATU

professionals] were a good team and formed a good team with me and my parents. They understood what was needed and they heard our suggestions. Without the caring and effective work from them I wouldn't be able to communicate well and comfortably."

Figure 7a: *Final Custom-Built Lap Tray and New SGD*

Figure 7b: *Cami With the New SGD and Custom Lap Tray*

Note: The final custom-built lap tray with the metal spring to hold Cami's stylus, the Kydex compartment to hold the SGD flush with the lap tray top, and the Velcro to secure the padding and lap tray to Cami's wheelchairs.

For AT professionals, we implore you to consider customization of AT when standard-issue equipment will not meet the needs and abilities of the consumer. The alternative is using a piece of equipment that does not fit or work with the consumer's abilities and needs. As observed in Cami's story, a standard-issued wheelchair mount for the SGD would not have supported Cami in directly accessing her SGD via touch, nor would it have allowed her access to her SGD when she is using both of her wheelchairs (i.e., powered wheelchair and manual wheelchair). Sure, the team could have tried an alternative access method such as eye tracking. However, this was not Cami's preference, and it did not capitalize on her physical upper extremity abilities. Fabricating custom AT equipment can sometimes be the only way to meet a client's needs. While 3-D printing is making one-of-a-kind designs available to everyone, not all custom projects can be 3-D printed. Collaborating with a team of therapists, engineers, and design specialists with access to a variety of tools and materials is needed to ensure the ability to make customized AT and ensure fit and usability for the individual. This story outlines the importance of adhering to a person-centered team approach that Smith and colleagues (2018) describe as a key principle to developing a sustainable strategy for AT provision.

During the customization process, collaboration among therapists, rehab engineering, and a design specialist is critical to ensuring that all aspects of the customization are safe, preferable, and comfortable for the AT consumer. For example, in Cami's story, Cami and her family called the team's attention to the placement of the Velcro strips, noting that the softer loop side of the strip should be upright for comfort and protection of skin integrity. Additionally, sometimes during customization, trial and error is needed. While this can increase the time and materials needed, it can ultimately work to ensure the desired outcome. When making Cami's lap tray, Adrian used this method to ensure a comfortable fit for Cami, but a snug fit of the SGD, which meant that he needed to subtract material from the lap tray sparingly since it cannot be put back once removed. This required strategic planning, measuring, garnering feedback from Cami, and an understanding of the use of the tools. For future iterations, Adrian plans to streamline the process and make it less labor intensive by taking a large format scan of a stencil that can be digitized to produce a laser-cut stencil from acrylic, which can be used to overlay material. This can then be routed out like a guide to be used repeatedly.

With regards to recommendations for speech-generating device manufacturers and vendors, we want to implore them to consider the impact of taking previous iterations of products off the market and changing speech-generating software systems. Cami's father likened the process of obtaining a new SGD for Cami to buying a new car. He noted that as SGD models change in size, shape, and operation, it's like needing to change the size of your garage every time you buy a new car. Cami noted,

> I wish companies would try to make new equipment fit with old equipment. If [device vendor] changes the software that does not accept the word program that I am familiar with, then it is very stressful and frustrating to develop and learn a new word system different from my one that I've used for years. Besides that, each software change also comes with a change in the size of the [SGD], which means a new tray has to be made to hold my new device to my wheelchair. That is more difficult than you might think. The tray is on my wheelchair at least ten hours a day. So, it has to fit right or it hurts me.

Conclusion

The role of AT is to support those with disabilities in meeting their own personal goals, whether that be making a camera accessible to explore a hobby in photography or ensuring that a wheeled mobility system can navigate through the home and community. Cami's story is one of a team approach to AT services that centers the client at the heart of services and recognizes when standard-issued equipment will not meet the needs, abilities, and preferences of the AT consumer. This person-centered, team approach is critical to increasing the likelihood of AT adoption and decreasing the chances of AT abandonment. Overall, it is the pathway needed to support the individual in meeting the personal goal they set out to achieve when seeking AT services.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 164-177
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Field

Tactile to Tangible: Lessons from the Monarch Braille Display

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Abstract

Multiline refreshable braille displays are reshaping tactile access and instruction. Centering the Monarch, a ten-line, 32-cell device that supports formatted text and tactile graphics, this article synthesizes classroom practice, pilot feedback, and user perspectives to show how multiline access strengthens reading fluency, spatial understanding, and independent editing across subjects. We illustrate applications in ELA, STEM (including real-time graphing and spreadsheet datasets such as Mr. Trash Wheel), and computer science (code structure and debugging). We argue that multiline braille shifts access from reactive accommodation to active participation, aligning with emerging eBraille standards and supporting equity, motivation, and self-efficacy for blind and low-vision learners.

Keywords: multiline braille display, tactile graphics, Monarch, eBraille

Tactile to Tangible: Lessons from the Monarch Braille Display

Refreshable braille displays (RBDs) have transformed how braille readers access digital content by generating characters on demand using small mechanical pins that form tactile braille cells, rather than relying solely on embossed braille produced in advance on paper (APH, 2024; Dangat et al., 2025). Yet access to timely, well-formatted braille remains problematic. Embossed braille and tactile graphics are often produced in limited quantities, updated slowly, and distributed in bulky volumes, which makes them poorly suited to fast-changing digital information and classroom work (Yang et al., 2021). Even when digital braille is available, most RBDs present a single line of 20 to 40 cells, requiring frequent panning to move through text and structured documents. These constraints raise equity questions and can reduce fluency and hinder interpretation of headings, lists, code, and other spatially organized information (McCarthy et al., 2022; Wiazowski, 2014).

Researchers in haptics and accessibility frame these issues as part of a broader access problem. Frediani et al. (2018) argue that affordable, portable, full-page, electronic RBDs are urgently needed as tactile counterparts to mainstream digital screens yet remain largely "technological fiction" (p. 3). Bhatnagar et al. (2023) report that two-dimensional pin-array displays can have a substantial impact on education, but are often prohibitively expensive, which limits adoption and affects educational and employment opportunities. Review findings further emphasize that reading efficiency and aspects of quality of life are linked to timely, high-quality braille access, which strengthens the rationale for investments in multiline displays (Rose et al., 2025). Together, these studies situate multiline tactile displays as part of an international effort to make braille and graphics more timely, portable, and scalable for everyday use.

The Monarch multiline braille display sits within this evolving landscape. Co-developed by APH, HumanWare, and the National Federation of the Blind (NFB), the Monarch is a ten-line, thirty-two-cell refreshable braille device that can also render tactile graphics on the same surface (APH, n.d.-a; APH, 2025a; HumanWare, n.d.). This article explores the instructional and technological implications of multiline braille through classroom application, informal pilot experiences, and professional practice. Our goal is to contribute a grounded practitioner perspective that complements existing engineering and design literature by illustrating how a multiline braille and tactile graphics display can affect reading fluency, spatial understanding, and independent editing across subject areas.

Target Audience and Relevance

This article is relevant to educators, assistive technology specialists, curriculum developers, families, policymakers, and technology designers seeking to advance equitable access to literacy and STEM. For educators and assistive technology specialists, it offers classroom-based examples of how multiline braille can support reading, writing, editing, data interpretation, and computer science learning. For curriculum developers and technology designers, it highlights the importance of formats, interfaces, and tools that support structured tactile access across text, graphics, and digital learning tasks. For families and policymakers, it underscores why timely access to multiline braille and tactile graphics matters for educational participation, independence, and broader equity in literacy and STEM.

Monarch in 2026: Technology Snapshot

The Monarch has moved from prototype to a standards-aligned literacy and productivity tool. It was also recognized by *TIME* as one of the Best Inventions of 2025 in the Accessibility category (TIME, 2025). Cost remains a persistent barrier in braille technology, but the Monarch is Federal Quota Eligible and currently listed by APH at $15,500 (American Printing House for the Blind [APH], n.d.-a). As of February 2026, software version 1.4 expands the Monarch's functionality with Bluetooth braille terminal support, KeyDrive cloud file access, improved eBraille formatting and performance, app refinements, and additional language support (APH, 2026; APH, n.d.-a). In parallel, eBraille 1.0, developed by the DAISY Consortium with international partners and informed by a problem statement from a working group of more than 100 experts across 20+ countries, has progressed from concept to public implementation on Monarch via the first publicly available eBraille title, *Treasure Island* (DAISY Consortium, 2025a; APH, 2025a). Built on an EPUB-compatible file set, eBraille supports refreshable braille with metadata for braille codes, tactile graphics, and navigation, enabling efficient movement across sections, pages, and embedded graphics (DAISY Consortium, 2025b). Together, these developments position Monarch as a flexible platform for literacy in K–12 settings and beyond.

Historical and Technical Context of Braille Displays

Experimental electronic braille devices appeared by the mid-twentieth century, including early belt-based and electro-mechanical systems that rendered braille dynamically. Engineering accounts describe the development of refreshable braille displays as beginning in the 1970s with mechanical pin systems, followed by major advances in portability and microelectronics that made displays more compact and practical for everyday use (APH, 2024; Dangat et al., 2025). By the 1980s, commercial refreshable braille displays were reaching the market, and subsequent decades brought significant diversification in size, shape, and function as manufacturers refined actuation methods, power management, and integration with computers and mobile devices (APH, 2024; Tkacik, 2023).

Consumer and professional guides describe a range of braille display configurations. Portable braille displays are often 20 cells or fewer and designed to pair with smartphones, tablets, or laptops, while 40-cell displays have become a common mid-range option for everyday reading and writing. Larger 80-cell desktop displays are intended for extended editing and complex document review (American Foundation for the Blind, n.d.; APH, n.d.-b; Davert, 2023). Most of these devices present a single line of braille, which requires frequent panning and limits how much structure a reader can access at once (McCarthy et al., 2022; Wiazowski, 2014). Engineering reviews further note that many existing devices remain expensive and offer limited text capacity relative to user needs, reinforcing the importance of ongoing innovation in cell count, layout, and connectivity (Dangat et al., 2025).

Classroom practice evolved alongside these hardware developments. The pin-array mechanisms behind refreshable braille involve trade-offs in force, refresh rate, pin density, power, and cost that have kept multiline and page-scale layouts rare for decades. Surveys of tactile display technologies highlight how these design constraints, combined with high component costs, have limited the availability of larger multiline and full-page pin arrays, even as the educational need for them is well documented (Bhatnagar et al., 2023; Yang et al., 2021).

Literacy Access, Editing, and Fluency

Challenges in editing and navigation are not limited to professional workflows. Student IDEs often require deliberate adaptation of the full environment, including structure-aware navigation, to support blind programmers as programs grow beyond a few lines (Schanzer et al., 2020). In both literacy and programming tasks, braille displays serve as essential tools for editing and efficient navigation. Unlike screen readers, which convert text to speech, RBDs allow blind and low vision (BLV) users to tactually access exact spelling, punctuation, and formatting. These details are critical for verifying syntax, proofreading written work, clarifying homonyms, and interpreting structural elements such as paragraph alignment or code indentation (McCarthy et al., 2022).

In programming, a single missing symbol or misaligned bracket can prevent code from executing. Baker et al. (2019) observe that blind programmers frequently rely on braille displays to verify structural syntax that screen readers may not reliably convey, including indentation, nesting, and matching delimiters. Similar dynamics appear in basic literacy tasks, where homonyms and punctuation can be interpreted unambiguously through braille.

Most braille displays in use today are limited to a single line of 20 to 40 cells. This restricts the user's tactile field of view and forces frequent scrolling to access a full sentence, lines of code, or complex mathematical expressions. Repeated panning introduces cognitive load and interrupts reading fluency, particularly for students who are still developing literacy skills or learning demanding content (McCarthy et al., 2022). A scoping review notes that braille fluency is defined inconsistently across studies and is influenced by both the purpose and modality of reading, which reinforces the need to match tasks with appropriate braille technologies (Rose et al., 2025). Longitudinal findings from the ABC Braille Study further show that young braille readers, even when they acquire foundational decoding skills, often fall behind sighted peers in reading rate by the upper elementary grades (Emerson et al., 2009).

As McCarthy et al. (2022) argue, braille should be recognized as a primary mode of literacy acquisition for many students who are blind or have low vision. Emerson et al. (2009) similarly highlight that braille-reading children can develop core literacy skills yet still lose ground in reading speed and some aspects of comprehension over time, underscoring the importance of robust instruction and appropriate tools. Devices that expand beyond single-line formats offer one way to address these concerns by presenting more text and structure at once.

Braille Literacy and Multiple Formats

Braille literacy today is supported by a range of tools. Embossed braille remains a vital tactile format, especially for long-form reading, tactile diagrams, spelling practice, and everyday items such as labels or lists. At the same time, embossed braille is bulky, slow to update, and often produced in limited quantities, which makes it less suited to rapidly changing digital content and iterative classroom work (Yang et al., 2021).

Electronic tools extend this ecosystem. Studies of electronic notetakers have found literacy gains comparable to embossed braille while documenting motivation benefits and spatial trade-offs associated with single-line displays (Bickford & Falco, 2012). Teachers report benefits of electronic

braillers for early writing, immediate feedback, and classroom participation, along with practical considerations such as noise, training, and device management (Holbrook et al., 2003). These findings reinforce that embossed braille and electronic tools are complementary resources.

RBDs provide immediate, interactive access to digital content. Students and professionals can use these devices to read emails, browse websites, edit documents, and access textbooks in real time. Federally supported 20-cell eReaders from the National Library Service for the Blind and Print Disabled (NLS) allow eligible users to download books, magazines, and newspapers from services such as BARD, Bookshare, and NFB Newsline (National Library Service for the Blind and Print Disabled [NLS], n.d.).

Multiline Displays in Practice: The Monarch in Focus

This trajectory now includes multiline and graphical refreshable braille displays, which aim to increase page-like access to text and tactile graphics. Devices such as the Canute 360, Graphiti, and Dot Pad demonstrate different approaches to presenting multiple lines of braille and tactile graphics and are often cited as early examples of a broader shift toward page-like tactile interaction (Tkacik, 2023). The Monarch is part of this emerging class of multiline displays, combining ten lines of thirty-two cells with support for text and tactile graphics on the same surface (APH, n.d.-a; APH, 2025a).

In educational settings, the Monarch is being piloted at scale through the Monarch Student Pilot Project (MSPP), which includes more than 225 students across the United States (APH, 2025c). The Monarch's ten lines of thirty-two cells and adjustable line spacing allow readers to perceive more structure at once and to explore charts, diagrams, and paragraphs in ways that are difficult to achieve on single-line displays (APH, n.d.-a).

In everyday instruction, a device like the Monarch allows students to read a novel, examine a graph, and check an assignment prompt. Source code, paragraphs of literature, mathematical equations, and data tables can be rendered and revised directly on the display (APH, 2025b, 2025d). For decades, braille learners have worked within a digital landscape shaped largely by visual design assumptions and heavy reliance on audio (Baker et al., 2019; Schanzer et al., 2020).

These changes are particularly important as artificial intelligence, data science, and computing gain prominence in national education and workforce priorities. Tasks such as working with spreadsheets, analyzing data tables, or interpreting graphs are now common in K–12 and higher education. In our classroom applications, locally meaningful datasets such as Mr. Trash Wheel's publicly available trash-collection data provided an authentic context for spreadsheet work and data interpretation (Mr. Trash Wheel, n.d.-a, n.d.-b). Multiline access allows students to move between the dataset, formulas, and the graph output without switching devices or relying on a sighted intermediary. Because mathematics, including algebra, often functions as a gatekeeper to advanced coursework and STEM pathways, access to graphs, tables, and structured math layouts is consequential rather than optional (Beal & Rosenblum, 2015). Without inclusive access tools, including reliable braille and tactile graphics access, students who are blind or have low vision risk further exclusion from STEM learning that relies on dynamic data and multimodal information

(Maguvhe, 2015). Multiline braille supports braille-immersed education, a model that treats braille as a primary literacy medium rather than an add-on accommodation.

Federal Priorities, Disability Legislation, and the Case for Inclusive Innovation

The development and classroom deployment of multiline braille displays such as the Monarch sits within a broader national agenda emphasizing equitable access to STEM and digital participation for people with disabilities. Obama's Computer Science for All initiative called for universal K–12 computer science education and explicitly highlighted students with disabilities as a key constituency (Office of Science and Technology Policy, 2016). Trump's Executive Order 13859 on artificial intelligence and Biden's Executive Order 14035 on diversity, equity, inclusion, and accessibility extend these priorities into workforce preparation and federal digital services (Executive Office of the President, 2019, 2021; Exec. Order No. 14035, 2021). These efforts build upon long-standing disability legislation requiring equal access to programs and services and extend those expectations explicitly into digital environments. For education, this means that curricula, learning platforms, and assessment tools must be designed and procured with accessibility in mind, including reliable braille and tactile graphics access for students who are blind or have low vision. Multiline braille displays, together with standards such as eBraille, illustrate how investments in tactile literacy technology can align with these national priorities for educational equity, workforce preparation, and lifelong inclusion. Related research suggests that disability affirmation and robust braille access are associated with improved employment and aspects of quality of life, underscoring the importance of accessible pathways in education (Rose et al., 2025; Zapata, 2022).

Within K–12 education, recent federal guidance further clarifies that assistive technology is not an optional enhancement but a required component of a free appropriate public education when needed. A Dear Colleague Letter from the U.S. Department of Education emphasizes that AT devices and services under IDEA must be "available, accessible, and appropriate" for children with disabilities and their families, and that IEP and IFSP teams are responsible for determining what AT is necessary for meaningful access and engagement in education (U.S. Department of Education, 2024a). A companion "Myths and Facts" document explicitly rejects cost, procurement delays, and local technology policies as valid reasons to deny or postpone AT included in a student's IEP and encourages teams to plan for timely acquisition, implementation, and evaluation of AT as part of routine practice (U.S. Department of Education, 2024b).

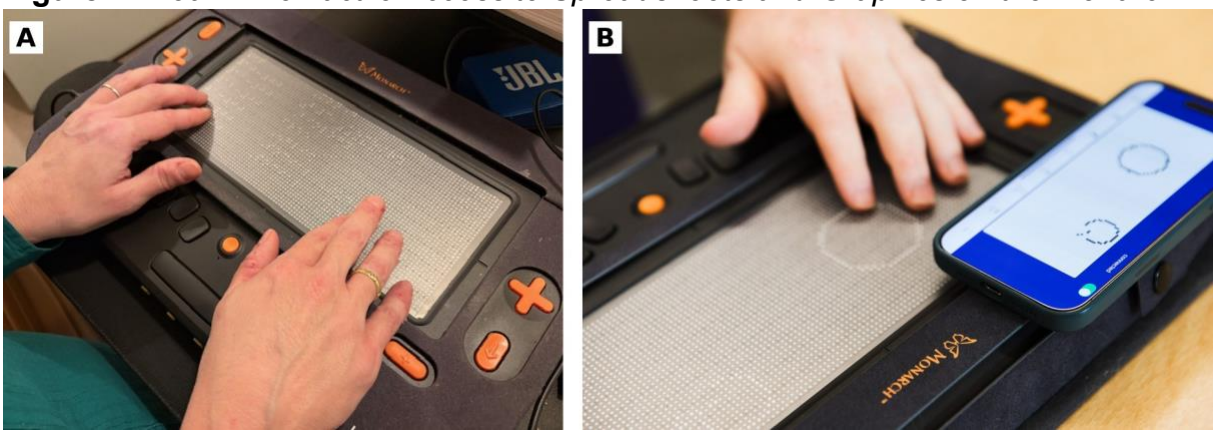
In this context, investments in multiline braille and standards such as eBraille are not simply innovative products. They represent concrete steps toward fulfilling longstanding legal and ethical obligations to blind and low vision learners.

The Monarch in Classroom Practice

The Monarch is being piloted in U.S. classrooms through a collaboration between APH, HumanWare, and the NFB (HumanWare, n.d.; APH, n.d.-a; Tkacik, 2023). Key features include 10 lines of 32 braille cells, adjustable line spacing, and pan keys adjacent to the tactile surface, supporting page-like layouts, efficient reading, and one-handed control (APH, n.d.-a). The same surface presents formatted text and tactile graphics, so students can move between narrative, data

displays, and diagrams without changing devices (APH, n.d.-a). When used as a multiline braille terminal with JAWS or NVDA on Windows, the Monarch can present tables, spreadsheets, and blocks of code across multiple lines, and the Wing It application allows drawings created on an iOS device to appear instantly as tactile graphics (see Figure 1; APH, 2025b, 2025d).

Figure 1: *Real-Time Tactile Access to Spreadsheets and Graphics on the Monarch.*



Note. (A) A spreadsheet-like grid (e.g., Excel) rendered on the Monarch tactile surface for tactile exploration. (B) An iPhone running the Wing It app with a drawing that appears immediately as a tactile graphic on the Monarch. Photographs by the authors.

Broader Implications for Access and Innovation

As multiline braille technology enters classrooms, the need for a standardized digital format is essential. eBraille, developed by a working group led by the DAISY Consortium and APH, addresses this gap. It is a standards-based format built on EPUB 3 that supports dynamic, multiline refreshable braille, encodes tactile graphics, and improves navigation across both multiline and single-line devices (DAISY Consortium, 2022, 2025a, 2025b). This makes it possible for materials to move more seamlessly between embossers, RBDs, and mainstream digital platforms without extensive retrofitting.

The problem statement behind eBraille highlights that electronic braille files have historically been tied to proprietary systems or local production workflows, limiting portability and consistency across devices (DAISY Consortium, 2022). Existing text-based braille formats such as BRF, BRA, BRL, and PEF can present transcribed braille but lack markup, offer limited navigation, and do not integrate tactile graphics in a single file. By aligning eBraille with open standards, developers aim to ensure that a file prepared for one device or service can be read on another without loss of fidelity and that dynamic multiline displays become a routine means of providing braille access (DAISY Consortium, 2022, 2025a).

Outcomes and Benefits

The informal Monarch pilot and classroom examples point to outcomes and benefits for BLV students, their families, educators, and the broader education system. For BLV students, the most immediate outcomes involve increased access, engagement, and independence. Students reported

renewed interest in reading and writing when they could view multiple lines of text at once, skim more efficiently, and perceive their work as coherent paragraphs instead of isolated strips of braille. Educators in the MSPP noted increased interest in reading, writing, and tactile graphics, and students described feeling more like “real writers” when they could edit and revise their work in multiline braille rather than constantly panning on single-line displays. These experiences align with research emphasizing that timely, high-quality braille access supports literacy, confidence, and quality of life (Emerson et al., 2009; McCarthy et al., 2022; Rose et al., 2025).

The Monarch also expands participation in content areas where BLV students have faced persistent barriers. In mathematics and science, multiline braille and tactile graphics support spatial exploration of equations, tables, and graphs, addressing some of the gaps documented around late or inaccessible materials (Beal & Rosenblum, 2015; DePountis et al., 2015). In computer science, multiline braille supports more efficient navigation of text-based code, enabling students to track indentation and syntax without relying solely on audio, reflecting the importance of braille for precise structural information (Baker et al., 2019). Collectively, these outcomes counter the tendency to steer BLV students away from STEM pathways because of inaccessible graphs, maps, tables, and code (Maguvhe, 2015; Żyła et al., 2024).

Families and educators experience parallel benefits. Shared reading on a multiline braille display creates opportunities for inclusive literacy rituals, and MSPP reports indicate reduced preparation time when lesson materials are provided in digital braille and tactile graphics formats compatible with the Monarch. At a systems level, technologies such as the Monarch and the eBraille standard contribute to longer-term outcomes in equity, employment, and well-being; research links robust braille access and disability affirmation to improved educational attainment, employment, and aspects of quality of life for adults with visual impairments (Rose et al., 2025; Zapata, 2022).

Conclusion and Future Directions

Multiline refreshable braille displays are not replacements for embossed braille, single-line braille displays, or speech. They expand the tactile access ecosystem by making it possible to read and edit with more context, interpret structured layouts, and interact with tactile graphics in real time. Just as sighted learners move among laptops, tablets, paper, and phones depending on the task, blind and low vision learners rely on a complementary toolkit. Current guidance for high school students who are blind reflects this reality by emphasizing competence with multiple screen readers, braille displays, and portable notetakers rather than reliance on a single device (Kelly & Kapperman, 2018). Cost should therefore be weighed alongside the access gaps these technologies are designed to reduce.

At the same time, engineering and user studies note that many refreshable braille devices remain costly and provide limited text capacity relative to user needs, constraining access even when devices exist in principle (Dangat et al., 2025). Investments in multiline braille are thus equity-focused interventions that can reduce retrofitting, accelerate access to critical content, and support fuller participation in literacy, mathematics, science, computer science, and digital citizenship. Evidence also suggests that robust, timely braille access is linked to literacy outcomes, postsecondary

success, employment, and aspects of quality of life (McCarthy et al., 2022; Rose et al., 2025; Zapata, 2022).

Recent federal guidance further reinforces that assistive technology is an essential component of a free appropriate public education under IDEA and that cost, procurement processes, or local technology policies do not negate this responsibility (U.S. Department of Education, 2024a, 2024b). Multiline braille is therefore more than a hardware innovation; it is an emerging civil rights tool and pedagogical resource for full participation in the digital, data-rich environments shaping contemporary life. The Monarch offers one current example of this shift and highlights both the promise of multiline access and the importance of sustainable pathways for adoption and long-term use.

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. Regina Fugate reports a non-financial disclosure based on collaboration with APH related to the Monarch. Jennifer Wenzel and Willow Free report financial disclosures as employees of the American Printing House for the Blind (APH).

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 178-197
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Field

Learn Lead Launch: Reimagining Assistive Technology Professional Learning

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Abstract

Professional learning (PL) or professional development (PD) in assistive technology (AT) must be adaptable and flexible, and it must meet the diverse needs of educators and service providers. Integrating assistive technology into classroom instruction requires more than access to tools; it demands high-quality, ongoing professional learning. Research highlights that teachers' confidence and comfort with technology directly influences classroom integration (Liu et al., 2017). Professional development that includes job-embedded coaching and evidence-based strategies has been shown to improve instructional practices and increase student achievement (Darling-Hammond et al., 2017; Kraft et al., 2018). The Nevada Special Education Technology Assistance Project (NSETAP) has reimagined PD by offering differentiated learning pathways to ensure that educational partners are well-equipped to implement AT. This article explores how NSETAP employed three interconnected strategies to develop a comprehensive statewide model: Project ECHO Nevada, a structured in-person professional learning scope and sequence, and an Assistive Technology Consortium.

Keywords: professional development, assistive technology, job-embedded coaching, special education

Learn Lead Launch: Reimagining Assistive Technology Professional Learning

Professional development (PD) for special education teachers and professionals often lacks focus on assistive technology. Research states that there is a need to support special education teachers in the areas of teaching strategies, social emotional support, professional knowledge, and collaboration and advocacy within professional development (Du & Lyublinskaya, 2022; Root-Elledge et al., 2018). The Nevada Special Education Technology Assistance Project (NSETAP) has five objectives, three of which involve capacity building for school districts across Nevada. Those objectives are as follows: Develop a curriculum that addresses the appropriate selection, implementation, and best practices for the use of assistive technology devices and/or services for students in Nevada; partner with Project ECHO on an ongoing basis; implement a 6-session teleconference series to support up to 50 special educators, AT personnel, and district administrators with assistive technology training needs; and provide quarterly facilitated opportunities for collaborative planning, problem-solving, and strategic planning with the AT Consortium. With these objectives, NSETAP reimagined PD by offering differentiated learning pathways to empower educational partners to implement AT in academic settings using the UDL framework. This article explores the question: How might NSETAP leverage three interconnected strategies to develop a comprehensive, statewide model: Project ECHO Nevada, a structured in-person professional learning scope and sequence, and the facilitation of a Quarterly AT Consortium that supports coaching and leadership development. In addition, it discusses NSETAP's experiences in creating and curating this statewide model, which engages with the interconnected strategies to develop a comprehensive statewide model of support, as seen through the lens of the project's director and associate coordinator.

Target Audience and Relevance

This article is intended for district leaders and/or special education leaders who wish to design a sustainable professional learning and coaching program focused on assistive technology and special education practices to improve outcomes. It is intended for researchers seeking to identify their next project to support special education programming and supports for both learners and educators. Lastly, but certainly not least, it is for the special education teacher who is wondering which practices and programs to advocate for to support themselves and the learners they serve in the classroom.

Universal Design for Learning & Assistive Technology

Universal Design for Learning (UDL) provides opportunities to design and deliver learning experiences that are teacher-driven and goal-oriented, eliminate barriers, offer choice, and provide regular feedback. As NSETAP began developing PD offerings for the state, we listened to and gathered input from district personnel across the state, and we reviewed prior data on the project before its inception at the University of Nevada, Reno's Nevada Center for Excellence in Disabilities (NCED). Upon reviewing the initial data, we found that our districts, particularly our rural districts, had limited awareness of UDL, held mixed views on assistive technology, and struggled to implement

it across content areas. Special educators and professionals also had limited opportunities for professional learning within the state outside of their district offerings.

In conjunction with our state's January 2024 review of surveys and dispute resolution data, the United States Department of Education Office of Special Education Programs (OSEP) released guidance refuting myths about assistive technology. This was released alongside the 2024 National Education Technology Plan from the Office of Educational Technology. It was clear from these documents that it was not simply our state and districts that had misconceptions and required capacity building. As a result, we aimed to design professional learning that includes multiple access points, develops skills, and applies professionals' internalization of the knowledge gained. Our offerings are grounded in the UDL framework, in collaboration with our Portrait of a Nevada Learner, to guide professionals in their work. Our Portrait of a Nevada Learner represents a shared vision for our education system. Developed in collaboration with students, educators, caregivers, and community members, it captures the mindsets and skills that Nevada learners need to bring their learning to life. The Portrait of a Nevada Learner (2023), grounded in the pillars of Empowering, Connecting, Impacting, and Thriving, asks four questions: (a) How will I grow in my learning? (b) How do I build & sustain relationships & community? (c) How will I contribute to make an Impact? (d) How will I thrive? We utilized these in each session we facilitated to guide our process and encourage reflection. Each of our professional learning offerings provided clear connections to the portrait, UDL, and adult learning principles. NSETAP adopts this perspective and educates from it, always considering the individual's goals, preferences, and cultural norms in education and in AT selection and implementation, guided by a UDL mindset.

Professional Development

Professional learning occurs within the structure and activities of professional development and ongoing instructional coaching. Effective professional learning uses evidence-based practices to support teachers in implementing new instructional methods and tools with fidelity (e.g., Darling-Hammond et al., 2017). Research suggests that professional development: (a) be learner-centered, building on individual teachers' strengths and needs; (b) address essential content knowledge; (c) provide individuals with opportunities to test their understanding by trying things out and receiving feedback; and (d) occur within a collaborative environment (Darling-Hammond et al., 2017). Kirkpatrick's 4 levels—results, behavior, learning, and reaction—of training evaluation can ensure that professional learning is effective and continues to meet educators' needs (Alsalamah & Callinan, 2021).

This emphasizes the importance of individualized work with teachers, focusing on content knowledge and effective pedagogy within an identified domain (e.g., literacy, mathematics), as crucial to professional development. An initial professional development (e.g., workshop, webinar) is supported by sustained, job-embedded instructional coaching. Research-based coaching cycles include observation with feedback, problem-solving, data-driven decision-making, reflection, and resources for new learning (Knight et al., 2018). Technology features enhance professional learning and coaching processes more efficiently (Hardesty et al., 2020; Weiser et al., 2019) and provide an easily accessible repository of resources, such as videos, vignettes, and modules, that facilitate the acquisition of new knowledge and skills. Comprehensive and supportive professional learning

opportunities are crucial for teacher retention. A recent teacher retention study found that teachers were more likely to remain in schools with mentoring programs, organized PD, options to set their own instructional improvement goals, and sufficient instructional resources (Lindsay et al., 2021).

Teachers' professional development is a key factor in successfully integrating technology into classroom instruction (Hardesty et al., 2020; Schladant et al., 2022). Technology integration is a process, and a positive relationship was detected between a teacher's confidence and comfort using technology and the integration of technology into the classroom (Liu et al., 2017; Rutledge, 2025).

The use of technology can be transformative. It can increase differentiation, decrease isolation, provide specialized resources, and increase productivity for teachers and students. Accessible and assistive educational technology can empower students to develop their knowledge and skills in a variety of learning environments. It enables individual and collaborative growth while embedding assessment and providing immediate feedback. Thoughtful intervention and attention to how technology is designed are also required for successful integration, allowing teachers to provide multiple means of representing information to learners, conduct quick assessments, and produce student data and patterns that help teachers (Rutledge, 2025). Launching Project ECHO in concert with the AT Consortium and in-person professional learning created opportunities to use technology in differentiated ways, to increase access to support, raise awareness of assistive technology, and make learning applicable to practitioners' needs.

Project ECHO

NSETAP introduced Project ECHO to expand statewide services. As the project director and the previous regional coordinator for MTSS, Dr. Rutledge learned how Project ECHO was being used in education, specifically with special education teachers addressing challenging behavior, and later learned that other states were using Project ECHO for assistive technology, such as the University of Wyoming (Hardesty, et al., 2017, 2020; Root-Elledge et al., 2018). A colleague mentioned that the University of Nevada, Reno (UNR) has a Project ECHO, but it has primarily supported the medical/healthcare sector. Project ECHO Nevada (PEN) aims to meet the needs of primary care providers by offering an alternative to costly travel and long waits for patients seeking specialty care. By expanding the knowledge base of primary care providers through Project ECHO's innovative telehealth consultations, patients in rural and underserved areas benefit from specialty care becoming available locally, without the cost and time required to access specialists directly. While Project ECHO for education has been implemented in other states, it had not been implemented in Nevada for special education teachers and professionals. Nevada is large and has diverse needs for services and supports. It is home to the fifth largest district in the nation, alongside 16 districts and various charter school organizations, and NSETAP is responsible for supporting all of them. For us, it was/is essential to model what we would recommend and/or suggest schools do to support the evaluation, selection, implementation, and monitoring of assistive technology while anchoring each session to UDL.

Prior to our PEN in Special Education launch, we established an Echo Hub team. The Hub is an interdisciplinary team of subject-matter experts. Ours included a speech pathologist, a physical therapist, an occupational therapist, a teacher, an assistive technology specialist, an assistive

technology user, the NSETAP director, and PEN staff. This was a relatively large team in comparison to other ECHO models. Once the Hub team was established, we had to define our purpose as we came together. Our aim became to support school personnel and IEP teams with the knowledge, skills, and resources necessary to identify and implement assistive technology to maximize students' learning opportunities through a collaborative model. This 6-session series supports special educators, AT personnel, and district administrators with special education and assistive technology needs. This program fosters statewide collaboration among colleagues and provides an opportunity to consult with an interdisciplinary team.

In collaboration with the University of Nevada's Project ECHO, NSETAP launched its first ECHO series in the spring of 2024. During each session, experts shared their expertise via mentoring, guidance, feedback, and didactic education. With this partnership, NSETAP created and curated the 6 Session Echo Series to increase knowledge of Special Education and AT and to provide consultative support to educators across Nevada. The topics we covered are as follows:

1) Orientation & Misconceptions of AT
    a. Introduces the IDEA definition of assistive technology and addresses common myths about AT and its users.
2) Categories of Assistive Technology
    a. Explores low-, mid-, and high-tech AT types including devices, resources, and services, while continuing to dispel misconceptions.
3) Identifying & Evaluating Student Needs
    a. Provides hands-on work with data sheets and case studies to determine appropriate AT solutions.
4) Collecting & Using AT Data
    a. Covers methods for gathering data before, during, and after AT implementation and analyzing it for informed decision-making.
5) Normalizing AT & Overcoming Barriers
    a. Reviews the history and normalization of AT and discusses practical strategies for integrating AT using UDL principles.
6) Team Development & the SETT Framework
    a. Examines team roles and responsibilities using the SETT framework to ensure coordinated and effective AT support.

In these quick sessions, participants learned through case study analysis and a didactic flash talk. Participants submitted cases that they wanted collaborative problem solving to provide suggestions to support them in their learning environments. A protocol was reviewed, utilized, and adhered to during the sessions. Because cases have a wide range of needs, it was determined during the initial Hub team meetings that each session would discuss and provide suggestions for one case. The presenter of the case stated their main concern or asks, then discussed the particulars while maintaining students' confidentiality. All participants were welcome to join the next two segments, where they could first ask clarifying questions and then offered recommendations. In each segment, participants had their opportunity before the interdisciplinary Hub team. Because in years one (50–80) and two (200–250), we had large groups of professionals, we encouraged attendees to share questions and ideas in the chat that we also captured. After each case, the Hub would summarize what we heard and provide space for additional suggestions. Our approach was intentional as it invites and honors everyone's experience, fostering a sense of belonging and value.

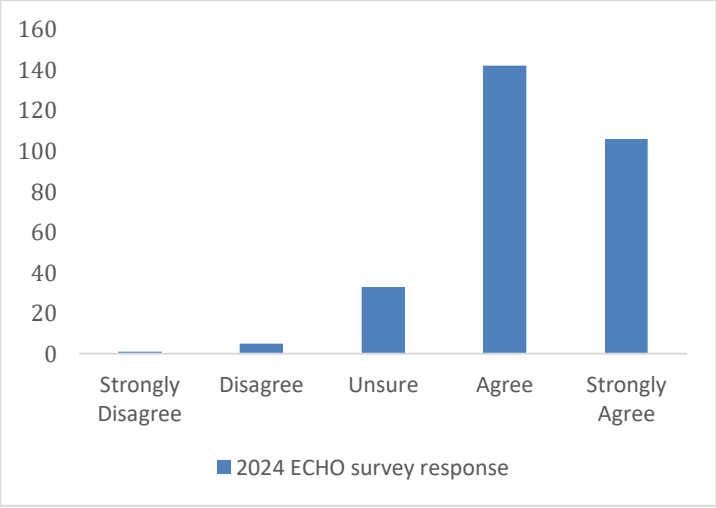
Educators and professionals who submitted a case received a list of suggestions that our team collected during the session.

The 10- to 15-minute didactic flash talk, initially held in year one before the case study, was collectively decided by the Hub Team to be held after the case study in year two. This change allowed for full time and space to explore the case and offer quality feedback. During the remaining time, one of the Hub team members presents a brief overview of the topics above. This is designed to give quick, actionable steps and resources for further study.

Below are the overall outcomes for increased knowledge, changes in practice, and the ability to provide appropriate support to learners. During the 2024 cycle, 248 of 287 (86%) respondents reported that their learner support improved after participating in the ECHO series. 95% affirmed that their knowledge of AT increased after attending the ECHO series; 79% said that, as a result, how they engaged in their role or practice would change; 83% said they felt less isolated. In the 2025 ECHO series cycle, 79% of respondents either planned to or had already implemented strategies learned in the ECHO sessions, and 81% said they learned from the ECHO series and would make changes, or had already made changes, based on its recommendations. Based on Kirkpatrick's framework (2016), Level 3 Behavior evaluates the effectiveness of professional development, including application of practices, and Level 4 Results includes analyzing targeted outcomes, which is a critical indicator of the impact and need. These results further indicate the need for ongoing professional development, particularly in assistive technology.

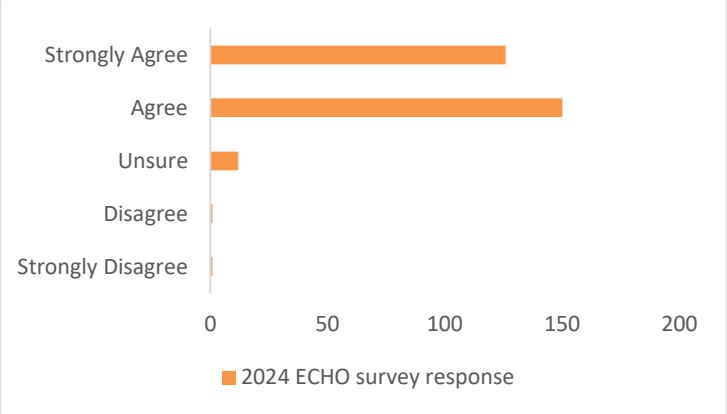
Year 1

Figure 1: *Improved Support*



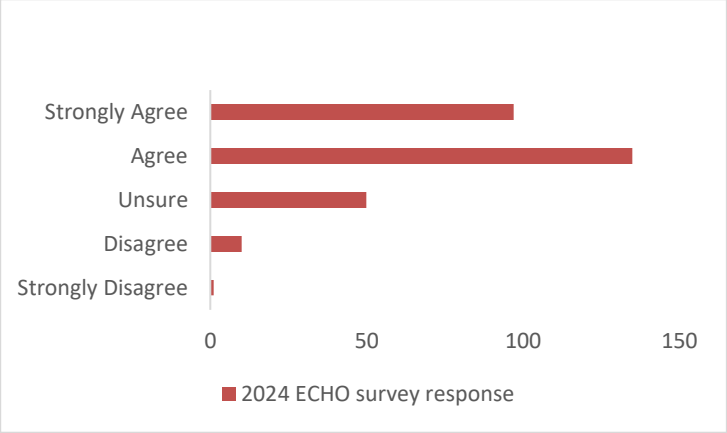
Note. Participants' improved learner support after ECHO 2024 participation.

Figure 2: *Knowledge Gained*



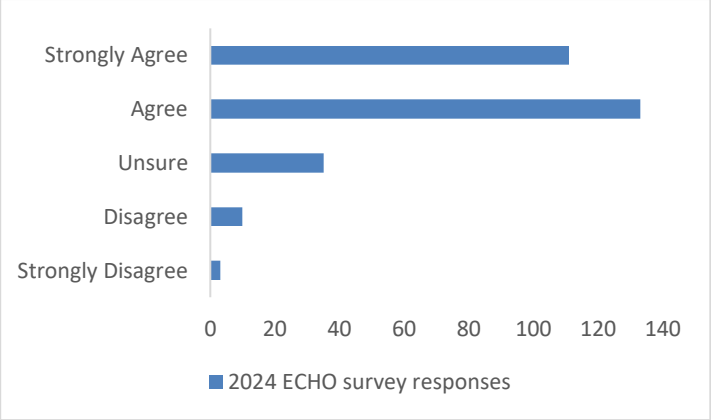
Note. Participants' knowledge gained after ECHO 2024 participation.

Figure 3: *Changes in Practice*



Note. Participants' change in practice after ECHO 2024 participation.

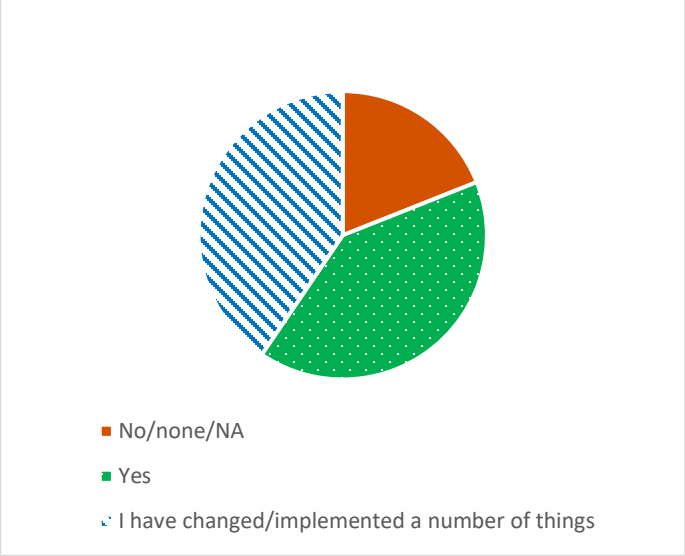
Figure 4: *Decreased Sense of Professional Isolation*



Note. Participants decreased isolation after ECHO 2024 participation.

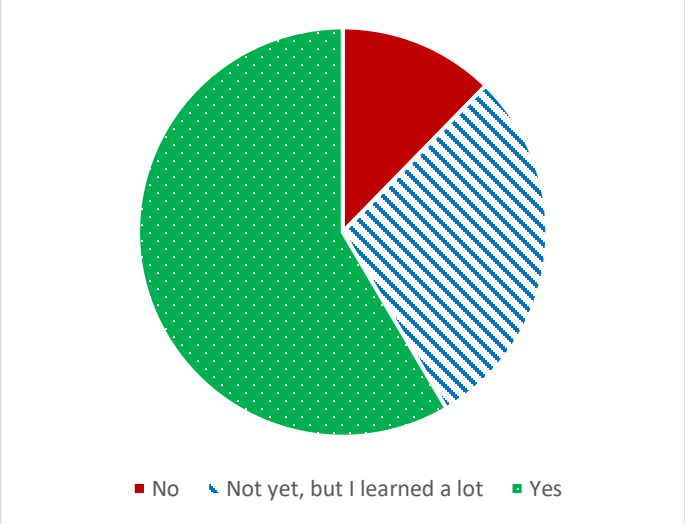
Year 2

Figure 5: *Implementation*



Note. Participants implementation of strategies after NSETAP ECHO 2025 participation.

Figure 6: *Changes Based on Recommendations*



Note. Participant changes based on recommendations from ECHO 2025.

While the ECHO series was scheduled for the spring each year, we provided additional opportunities for professional learning, such as our AT Consortium and, in year two, our in-person professional learning sessions. Our outcomes from year one led us to guide participants to NSETAP's other offerings, which dive deeper into each topic and illustrate UDL in practice. As we noted, UDL is also an area our districts identified as needing more support.

Assistive Technology Consortium

NSETAP's Assistive Technology Consortium is a statewide network for school districts to support universal design for learning, assistive technology, and access to instructional materials to improve student achievement, with meetings in November, February, and May. Using the districts' needs to determine the topics and/or themes for each session, each consortium hosted is four hours long. The consortium includes guest speakers, resource sharing, and a collaborative problem-solving component. We intentionally used the Quality Indicators for Assistive Technology (2015) as the foundation throughout the consortium. This has helped us draft guidance and support districts in creating sustainable, implementable AT systems and practices. Holding quarterly consortiums provides a forum for district leads to learn and gain support in the network. Each quarterly consortium is themed based on the data we received the prior year regarding topics, needs, wants, and satisfaction from Kirkpatrick's framework (2016) form evaluating programming Level 1 Reaction. For our 2023–2024 Consortium, we had the following themes:

1) November 2023: Setting the Stage
    a. Hearing from adults who utilize assistive technology and setting a space of learning from one another, including resources.
2) February 2024: Setting the Foundation
    a. Myths and facts, including how to curate and create foundational systems and supports with AT.
3) May 2024: Accessibility and AI
    a. Review accessibility features in technology and the use of AI to support accessibility and learners with disabilities.

It is important to note that this was the first year the project, specifically the AT Consortium members, was hosted by the NCED's NSETAP, so we wanted to gain an awareness of their needs. During this year of the project, we introduced a new model: consumers participating in the project and providing their perspectives, as well as facilitating themed sessions.

For our 24–25 Consortium, we had the following themes, based on the need to provide both system-level support and practices, while ensuring that districts were aware of new technologies and how to integrate assistive technology into content areas. This is where we shifted our approach by adding system awareness, integration practices, and a space for guests with experience in practice or assistive technology to collaborate on problem-solving. Our themes for these sessions are as follows:

1) November 2024: AT and STEAM
    a. Our focus was on the QIAT one through three and the integration of AT in the Science, Technology, Engineering, Arts and Mathematics.
2) February 2025: AT and Accessible Education Material (AEM)
    a. Our focus was on the QIAT four and five, and the integration of AT and Accessible Education Materials in literacy and communication.
3) May 2025: AT and Mental Health, Social Emotional Learning (SEL), and Behavior
    a. Our focus was on the QIAT six through eight and SEL, Behavior, and Mental Health. This included brief considerations and resources when learners are transitioning.

As the Consortium is a network, many participants have noted that they would like to explore potential funding sources, incorporate typical learners and other peers on campus, and implement Speech-Generating Devices, Light Technology, and Mid-Technology solutions. Additionally, they expressed interest in buy-in and resistance implementation, as well as transitional services and technology. As a result, participants in the AT Consortium have found the initiative resourceful and would like NSETAP to create resource guides based on the information shared throughout the year. We continually identify ways to support them better and to expand their awareness and network of support each year.

Each consortium facilitated is a collaborative effort, bringing together administrators and leaders in their respective fields, representatives and distributors, and those involved in resources and advocacy to provide the most up-to-date and relevant information for our education community. Decision makers can hear from the source and broaden their network, while also having an avenue to seek support directly. The information provided in these sessions, along with the resources in our shared folder and the networking opportunity, creates a unique space to address each district's specific needs.

In-Person Professional Learning Series

After the first year of NSETAP with UNR's NCED, the team began examining the needs based on what they had learned from working with districts and special education personnel. Based on our PEN series and AT Consortium data, we learned that professional learning needed to be differentiated because both offerings have been online; our districts really wanted an in-person option that offered depth. Within the professional learning offerings, NSETAP implemented an in-person professional learning sequence that aligned with the Project ECHO series and was anchored more in depth to the UDL framework. This was intentional and strategic because, during those sessions, professionals received a 10- to 15-minute flash talk and a consultation on a case study. However, during the 3-hour in-person professional learning sessions, we emphasized exploring and utilizing various types of assistive technology, based on case studies developed. This encourages professionals to engage in high-leverage practices in special education, use Universal Design for Learning, and debunk myths while upholding their expertise as practitioners.

Part of the emphasis in NSETAP's Scope and Sequence series is on interactive, engaging learning sessions each time we facilitate. For highly cerebral sessions, such as data collection and analysis, NSETAP employed a great deal of hands-on, independent group activities in addition to audiovisual presentations. In each session, a variety of AT is available at the participants' tables, and a collection at the AT table is available for exploration after the core presentation.

NSETAP does not simply train on AT; we use AT in our professional learning sessions, both for accessibility and to demonstrate the tools in practice. We intentionally used the UDL framework in the curation and creation of our professional learning sessions. We utilized multiple means of engagement through in-person and online AT tools exploration, using physical manipulatives and fidgets, and actively moving groups in the physical space to engage the whole body and mind in the learning process. To support multiple means of representation we used videos, overhead slides, audio, captioning, along with digital data sheets, and printed materials, considering prior knowledge

of the group and relating information in a relevant way. We also engaged multiple means of action and expression through interactive web-based polls and Q&A, along with the use of physical and verbal engagement, using gesture, signs, or pictures. We intentionally used all of these to maximize engagement and learning and to demonstrate how to implement AT tools in a learning environment.

Participants could access content in multiple formats and engage with it in various interactive ways. They worked through fabricated case studies and scenarios from their own schools, collaborating to analyze challenges and identify appropriate resources and solutions. This process equipped them to generate recommendations tailored to their students' needs, and we guided them through the steps for requesting AT from NSETAP's lending library for trial use. Throughout the sessions, NSETAP received several requests from educators to trial equipment with learners. NSETAP also demonstrated various applications and provided hands-on guidance in their use. A district leader participated in each session and observed strong educator interest in implementing one of the AAC applications with learners; as a result, the district team received approval to adopt the application in their schools. Overall, the in-person professional learning series had a substantial impact, increasing awareness of available technologies and strengthening participants' confidence in exploring new tools to support learners.

Outcomes and Benefits

As NSETAP, we wanted to ensure that we are seen as a resource for school districts and the professionals who support and serve learners. Through our Project ECHO series, we expanded our reach to 13 school districts and 300+ professionals over the two years. Educational leaders must promote professional development that ensures that teachers are equipped with and supported in implementing AT and UDL-aligned practices. Research consistently informs us that teachers' professional development is essential for successfully integrating technology, educational and/or assistive, into classroom instruction (Moody, 2015; Rutledge, 2025).

Professional learning should focus on building and sustaining the knowledge and skills needed to support learners who require special education supports and services. Special Education High Leverage Practices state that teachers are responsible for selecting, implementing, and utilizing assistive and instructional technologies to support the needs of learners with disabilities (Du & Lyublinskaya, 2022; McLeskey et al., 2017; Pennington et al., 2022). The selection and use of augmentative and alternative communication devices, assistive technology, and instructional technology products to promote learner learning and independence are informed by awareness of the various types of assistive technology. Educators must understand the types of assistive technology and how to integrate these technologies into their classrooms to ensure equitable access to the learning environment for all learners (Rutledge, 2025; Zabala, 2020). NSETAP provides these opportunities through our professional learning offerings.

Providing differentiated learning pathways modeled the support and services learners need, along with offering opportunities for educators to identify the benefits of professional learning experiences. Many educators and professionals who attended the ECHO series and/or our in-person professional learning series have identified aspects of the information learned that would change the way they do their jobs and/or increase their AT knowledge. While participants in the AT Consortium

gain access to a network of professionals to learn from, they also shape their learning by providing constant feedback and input before, during, and after the quarterly meetings.

The ECHO model research indicates that professionals reported increased AT knowledge and skills, improved professional satisfaction, and diminished professional isolation, and that AT can be used on a large scale to transform AT implementation practices (Hardesty et al., 2020; Root-Elledge et al., 2018). Based on NSETAP's engagements, interviews, and survey results from the past two years (see figures 1, 2, 3, and 4 above), the researchers' findings are also applicable locally in Nevada. Participants commented on the impact of these sessions, noting that the information and insights gained would change how they approach their roles in the future. One participant commented, "The resources and indicators helped a ton. I will be creating a district AT Guide and Checklist :o)." Participants were also asked to identify an action, tool, or practice they would commit to taking after the PL session, another critical aspect of Kirkpatrick's Four Levels of Training Evaluation (Kirkpatrick & Kirkpatrick, 2016), specifically Level 2 Learning.

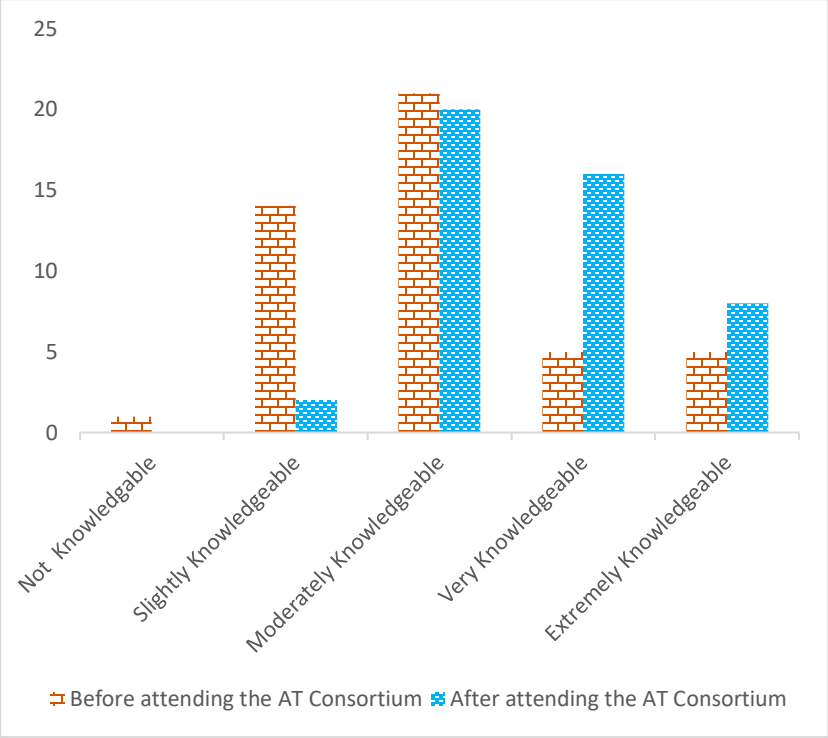
The NSETAP PEN series has served as a bridge between the AT Consortium and the in-person scope and sequence professional learning series. Through exposure to flash talks/didactics, case studies, and consulting in the PEN series, participants have broadened their awareness of AT and districts contacted NSETAP for more in-depth training on various topics and technical assistance, including assessments, consultations, and coaching, indicating the need for ongoing programming.

The provision of AT is a systematic process that requires a sustainable approach and there is a need for properly planned AT education and training (Bowser et al., 2015). Through NSETAP's three-strand approach, educators gain awareness, skills, and competency to implement AT with fidelity. There is a broader group of individuals who require professional learning and development in AT beyond special education teachers and their classrooms. As mentioned, we had administrators attend our in-person professional learning, and it was essential to include a range of professionals who support and provide special education services. Administrators are crucial to note because they are the decision makers for access and fiscal matters. Service professionals, such as speech-language professionals, occupational and physical therapists, and general education teachers, are encouraged to attend any NSETAP offerings because they are indispensable to the education of students with disabilities.

If only one classroom or one educator is involved in developing their competency and capacity in AT, they will likely be the only person students can go to for help. AT embedded with universal design becomes something accessible to everyone. Learners are not limited to a core classroom or core teacher for access, communication, and connection. This fosters and nurtures belonging, which is necessary for academic growth and development (Chambers, 2020). Through NSETAP's three-strand approach, educators are gaining the awareness, skills, and competency to implement AT with fidelity, lifting the veil and providing authentic, realistic, hands-on exposure to a variety of AT. It removes stigma, dispels misconceptions, and provides a foundation for further exploration of AT without hesitation.

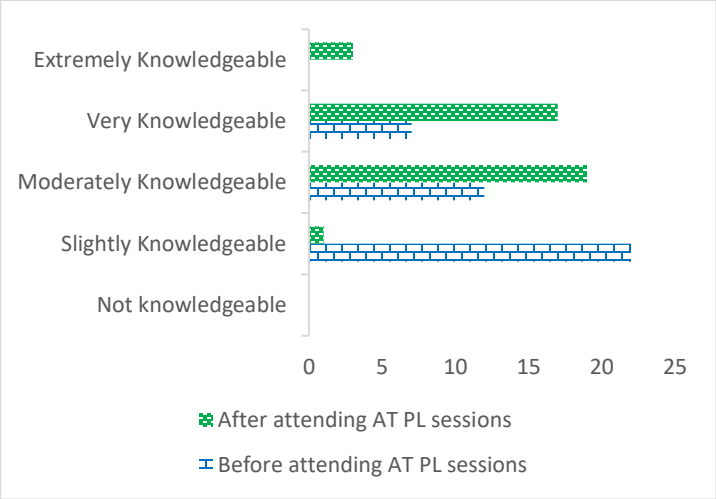
After each session of ECHO, AT Consortium, and Scope and Sequence, NSETAP invited feedback through an anonymous survey. These end-of-session surveys distributed to participants measured satisfaction, knowledge gained, and change of practice, and are in alignment with Kirkpatrick's framework. The input was conclusive that the training had impacted the way the attendees would teach or engage with AT, their AT users, and learners overall, with 87% of Consortium participants and 97% of in-person Scope and Sequence participants saying that the NSETAP sessions changed their practice in their role and capacity (see figures 7, 8, and 9). Following the ECHO series, more districts requested NSETAP's services and offerings. Local education agencies have asked for specialized curriculum development tailored to their specific needs in language, literacy, and communication. This includes an AAC series and the Science of Reading for Deaf/Hard of Hearing, which incorporates meaningful engagement strategies using AT tools, devices, and resources.

Figure 7: *Knowledge Before and After 2025 AT Consortium*



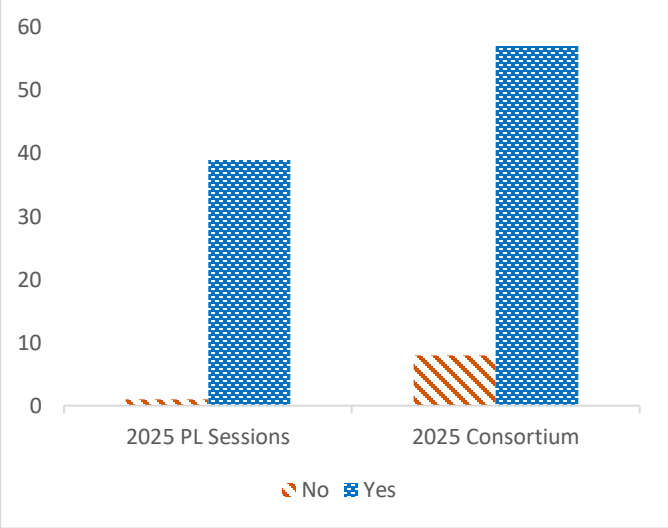
Note. Participants' knowledge gain from NSETAP Assistive Technology Consortium 2025.

Figure 8: *Professional Learning Knowledge Gain*



Note. Participants' knowledge gain from NSETAP Assistive Technology Professional Learning (PL) 2025.

Figure 9: *Change in Practice*



Note. Participants' change in practice from Consortium and Professional Learning (PL) sessions 2025.

In the second year of offering the ECHO series, each session maintained a high level of attendance, never falling below 200 and reaching a high of 250 participants. This emphasizes the need and desire for high quality AT professional learning opportunities in Nevada. Because NSETAP approaches professional learning offerings with a UDL focus providing multiple means of representation (online and in-person content), various access points (digitally and physically), and options for different needs, we are actively seeking to remove barriers before they are an issue. This has been crucial in providing a clear pathway for learners to achieve success in their academic and professional pursuits.

We know that some of our rural districts have professionals who work in isolation and do not have large teams. This was evident when some of NSETAP's participants reported working alone or only with those in their classroom. Part of the Scope and Sequence PD from NSETAP is Team Development. Teamwork and shared responsibility are crucial to the implementation of AT. Ongoing team collaboration, communication, and coordination shape a student's path toward success and through challenges. We provided participants with a team responsibilities document, encouraged them to work together during in-person professional learning sessions, and modeled interdisciplinary teaming during the ECHO series sessions. Research suggests that educator training and the coordination of multiple expertise areas are essential for optimal outcomes (Hardesty, 2020), and leveraging PEN and the AT Consortium has been beneficial for supporting districts through collaborative team approaches to AT.

The practical hands-on engagement with assistive technology is an intentional feature of our in-person PD offering. Participants commented that "It really helped normalize when doing the station activities," with another saying, "[the best features of Normalizing AT and Overcoming Barriers were] the things we were able to interact with." We observed and read about their enthusiasm for the convenience of the ECHO series and the quality of the information they received. Participants complimented the consortium and their ability to influence what would be covered in future sessions, stating "[Best feature of the AT Consortium was] The tools and resources shared—also sharing at the end, indicating we are part of a larger community." Attendees appreciated the relevance of the guest presenters and the insights and resources they provided, saying "[The best feature of the AT Consortium was] The variety of speakers," and "[The best feature of the AT Consortium was] The presenters—great information that can be shared" and also, "Very good presentations." Teachers value hands-on demonstrations, a lending library of AT, coaching, and online modules (Schladant et al., 2022). What Schladant asserts, we can affirm are primarily the results of our efforts, as noted in the participants' feedback above.

NSETAP's three-strand approach to the AT ECHO series, AT Consortium, and Scope and Sequence raised awareness. It helped educators develop competence in AT, as evidenced by numerous survey results and general feedback. Having educators who are well informed, trained, and competent with assistive technology helps in the AT selection and implementation process. Educators with these skills support their students in the classroom and beyond, as students are more likely to develop self-advocacy and independent living skills (Tamakloe & Agbenyega, 2017; Zabala, 2020).

Part of NSETAP's conclusions, based on feedback, is the increased amount of valuable data and anecdotal information for the assessment process. Many of the assessment request documents NSETAP previously received were missing information or irrelevant to the situation. After participants completed NSETAP's professional development sessions using case studies, they recognized the importance and effectiveness of having appropriate data for selecting and implementing AT. We guided participants in completing Zabala's (2020) Student, Environment, Tasks, Tools (SETT) form and the Wisconsin Assistive Technology Initiative (WATI) Assessment Package (2004). Post-training, we received more detailed, informative assessment requests that included all pertinent information, with no missing forms or documents. Schools in that district began engaging in the assessment process and needed only NSETAP's lending library resources post-training. This was one of the

most critical markers of increased competence and confidence among participants in NSETAP's PL offerings, core aspects of Kirkpatrick's Four Levels of Training Evaluation (Kirkpatrick & Kirkpatrick, 2016).

Conclusion

We found that during our differentiated approach to professional development creation, launch, and implementation, specific considerations had to be addressed to provide comprehensive support to professionals. Each state and local education agency (LEA) has different guidelines and limitations on resources and opportunities. For instance, Nevada's LEAs are locally controlled, meaning each district and school has autonomy, and as a Nevada Department of Education's Office of Comprehensive Student Supports sponsored project, we can only provide guidance, recommendations, and/or suggestions. This model of a three-strand approach to professional development (PD) is not a roadmap for success, but an example of working within the structures we have to produce the results we desire. Understanding our unique situations, both advantages and disadvantages, gives perspective on how best to approach PD. Nevada has the fifth-largest school district in the United States, and also serves rural and frontier communities. Each district, both urban and rural, needs to span a spectrum and requires a differentiated approach. As such, we designed a flexible PD model that enables quick sessions, remote attendance, lengthy in-depth discussions and collaborations, and personalized, in-person, focused, engaging PD. This is both a strength and a disadvantage of this approach, as each LEA has its own limitations and restrictions. As a state project, we are adapting to what works and adjusting, or abstaining from, what does not.

Anyone seeking to provide this level of support must engage in Collaboration & Partnerships, continually increase capacity through training and ongoing consultation, and build service infrastructure. We (NSETAP) recommend investing in additional partnerships to support mentorship, emerging technologies, and agencies that aim to reduce barriers, thereby increasing access to further education, employment, and independent living (Wright & Wright, 2023). These recommendations include:

Collaboration and Partnerships

- Cross-collaboration and partnership with agencies to increase awareness of resources and knowledge of additional supports.
- Partnership with national organizations to increase knowledge and skill capacity with existing and emerging technologies.
- Collaboration with other projects to increase understanding and throughline of how to integrate assistive technology and accessible education material versus the silo operation.
- Encourage cross-departmental and service provider collaboration within districts and schools.
- Encourage district-to-district collaboration to expand learning opportunities, such as an AT Consortium.

Increase Capacity Through Training and Ongoing Consultation

NSETAP recommends that resources, both human and monetary, be allocated to provide ongoing, differentiated training and technical assistance pathways related to assistive technology, universal learning design, and accessible educational materials. Such training should be routinely offered to school districts and families. Educators, education professionals, and families should be trained to support the identification, implementation, and effectiveness of assistive technology, as well as the creation of accessible educational environments and materials.

Improve Service Infrastructure

Ultimately, states must invest resources in improving infrastructure to support school districts. Suggested improvements include:

- Provide statewide guidance on assistive technology and accessible education materials based on the federal guidance released by the National Education Technology Plan and the United States Department of Education.
- Convene a cross-agency committee to draft recommendations for the more flexible use of existing funding mechanisms and to reduce siloed initiatives.
- Seeking and applying for grant opportunities that support building service infrastructure, such as an outward-facing platform for professional learning and human capital for mentors, and coaching.

NSETAP developed this three-strand professional learning approach to differentiate offerings and support professional learning. Our approach has impacted our districts in various ways, and we hope to continue to influence and serve. We leave our readers with three questions to reflect on:

1) How can we support our districts to thrive and, in turn, support learners in thriving?
2) How can we partner with or collaborate with organizations to effectively support our districts and drive impact?
3) How might we empower and connect our districts to build capacity and a culture of learning?

Declarations

This content is solely the responsibility of the author(s) and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author(s) of this paper.

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Assistive Technology Outcomes and Benefits
Volume 20, Spring 2026, pp. 198-210
Copyright ATIA 2026 ISSN 1938-7261
Available online: www.atia.org/atob

Voices from the Field

A User's Perspectives on Implementation, Quality and Outcomes for AAC and AT

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Abstract

This paper examines critical factors affecting Assistive Technology and Augmentative and Alternative Communication device outcomes from a user perspective. Drawing on 25 years of experience, the authors demonstrate that involving disabled people in design processes alone does not guarantee success. Poor implementation, inadequate quality control, feature creep, and commercial pressures all serve to undermine well-designed products. The paper highlights recurring problems across multiple product types including software crashes, accessibility failures, and design flaws that compromise safety and independence. We recommend that increased attention throughout the entire product development cycle is necessary to ensure that products genuinely meet both users' needs and regulatory fitness-for-purpose requirements. To this end, we emphasize the need for more comprehensive user consultation spanning quality assurance processes and rigorous product acceptance testing, as well as conceptual design and commercial prioritization of features. This must encompass diverse user experiences and skill levels.

Keywords: user perspectives, AAC, AT, implementation, quality, testing, product evaluation, outcomes

A User's Perspectives on Implementation, Quality and Outcomes for AAC and AT

I have been a user of Assistive Technology (AT) and Augmentative and Alternative Communication (AAC) speech generating devices for 25 years. I am probably best described as a power user, and I need my AT systems to deliver efficient and consistent performance to enable me to access as independent a lifestyle as possible.

Over the years I have used a wide variety of AT devices and evaluated (and broken!) my fair share. I have significant fine motor difficulties such that using a computer or a Voice Output Communication Aid (VOCA) speech generating device takes considerable effort. Poorly implemented or inefficient systems make my everyday life harder as they take more time and effort to use. This critically affects my energy levels, my ability to take part in daily human interactions, and my independence and safety — factors that can be very demotivating and contribute to abandonment of AAC in others (Baxter et al., 2012; Riemer-Reiss & Wacker, 2000).

My co-author and parent is a retired embedded systems engineer and computing technology specialist with experience in the development and deployment of mission-critical systems for science and engineering, as well as some AT systems engineering. We have both watched Assistive Technology evolve and have been active participants in the AAC community in the UK for many years.

There have been many superb developments in AT with some really great uses of technology which have really helped my life and that of my peers. However, I am critically dependent on AT systems working in a specific way at the point of need. We have experienced some poorly implemented new technologies which failed to deliver their promise. This leads us to question whether the rush to use the "latest and greatest" emerging ideas carries risks if attention is diverted away from the basics of accessibility, availability, consistency, privacy, and reliability. We hope to show how it is these properties that make all the difference, and how if AT fails to provide these basics, it risks failing its core purpose of making systems available for daily living.

Target Audience and Relevance

This essay is aimed at company managers and developers considering how to adopt best practices. We offer observations about a range of factors that influence Assistive Technology outcomes which need to be taken into account alongside user led design methodologies. It is also relevant to clinicians, assessors, and professionals working in the field who have a role in selecting and recommending products for clients. We aim to help them understand some of the real-world complexity and practical issues that can arise to hinder technologies from delivering on their promises. Whilst the article predominantly discusses communication aids, many of the issues raised are relevant to other categories of assistive technology.

Feature Creep versus Reliability and Quality

In our experience, the reality of choosing a new VOCA has often been, and still is, one of choosing the least worst option. After shortlisting appropriate devices, I have been left with only a very small pool to choose from, yet with each option having significant flaws. For example, I have had to make a stark choice between a device with the most suitable eye-gaze camera but unreliable software versus one with reliable software that was missing important prediction features and had a less effective eye-gaze system.

Over the last decade or so, many communication aids have extended their functionality to include support for internet and social media messaging and have added eye-gaze as an access method. These are really useful features which I now use extensively. However, our experience is that over the same period, there seems to have been a reduction in reliability and a greater prevalence of poorly-thought through areas that become accessibility traps for people with marginal access like me.

This situation is really frustrating, as VOCAs have been around since the 1980s and many of these problems have been solved, yet keep re-appearing in different guises. Some still suffer from basic practical flaws or quality issues that make them feel rushed to the market. Examples we have witnessed with AAC systems include things like:

Figure 1: *An Example of Poor Power Button Accessibility*

- Power buttons that are too small, badly placed for the user, or require too much force to operate (Figure 1).
- Access to timing delays implemented for some features but not others.
- Keyguard holders that are too flimsy and break frequently, or keyguards that are awkward to remove for cleaning.
- Touchscreens that stop working when the keyguard provided by the manufacturer is fitted.
- Newer models of a product with a revised mounting arm connector using a lightweight alternative that is not robust enough (and not replaceable).
- Partner-facing message screens that are poorly angled and not adjustable.
- Cameras that point at the floor when the device is mounted on a wheelchair (Figure 2).
- Software flaws that undermine the application's accessibility methods and trap the user in an area they cannot navigate out of.
- Software that keeps freezing or crashing.

Figure 2: *Using a Communication Aid Camera Mounted on a Wheelchair*

Design Choices

We have found some assistive technology products with frustrating limitations to their functionality. No doubt these products satisfy a large range of low-demand needs, but they are unnecessarily restrictive for more demanding situations, or as a user's needs evolve. For these products, it appears to us that the restrictions are choices made during the conceptual or commercial design of the device rather than fundamental limitations of the technology. Where options are not made available to obtain fuller functionality (either within the same product or within the product line)

it leaves the impression that the design team's expectations of the users' capabilities are low. A few examples are:

- Joysticks for mouse control that don't have cursor acceleration. Without some form of acceleration it is impossible to balance the slow cursor speed needed for fine control (while homing in on a target) with having a high enough speed to cross the screen in reasonable time. This restricts the ability to control a computer beyond fairly basic use.
- Assistive TV remotes with a restricted number of buttons. How many buttons are on your TV remote? My TV has 54. I used to have a remote with a built-in keyguard and enough buttons to fully control the TV. It has now been discontinued and most of the currently available ones only have 15 to 18 buttons. This makes control of a smart TV difficult, needing multiple "levels," unless I restrict myself to basic usage.
- SMS messaging without message threading. Message threading has been widely available in communication technologies for many years. Not having it makes it very hard to track multiple conversations unless you only have a limited number of contacts.

Chasing Technologies

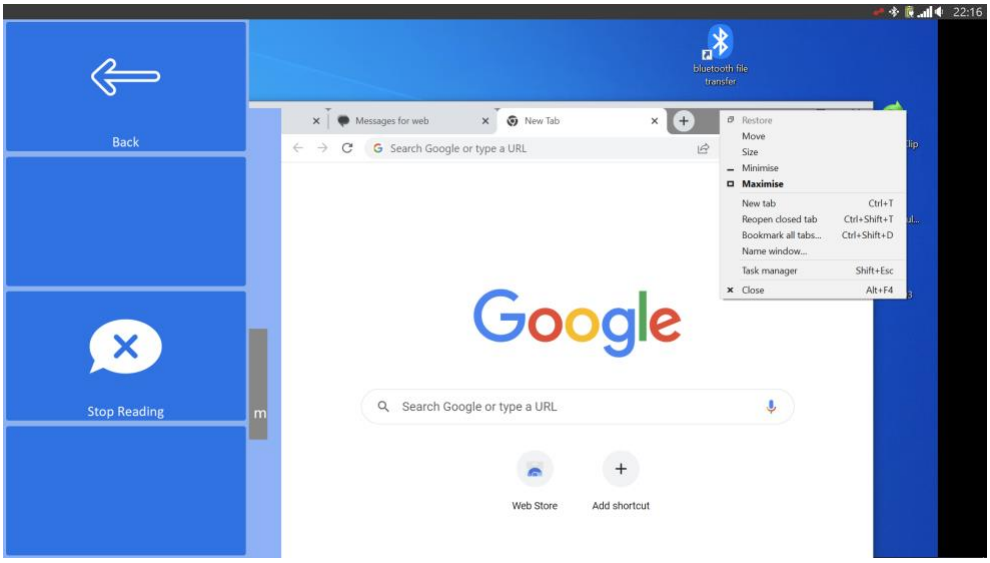
To work around the message threading mentioned above, we evaluated an alternative recommended by the manufacturer of my VOCA: This third party add-in software extension can be used with a range of different VOCA products to provide enhanced accessibility to social media and SMS messaging. It works by seamlessly integrating a browser frame into the VOCA's display pages and provides on-screen navigation buttons leveraging the VOCA's built-in accessibility methods. This is an attractive and useful feature and seems an impressive use of technology. It uses Google's latest Messages For Web ® for SMS messaging via a linked phone.

This sounds great, but the reality is more complex: The embedded web browser frame is not protected, so it allows the user to accidentally navigate away from, or be hijacked away from, the intended web application. It exposes standard browser context menus which can be launched by accident while trying to regain control (Figure 3). For example, as a touchscreen user with fine motor difficulties, if I accidentally touched the screen for too long it would cause an unintended right-click. This would launch a standard Windows context menu which is not designed for accessibility. At this point I would become trapped with a dialog I cannot close (or worse, could accidentally launch something unexpected outside of the VOCA's carefully crafted accessibility environment). I would lose the ability to communicate and lose the ability to use the VOCA to call for assistance.

In addition to these problems, social media requires the use of an active internet connection which introduces substantial security risks and a potential impact on device integrity. I have had unwanted malware appear unexpectedly on my VOCA (Figure 4). Thankfully for me, on this occasion it was just a nuisance interrupting my usage and didn't cause further damage. Are these risks acceptable when you rely on your communication aid for daily living? That's difficult to answer and depends on balancing risks and benefits. For the first few years living away from home as a student, we decided that reliability was a higher priority for me, and we turned the internet connection off on my communication aid. During this period, I only used social media on a separate laptop where failure would have been very awkward but not critical to my care. From an engineering perspective it would

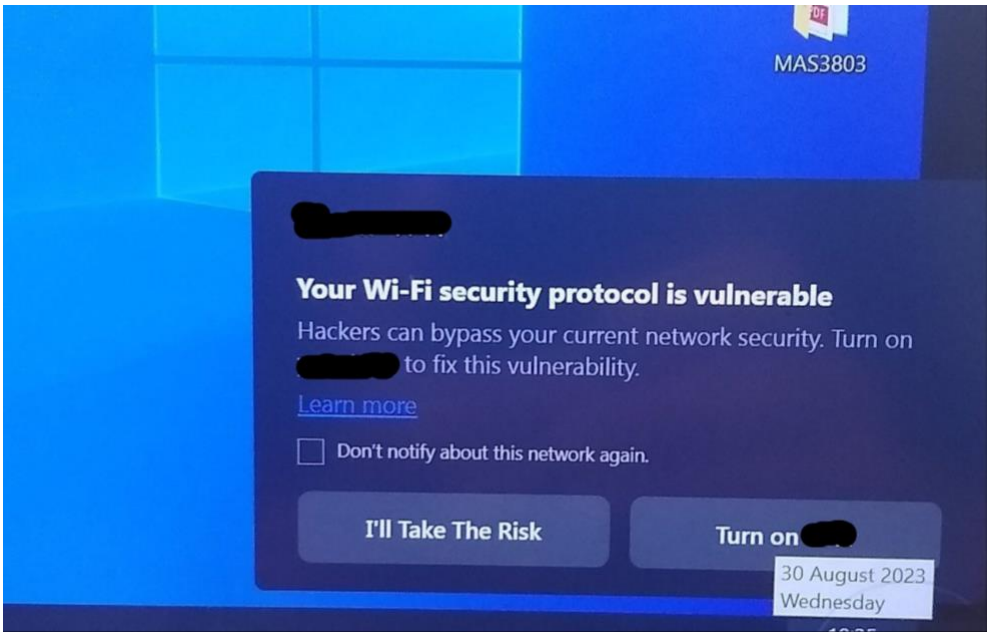
be better if these communications apps were fully managed through a proxy or virtual sandboxed system rather than on a live browser on the device.

Figure 3: *Accidentally Breaking out of an Accessible Application*



This illustrates some of the risks that come from adding functionality to communication aids. As noted by Williams and Holyfield (2025) “Innovation does not always result in improved outcomes.” Enhanced features such as social media access are very useful and compelling from a disabled person’s perspective and, of course, become very advantageous in terms of marketing a product, but need to be engineered with great care.

Figure 4: *An Example of Malware on a Communication Aid*



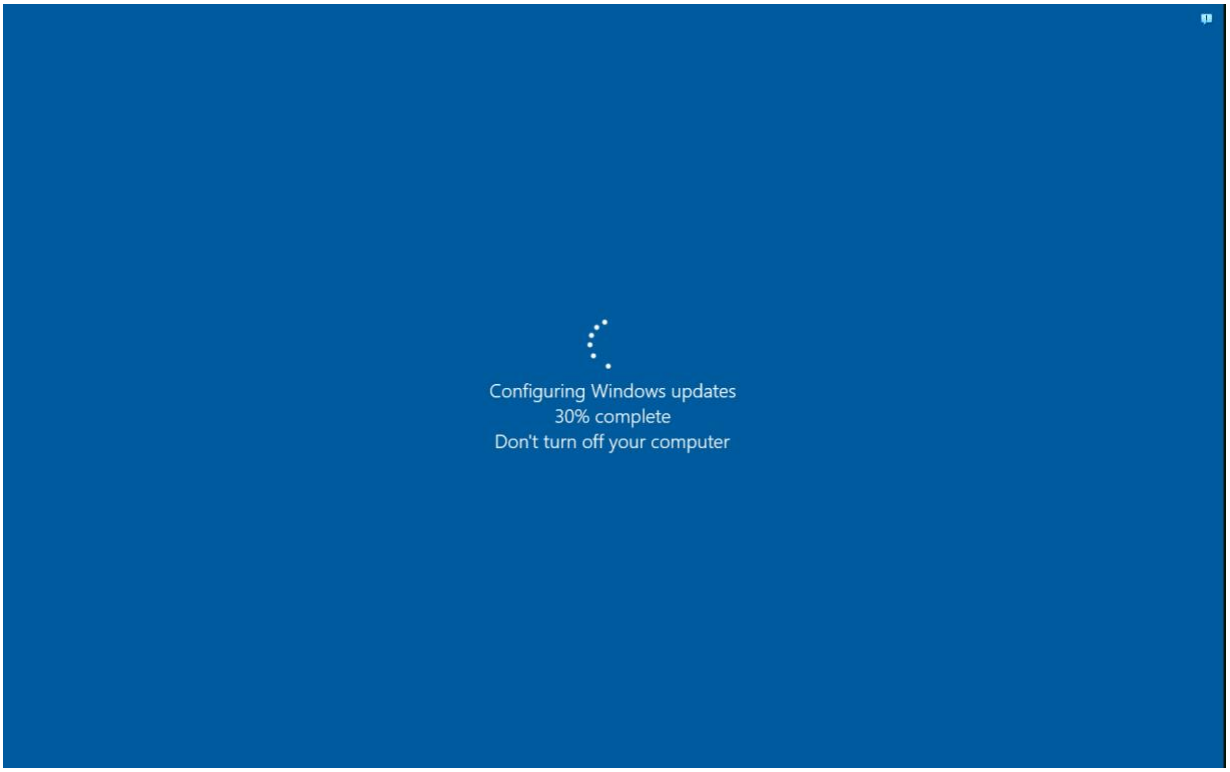
Consumer Technologies

As discussed above, consumer technologies can be really impressive but do not always provide the reliability and attention to detail that I require from AT solutions. They are of course typically not designed or marketed with the regulatory requirements for AT devices in mind, nor intended to meet the needs of those who require high levels of accessibility and reliability from their devices. Consumer technologies also change fairly frequently, so I cannot rely upon them to continue providing the same functionality over time and often end up being forced to re-configure my assistive solutions every time they change. Constant change is not helpful.

Most of the full-featured VOCAs that provide enhanced accessibility are based on Microsoft Windows. These use the standard consumer editions of Windows and suffer from periodic changes whenever Microsoft releases a new feature update. This can be very awkward, for example, if I've set a machine up in a very specific way and then things change or the positions of things on the screen change.

Windows Updates are even more problematic. These can interrupt the machine, making it unavailable at the point of need, sometimes with long delays before it can be used again, and sometimes needing intervention from IT support (Figure 5). This isn't acceptable in the middle of an exam or medical appointment. The original VOCA I had in primary school, based on 25-year-old technology, seemed more reliable than those I've used in the last few years.

Figure 5: *Windows Updates Interrupting Communication*

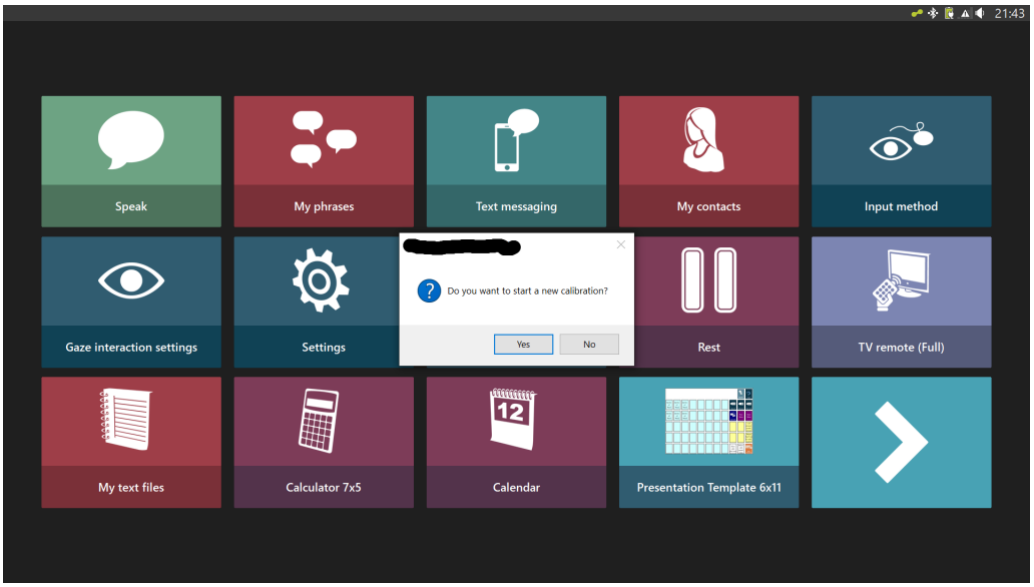


Implementation and Quality Control Issues

The following example shows how poor implementation of an AT system completely undermines good design. I tried using one particular computer access joystick as an alternative to a mouse. This product has some excellent design features that have clearly been very well thought through and is fully customizable. It has large, low-force buttons with the casing acting as a keyguard, and the buttons have time delays. The cursor movement has good speed control including acceleration to allow both fine controlled slow movement and faster gross movement across the screen. Unfortunately, though, the buttons are placed beyond the joystick shaft such that when operating them, you risk jogging your carefully-placed cursor. Worse still, whilst it has the four key mouse control functions (click, double click, right click, and drag) which can be flexibly assigned to the buttons, there are only three buttons to assign the four functions to. Without a fourth button, this joystick doesn't let me access my computer properly.

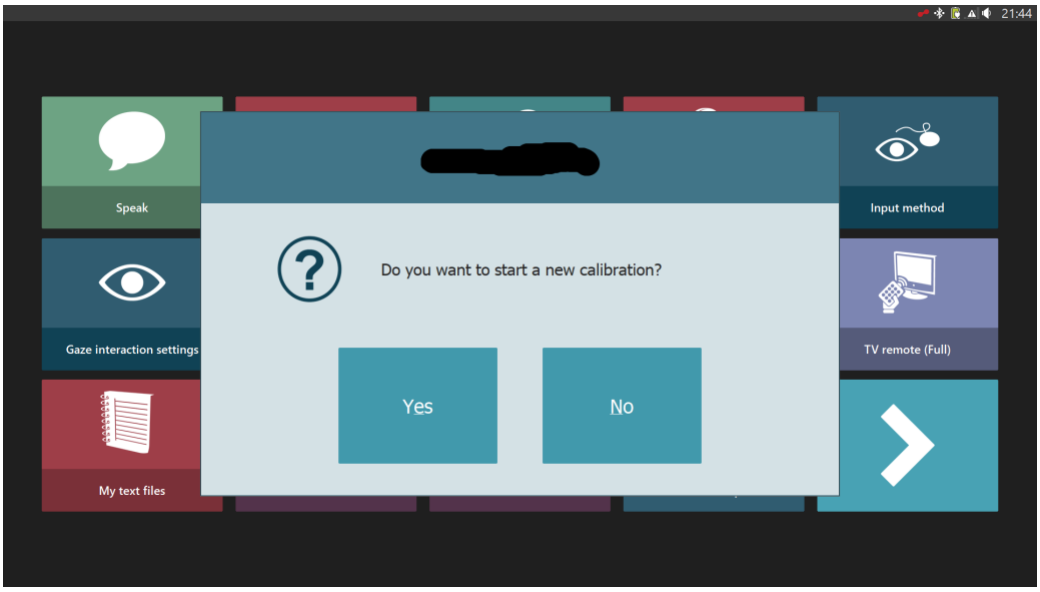
There is a similar issue with most wheelchair joystick controllers. The buttons to change speed, mode, etc., are again almost universally placed beyond the joystick shaft where it is very awkward to change speed or to switch the power off without knocking the joystick and causing unwanted chair movement.

Figure 6: A Non-accessible Standard Dialog Preventing Access



Software is a particularly frustrating area for quality issues. An example of this is the latest flagship VOCA model from one manufacturer which has well-designed accessible versions of all the dialogs that might pop up during use. These have large on-screen buttons and can be used from the built-in accessibility features. However, a software bug periodically causes a non-accessible standard Windows dialog to pop up instead (Figure 6). Every time this happens, I am stuck, unable to use the device, and have to call a caregiver to dismiss the non-accessible dialog. Ironically, the accessible dialog pops up immediately afterwards to ask the same question again (Figure 7). This has clearly had insufficient testing before release.

Figure 7: The Accessible Dialog that Should Have Been Displayed Instead



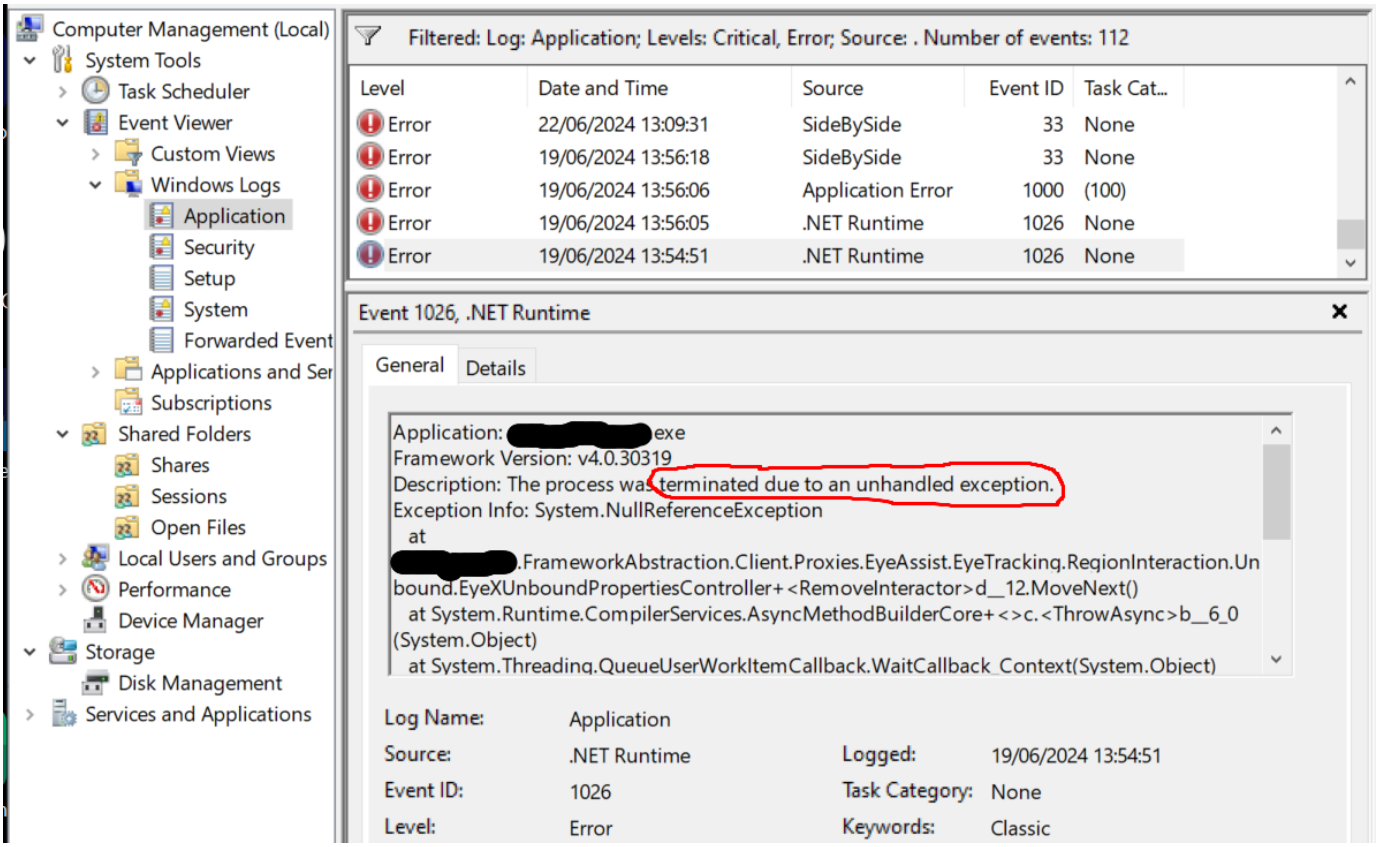
The VOCA I used through my university course had a software fault which we reported and was fixed with a software update. However, every subsequent update (fixing unrelated issues) re-released the first fault. If this is evidence of poor software version control in the software build process, it potentially demonstrates a catastrophic failure in the company's QA processes. Whatever the cause, it left me having to run a machine on an older release, and every time a new update was applied, I had to contact support to have my system reverted.

Some of the VOCAs currently on the market suffer from catastrophic software crashes and freezes. The operating system error logs show multiple unhandled software exceptions (Figure 8). When these occur, the underlying Windows operating system forces the VOCA application to quit. Software errors are almost inevitable, but on real-time medical devices, should errors not be handled gracefully as a bare minimum?

Commercial and Professional Issues

In the UK, and several other countries, medical devices such as VOCAs are often supplied through clinical assessment centers staffed with professionals who make decisions about what to purchase and provide. These agencies purchase large numbers of aids and thus become the effective principal customers for the AT producers. Consequently, they have influence on the market and potentially influence the commercial prioritization of features when products are being developed. From a user's perspective, it is frustrating that some of the faults we've highlighted have not been detected either by the manufacturers or by the assessment centers, and we know other families who informally echo our concerns. How do we help users build confidence that these influences on the market are aligned with their needs?

Figure 8: Unhandled Exceptions Cause Catastrophic Crashes



In terms of skills, typically AAC is mainly overseen by speech and language therapists (speech pathologists) supported by other clinicians. Nevertheless, it is well documented that in areas such as AAC and education there are significant gaps in skills and knowledge within provisioning and deployment staffing (Baxter et al., 2012; Light et al., 2025). We acknowledge that these professionals are doing their best with limited resources and therefore ask whether they have adequate technological and systems engineering support to capitalize on their efforts? Most of the problems we highlight lie in the technological and practical usage domains, which may explain why they are not always being addressed.

To answer this question, we call for debate on whether there are sufficient technical resources for them to fully evaluate complex product limitations and flaws in order to inform decision-making before purchase and deployment. Can better technical evaluation within assessment centers provide more robust feedback for manufacturers? Can device operating system platforms be better configured and managed to improve device usability, reliability and availability?

Discussion and Recommendations

We know many of the AT and AAC companies do work successfully with and employ users. We have highlighted many factors that can compromise AT products and demonstrated that involving people with disabilities in the initial design process isn't, by itself, a guarantee of success. Ultimately,

robust implementation and quality control practices are needed to avoid these initiatives being compromised.

Therefore, we call for closer involvement of users throughout the entire development cycle, not just the initial concept and design stages (Light et al., 2025). Users need to be fully involved all the way from commercial decision-making right through to the test and product acceptance phases of AT products. There may also be a role for more disabled people within the professional and assessment community.

When consulting users, it is critical to consider both the breadth and diversity of their needs and range of life circumstances. Methodologies should include the full range of user experience levels (from beginners right through to power users) to ensure that products are available to meet all levels of need. Addressing those small cohorts of users with more complex or fringe needs is likely to be a challenge in terms of commercial viability, but meeting this challenge must be a core purpose for AT providers.

The authors would like to see debate about how methodologies would help developers understand AT users' needs and priorities clearly. It is the hidden, implicit, or unspoken requirements that introduce unexpected complexities and consequent risks to outcomes. Whilst there are standard methods for working with people who may have no experience of product development, the particular challenge with AT is where users may have learning difficulties, or through their disabilities, have limited life experience. There have been some efforts in this area to train AAC users in user-centered design (Waller et al., 2005). These methodologies need to be extended to help people see through any "hype" surrounding new technology so they can be helped to appraise any flaws and complexities. In this way, the risks associated with new technologies can be managed and benefits delivered without compromising accessibility and reliability.

A further challenge is that methodologies should seek to avoid biases where people with disabilities may be prone to acquiescent or compliant responses (McLemore, 2021), whether because of their disability, life circumstances, deference to professionals, or everyday "awe of technology." We suspect that even people who are power users can sometimes be prone to "going along" with suggestions from professionals, so consultations need to be alert to this possible source of bias.

How do we guarantee that the final product matches what users need? Few would disagree that products must be fit for purpose, and for medical devices this is essential as a regulatory requirement. We support the current calls for increased involvement of people who use AT in all roles throughout the industry. This will help to ensure that product purpose and function are accurately identified, and that evaluation of products is grounded in end-user experience. In parallel, we call for better analysis of the risks and failure modes brought by newer technologies and matching drives towards improving implementation quality.

Outcomes and Benefits

We hope readers have gained insights into the complexities of ensuring that products are fit for purpose. Readers will have gained an understanding of the way technologies, no matter how impressive, can bring significant disbenefits if they are not engineered specifically to remediate the risks. With this understanding, we hope the audience will be better able to evaluate product quality.

Declarations

This content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the authors of this paper.

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