Contextual Scaffolding and Self-Efficacy: Supporting Computer Skill Development among Blind Learners in India

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Abstract

Inclusive computer literacy education efforts, broadening the participation of blind or visually impaired (BVI) individuals, have gained traction in recent years. Existing literature investigating these efforts primarily draws evidence from affluent Global North contexts, where accessibility resources and legal frameworks are relatively more mature. Little is known about the in-situ teaching and learning challenges faced by trainers and BVI students, respectively, in resource-constrained, multicultural Global South countries like India. To address this knowledge gap, we conducted a four-month contextual inquiry at two computer training centers catering to 94 BVI students in India. We notably observed a rigid, experience-driven training environment and a visually-centric curriculum that discounts the lived experiences of BVI learners and inadvertently undermines their learning self-efficacy. Informed by the findings, we discuss moving beyond functional accessibility-centered teaching toward a more culturally responsive computing pedagogy, facilitated by locally adaptable contextual scaffolds tailored for BVI students in developing societies like India.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; **Accessibility technologies**; **User studies**.

Keywords

Screen reader, Blind, Visually impaired, Learning, User experience

ACM Reference Format:
Akshay Kolgar Nayak, Yash Prakash, Sampath Jayarathna, Hae-Na Lee, and Vikas Ashok. 2026. Contextual Scaffolding and Self-Efficacy: Supporting Computer Skill Development among Blind Learners in India. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems (CHI '26), April 13–17, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 21 pages. https://doi.org/10.1145/3772318.3791509

CHI '26, Barcelona, Spain

ACM ISBN 979-8-4007-2278-3/2026/04
https://doi.org/10.1145/3772318.3791509

1 Introduction

Ubiquitous adoption of computers across industries and education, combined with growing inclusion efforts in HCI and computer literacy education, has enabled accessible employment opportunities for blind or visually impaired (BVI) individuals [62, 69, 86, 109, 115]. Today, a computer-proficient BVI individual can pursue not only traditional roles in information and communications technology (ICT) but also opportunities in the gig economy through accessible crowdsourcing platforms [158, 192], the creator economy via social media and content production [195, 212, 213], and emerging forms of remote knowledge work [6, 216].

To enable such participation, emerging literature advocates for introducing computers and screen readers (SRs) during early K-12 education through government-backed and non-profit initiatives [33, 36, 133], inclusive pedagogical practices [11, 25, 69, 137], and accessible software platforms [72, 82, 206]. However, these efforts largely draw evidence from and remain confined within affluent Global North contexts, where accessibility resources and compliance with disability legislation (e.g., the Americans with Disabilities Act [188] in the United States, the European Accessibility Act [49] in the EU) are relatively mature. Much less is known about how BVI learners in resource-constrained, multicultural Global South countries, such as India, where the majority of the world's BVI population resides [66], acquire computer skills.

India has the largest population of people with visual impairments worldwide, comprising approximately 70 million individuals, including 4.95 million who are blind, of which less than 10% are formally employed (contrast to 44% in the US and 27% in the UK) [81, 141, 168]. To promote increased BVI participation in the ICT sector, the government has launched initiatives (e.g., Digital India [110], Skill India [111], Vision-Aid's Project Springboard [194]) alongside non-government organizations (NGOs) that support *computer training centers*, which are where most BVI individuals first get access to desktop computers and SRs [72, 105, 106]. However, a persistent skills gap exists, and BVI graduates do not sufficiently acquire industry-standard computer skills and remain confined

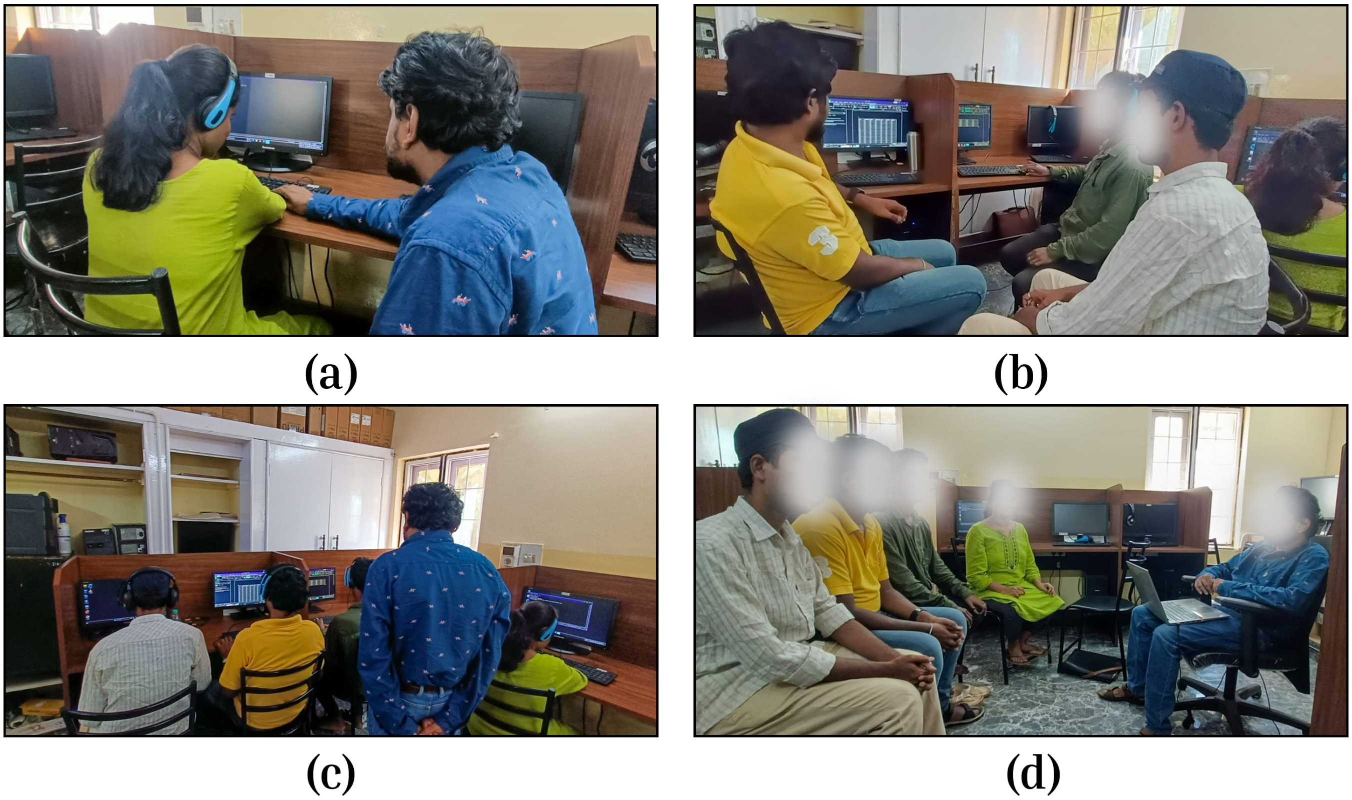

Figure 1: BVI learners engaging with computers at the urban training center: (a) task demonstration, where the trainer performs an application task with screen readers while the student listens and memorizes the sequence of shortcuts; (b) peer discussion between sessions, with a *"senior"* trainee guiding others while the trainer is occupied; (c) individual practice, where the trainer monitors and waits for questions as students attempt the day's task; and (d) group lecture and demonstration, where the trainer explains navigation steps on his laptop and invites questions for clarification.

to routine application-specific tasks [86]. This gap not only limits employment opportunities but also creates a cycle of repeated interview rejections, where the lack of constructive feedback further diminishes motivation, undermines self-efficacy, and hinders long-term computer skill development [86].

'Self-efficacy', a core concept in Bandura's social-cognitive theory [16], is an individual's belief in their ability to master academic activities, which profoundly impacts their motivation and career accomplishments. While BVI individuals often develop high 'general' self-efficacy from experiences in navigating a world designed for sight, they often experience lower 'domain-specific' self-efficacy in particular academic pursuits such as computer science [29, 107]. This challenge is amplified in resource-constrained societies like India, where inclusive educational efforts are in their nascent stages, and prevailing societal beliefs about the capabilities of BVI individuals (social persuasion) can limit a learner's own belief in their ability to master advanced computer skills [83, 86, 88]. Therefore, the support required to guide novice BVI learners in acquiring computer skills must be rooted in their specific socio-economic, linguistic, and pedagogical realities (i.e., contextual scaffolds), rather than an assumption that established pedagogical practices from the Global North will apply as is [68, 167].

Prior research on inclusive computer education for BVIs has largely taken two directions. First, it focuses on making instructional materials, curricula, and software platforms *'functionally accessible'*. Second, it examines the pedagogical challenges educators face in Global North contexts, where computers and SRs are originally designed, and teachers are generally professionally trained in assistive technologies (ATs) and inclusive practices [25, 62, 69, 174]. However, such works often overlook the *'social accessibility'*, i.e., challenges in technology learning and adoption when Western-designed computers, SRs, and inclusive pedagogical practices are imposed unchanged, without context-sensitive supports, on BVIs in linguistically fragmented, multicultural contexts like India. Even the sparse literature involving BVIs in Indian contexts is confined to the adoption of popular ATs (e.g., object recognition apps [74] and smartphones [190]), where the focus is on established SR users. Hence, a notable knowledge gap persists in (i) understanding when, how, and to what extent novice BVI learners in India acquire computer skills in situ, (ii) identifying the pedagogical supports and limitations in teaching industry-standard computer and AT skills, and (iii) the availability of accessible learning resources. We ask the following research questions:

- **RQ1:** How do 'computer trainers' in India teach computer skills to BVI learners, including the curricula they use, teaching and assessment methods, and the challenges faced?
- **RQ2:** How do the lived experiences of novice BVI learners shape their learning behaviors and self-efficacy as they navigate the pedagogical and technical challenges of resource-constrained computer training?

To answer these research questions, we conducted a four-month contextual inquiry study (two months at the beginning of the academic session and two months before completion) at two computer training centers (one rural and one urban, in India) that provide in-person skill training programs exclusively for BVIs. During this period, we closely observed the instructional methods used by trainers (Figure 1), documented how BVI learners interacted with training materials, and noted questions and comments raised during learning and evaluation sessions, without interfering in their natural learning environment. Before the main study period, we conducted semi-structured interviews with newly enrolled students to understand their prior experiences, background, and expected learning outcomes. At the end, we conducted semi-structured interviews with recent graduates and past trainees to assess overall learner satisfaction and to explore their perspectives on potential improvements to the current computer training program.

Analysis of the study data revealed key insights: (i) Computer skill curricula for BVI learners at training centers treated accessibility and SRs as peripheral 'add-ons' rather than foundational content; (ii) Trainers were hired mainly based on their computer proficiency and emphasized task execution (e.g., learning data entry in Excel) over conceptual understanding and transferable computer navigation skills; (iii) BVI learners faced significant cognitive burden from simultaneously learning SR shortcuts, keyboard layouts, English technical terminology, and multilingual input; and (iv) When formal instruction fell short, peer-based learning introduced challenges including feedback ambiguity and over-dependency. Situated in these findings, we identify contextual scaffolds that can inform a culturally responsive computer training for novice BVIs in resource-constrained contexts. In sum,

- We present findings from an in-situ contextual inquiry study that investigates the challenges faced by trainers and BVI trainees in acquiring computer skills at computer training centers in India.
- We propose locally-adaptable contextual scaffolds that support culturally responsive pedagogies and foster greater self-efficacy among BVI learners in resource-constrained computer training settings.
- We offer design recommendations for integrating intelligent educational technologies (EdTech) into inclusive computer literacy training for BVI learners.

2 Related Work

Our work builds on prior literature pertaining to: (i) inclusive computer literacy education practices for BVI learners, (ii) technology learning and adoption among BVI individuals, and (iii) scaffolding in complex educational tasks.

2.1 Inclusive Computer Literacy Education for BVI Learners

Research has focused on broadening the participation of BVIs in computer-dominated fields by making core computer literacy education accessible from K-12 through graduate programs. Efforts range from teaching basic computer skills (e.g., using SRs, MS Office, and web navigation) to adapting ocularcentric concepts (e.g., flowcharts, graphs) and software tools for AT users [62, 69, 91]. A seminal work by Mealin and Murphy-Hill [107] identified inaccessibility in software platforms and highlighted that BVIs often have limited exposure to computers and non-visual navigation during early education and formal training. Baker et al. [11, 13] further highlighted that inaccessible documentation, delayed learning of computer concepts, and inaccessible assignments, and instructor practices together undermined BVI students' conceptual and practical understanding of computers and SRs. From teachers' perspectives, Huff et al. [69] found that inaccessible materials and development environments forced frequent lesson redesigns, placing unsustainable cognitive and logistical burdens on educators. They also reported that mainstream tools often required extensive memorization or workarounds, while the lack of standardized, accessible curricula hindered consistent instruction.

In response, researchers have proposed inclusive pedagogical practices and accessible tools that accommodate the needs of BVI learners [25, 62, 82, 174, 176]. These include adapting text-based languages (e.g., simplifying syntax or using Quorum [174]), redesigning block-based environments with keyboard and audio support [37, 116], leveraging physical artifacts (e.g., robots, 3D models, tactile grids) [15], and incorporating auditory or haptic feedback to convey program state and structure [62]. Furthermore, government-backed initiatives have expanded access to computer education for marginalized groups, such as BVIs with limited resources, by integrating them into inclusive K–12 training. In the US, for example, AccessComputing [56, 180] promotes inclusion through mentoring, internships, and institutional outreach, while AccessCSforAll [91] adapts K–12 CS education via accessible curricula (e.g., an SR-compatible AP CS Principles course) and specialized training for Teachers of the Visually Impaired (TVIs). Specialized nonprofits in the US (e.g., Lighthouse for the Blind [183] and World Services for the Blind [122]) and government agencies in the US (State Vocational Rehabilitation (VR) programs [31, 145]) and Europe (e.g., RNIB in the UK [121]) provide rehabilitation and vocational training for BVIs that include AT assessments and job-ready computer instruction. These programs emphasize individualized teaching in SRs, SMs, braille displays, and MS Office, often delivered in one-to-one or small-group formats. Baldwin et al. [15] described how state-mandated training at EmpowerTech [47] occurred in structured classrooms with dedicated hardware, including personal laptops and auxiliary tools like Victor Readers [70]. In the Global North, educators also receive professional support through train-the-trainer workshops and mentorship structures [151], and AT training is included in many North American teacher preparation programs [172]. Legal frameworks such as IDEA and Section 504 in the US [187] and the EU Accessibility Act [49] further mandate accessible tools in schools. In contrast, India lacks a national computer literacy curriculum for BVI learners. Even mainstream K–12 curricula have only recently begun to incorporate accessible computer training, and provision in these settings remains largely ad hoc [41, 131]. While the Rights of Persons with Disabilities Act (2016) [59] and United Nations Convention on the Rights of Persons with Disabilities (CRPD) [186] obligations call for inclusive education and vocational training, how these commitments translate into practice for diverse, resource-constrained settings is still an open question.

Extant studies with BVI individuals in India remain sparse and have primarily addressed broader technology adoption challenges (e.g., SRs [105, 106], smartphones [77], social media [191], and object recognition apps [74]). Parthasarathy and Joshi [131] highlighted that digital accessibility was rarely integrated into mainstream computer programs, and teachers often perceived it as peripheral to the curriculum. They reported limited awareness of disability, and described a lack of pedagogical preparedness, concrete teaching resources, and institutional incentives to prioritize accessibility. Bhatnagar et al. [23] further traced how educational challenges emerge when interdependence [20] breaks down, and argued for stronger AT integration and 'genuinely inclusive' education and social structures for BVI students. India et al. [72, 73] adopted Microsoft's Project Torino (now Code Jumper) for BVI students in India and showed that when such tools are aligned with curricula, reflect local culture, support collaboration, and are reframed as playful media for music, rhymes, and storytelling rather than formal coding lessons, they can both motivate learners and help children in low resource settings grasp core computer concepts. While significant, the aforementioned works either diagnose broader systemic issues or evaluate focused interventions for specific programming tasks, and as such, they do not capture the realities of BVI learners in computer training centers. In particular, little is known about how technology and curricula can be designed or adapted to foster confidence and independence in acquiring computer skills, which is crucial for developing generic learning systems that respond to challenges rooted in structural and socio-pedagogical barriers.

2.2 Technology Learning and Adoption among BVI People

In resource-constrained Indian contexts, adoption of technologies such as computers and SRs varies widely, shaped by socio-cultural factors, affordability, perceived usefulness, and collective community awareness [30, 105, 124, 146]. Dawe [39] argued that, rather than labeling technology adoption outcomes as only *"successful or abandonment"*, researchers should examine the full range of usage contexts, i.e., *"hows, whens, and whys"* of technology usage. HCI scholars have broadly examined how BVI individuals adopt and use various technologies primarily designed for sighted users (e.g., smartphones [14, 61, 101], virtual assistants [4, 119, 125, 196], and virtual reality technology [53, 87]), with 'add-on' accessibility features (e.g., SR and SM support) to accommodate disabled individuals. In general, BVI users often approach new technologies with curiosity, necessity, and apprehension [54, 169, 170]. Initial exposure is often facilitated by family, friends, or peers, after which users gradually transition to self-reliance as they gain familiarity with their devices [149]. However, older adults who develop visual impairments later in life face steeper learning curves due to the emotional dynamics of 'retraining', limited experience with ATs, and age-related cognitive changes [50, 123, 129]. Younger users often turn to social networks for troubleshooting and learning, whereas older adults prefer to *"figure it out"* themselves, which slows their acclimatization [85, 129].

Studies show that technology adoption is shaped by demographic and cultural factors [61, 105, 208]. For instance, Yang et al. [208] noted that findings from high-income countries are not fully applicable to people with disabilities in China, where lack of visibility and social inclusion, compounded by stigma, affect adoption. They argued that ATs in China must support Mandarin and regional dialects, reflect local norms for public interaction, and function in everyday environments such as crowded public transport or markets with locality-specific objects and packaging. In India, India et al. [74] examined how BVIs use and perceive object recognition technologies, showing that while these tools can enhance independence, adoption is constrained by accuracy issues, contextual insensitivity, and limited localization. Much earlier, Pal et al. [126] found that AT effectiveness in India was hampered by poor compatibility with local software, lack of training in advanced features, and inaccessible workplaces. They also reported that stigma and low employer awareness reduced support for AT use, leading to under-utilization even when available. More recently, Nayak et al. [86] studied employment-intervention tools for BVI job seekers in India, finding that many of these tools have critical accessibility barriers, lack role-specific content, and provide generic rather than tailored feedback. They advocated for AT-compatible, multilingual, and contextually adapted tools that simulate realistic interviews and address the needs of BVI users in the Indian job market.

HCI literature has largely taken a device-centric (center-to- peripheral) stance, emphasizing accessibility of individual technologies and, occasionally, culturally sensitive design. Yet adoption of computers requires an ecology-centric (peripheral-to-center) approach that integrates culturally responsive pedagogy with technological adaptation. To this end, we present an in-situ study of BVI learners in computer training centers, surfacing support gaps across tools, curricula, and pedagogical practices, and translating these findings into design considerations for improved pedagogical and technological supports.

2.3 Scaffolding in Complex Learning Tasks

Research in educational psychology and HCI has often drawn on social constructivist theory [203], which posits that learners actively construct knowledge rather than absorb facts passively. Central to this framework is scaffolding: temporary, adaptive support provided by a *'more knowledgeable other'* (human or technology) that enables learners to accomplish tasks beyond their independent capability. Rooted in Vygotsky's theory of learning [78, 159] and the Zone of Proximal Development (ZPD) [165], this view holds that higher-order functions such as problem-solving and abstract reasoning emerge through social interaction rather than in isolation. Likewise, situated learning theory by Lave and Wenger [94] conceptualizes learning as *"legitimate peripheral participation"* within a community of practice, where newcomers advance from peripheral to full participation through authentic engagement. Building on these sociocultural perspectives, we consider *'contextual scaffolding'* as support that is not only situated in a context but fundamentally shaped by the learner's sociocultural, material, and institutional environment. Such scaffolding adapts to the realities of the learning situation and rejects one-size-fits-all approaches. A key outcome of well-designed scaffolded interactions is the development of *'self-efficacy'*, central to Bandura's social cognitive theory [16]. High self-efficacy strengthens motivation and persistence; learners who believe in their capabilities are more likely to embrace challenges, sustain effort, and remain resilient in the face of setbacks.

Emerging HCI research demonstrates sophisticated uses of scaffolding through adaptive feedback systems and intelligent tutoring platforms for teaching complex computing concepts. For instance, Weinman et al. [199] developed Faded Parsons Problems, an interface where students both reorder and complete partial code. This approach taught programming patterns more effectively than just writing code, and was perceived as easier despite comparable objective difficulty. Winkler et al. [201] created a voice-based conversational agent (*"Sara, the Lecturer"*) that interjected prompts and explanations during online lectures. Compared with text-only or non-scaffolding agents, Sara improved learners' retention and transfer, with voice interaction amplifying the scaffold's effect. Research has also operationalized scaffolding in adaptive interfaces, where systems adjust to users' skill levels, provide guidance when needed, and fade support as competence grows [75, 155]. By combining feedback with personalized help, such systems reduce frustration and promote mastery-oriented learning [42, 181, 199]. For example, Dillahunt et al. [43] studied employment tools for underrepresented job seekers and found that features such as positive reinforcement and guided self-reflection bolstered users' self-efficacy. Similarly, Bhattacharjee et al. [24] introduced SPARK, a GPT-4–based probe that scaffolds anti-procrastination support by presenting psychology-grounded strategies, tailoring messages to learners' contexts, and prompting "future-self" action emails.

HCI scholars have also explored *"scaffolding all abilities"*. For example, Gunupudi et al. [61] studied digital literacy training for disabled individuals in Global South contexts such as India and Kenya, highlighting how extended digital scaffolding via WhatsApp groups supported ongoing discussion, troubleshooting, and knowledge sharing. These peer networks enabled BVI learners to move from reliance on structured training to self-directed learning. Baker et al. [12] introduced StructJumper, an Eclipse plug-in that transforms a Java file into a browsable hierarchy and voices structural cues (classes, methods, control flow) to support non-visual code navigation. Similar research for BVI users has often produced novel artifacts such as tangible interfaces, haptic devices [127], and audio-based systems. However, these innovations are typically evaluated through short-term controlled studies of performance and usability [138, 139, 178]. While important for technological advancement, this approach overlooks the complex, long-term realities of computer learning in resource-constrained educational settings. We address this gap through a qualitative account of in-situ computer learning experiences and by identifying forms of scaffolding that facilitate effective learning in such contexts.

3 Research Context

India has become a global hub for offshore ICT services, creating opportunities in remote work, freelancing, and platform-based jobs. Yet BVIs remain underrepresented in computer-dominated fields due to suboptimal skill development [84], socio-economic and language barriers [190], systemic issues such as gender disparities, inaccessible mainstream platforms, and societal undervaluation of their abilities [86, 126]. To address these barriers, organizations such as the National Association for the Blind (NAB) [117] and government initiatives like the Rights of Persons with Disabilities (RPwD) Act [130], Digital India [110], Skill India [111], and Vision-Aid's Project Springboard [194] provide training and resources to equip BVIs for digital participation. However, gaps persist between policy and practice, especially in rural schools where teachers lack inclusive training and infrastructure remains limited [38, 86]. These shortcomings contribute to high dropout rates; by secondary school, many BVI students have exited the education system [60, 171].

In the absence of robust formal support, NGOs and community-led computer training centers have become critical in bridging education and skill gaps. They provide specialized training, AT access, and career development, but typically operate in silos or at limited scale, raising concerns of sustainability and reach [86, 142]. Geography further shapes access; urban centers have special schools, NGOs, AT vendors, and disability services, while rural and semi-urban areas offer few local opportunities [76, 112]. Moreover, computer education often emphasizes theory over practical software navigational skills, limiting real-world readiness [72, 86, 144]. Cumulatively, these factors erode BVI learners' self-efficacy and employment prospects, often pushing them toward careers unrelated to computers [86]. For technology to succeed in India, it must fit within a socio-technical system that reflects how people live, learn, and work [72, 74, 86, 90, 190]. Building on this perspective, we explore culturally grounded and technologically responsive solutions to systemic barriers in BVI computer literacy education.

4 Method

To address our research questions, we conducted an Institutional Ethics Committee (IEC)-approved multi-phase study (pre-study interview, contextual inquiry, and post-study interview) at two non-profit institutions in India – one in the urban city of Bengaluru and the other in Ranebennur, a rural village. Contextual inquiry, widely used in HCI, helps capture user experiences in the field and uncover challenges situated in everyday contexts, including those of marginalized groups [96]. The urban computer training center provided specialized education in job-oriented ICT skills (e.g., MS Office, data entry) and English communication needed for immediate employment. It also offered residential facilities, including accommodation, meals, and medical support. Alongside residential trainees, the center served non-resident BVIs who attended mainstream schools or colleges outside the facility. In contrast, the rural specialized blind school in Ranebennur catered exclusively to BVI students. It followed the standard K–12 curriculum, offering instruction in subjects such as science, social studies, and mathematics. Unlike the urban center, it did not prioritize digital or job-related certifications, though it included basic computer training with instruction on SR use.

Category	Subcategory	Urban Center	Rural School
Sample	Total participants	38	56
	Median age (years)	23	19
	Male	26	37
	Female	12	19
Age Range	12-25 years	23	39
	26-35 years	11	12
	>35 years	4	5
Visual Condition	Congenitally Blind	11	18
	Acquired Blind	21	27
	Low Vision	6	11
Computer Experience	0-3 years	30	37
	4-10 years	5	13
	>10 years	3	6
Computer Time/Week	0-5 hours	8	38
	6-15 hours	28	16
	>15 hours	2	2
Teachers	Computer	3	1
	Braille	1	2
	English	1	1

Table 1: Participant demographics across both venues. All information was self-reported by the participants. Age, gender, and vision conditions are representative across both groups.

4.1 Participants

The entire study was conducted on-site at the two partner organizations, in classrooms and computer labs. Access for our research team was granted following a collaborative agreement established through the second author's long-standing professional relationships with the NGOs. At the start, the urban center had 38 participants (33 trainees, 3 computer trainers, 1 Braille instructor, and 1 English tutor). The rural school had 56 participants (52 students, 1 computer trainer, 2 Braille instructors, and 1 English teacher). These numbers fluctuated as individuals completed training or left for personal reasons. From this pool, we purposefully sampled 15 participants (8 male, 7 female) for pre-study interviews, ensuring gender balance and diversity in socio-linguistic backgrounds and visual conditions. All participants were 18 years or older and identified as being legally blind, totally blind, or having low vision. Post-study interviews included two groups. First, 23 recent graduates (14 male, 9 female), including 9 from the pre-study cohort, were selected for their active participation and ability to articulate experiences, with overlap enabling longitudinal insights. Second, 8 past graduates (6 male, 2 female) were recruited retrospectively through the organizations. Table 1 presents the comprehensive overview of participants' demographic data at the beginning of the user study.

4.2 Study Procedure

Our study comprised a contextual inquiry along with pre- and post-study semi-structured interviews. Before the study, we administered a survey with support from the partner organizations to collect demographic information on BVI participants and trainers, including age, gender, visual condition, weekly computer usage, and educational and economic background.

4.2.1 ***Pre-study interview.*** In the pre-study phase, we conducted semi-structured interviews with newly enrolled students, focusing on their reasons for choosing computer training, expected outcomes, and prior experiences with computers and SRs.

4.2.2 ***Contextual inquiry study.*** We conducted a four-month contextual inquiry at both sites, with two months at the start (July and August, 2024) of the academic session and two months at the end (March and April, 2025). This timeline allowed us to compare how participants' understanding, confidence, and computer use evolved from initial exposure to course completion. Two researchers conducted these observations, visiting each site twice a week. Each observation session lasted approximately four to five hours, meaning the researchers remained present through most class periods and stayed afterward to speak with students. During the session, we documented instructional methods, learner interactions with materials, and key conversations between trainers and students. To preserve a natural learning environment, we took observational notes during classes and engaged participants only during breaks or after sessions. Guided by our observational notes, we purposively engaged students whose behavior raised analytically relevant questions, e.g., those who appeared to struggle with instructions that others followed smoothly, those who verbalized or demonstrated distinctive strategies, and those who were especially active in asking questions or helping peers. Many of these students, including 9 focal participants identified for their ability to articulate their

Category	Subcategory	Urban Center	Rural School
Infrastructure	Working computers	9	6
	Computers with internet	6	1 (hotspot)
Screen Readers	JAWS	7	6
	NVDA	5	1
MS Office	Office 2007 (Unlicensed)	6	6
	Office 365 (Licensed)	2	0
	None	1	0
Operating System	Windows XP (Unlicensed)	0	2
	Windows 7 (Unlicensed)	7	3
	Windows 10 (Licensed)	2	0
	Windows 10 (Unlicensed)	0	1

Table 2: Computer infrastructure comparison across urban and rural training centers, highlighting hardware, software, and accessibility tools available in computer labs. Note that some computers had both JAWS and NVDA installed.

thought process clearly, later took part in the post–study interviews. We often posed the same questions to different participants to capture diverse perspectives. Table 2 provides an overview of the computer resources available at the two centers. We also observed exams and co-curricular activities to build rapport and better understand group dynamics. All observations and reflections from informal discussions were documented as memos for analysis.

4.2.3 ***Post study interview.*** At the conclusion of the study, we conducted semi-structured interviews, which allowed us to thoroughly explore the findings that emerged during the observational period. The discussions focused on the participants' satisfaction with the training, their overall learning experiences, and their suggestions for potential improvements to the curriculum as well as ideas for support systems that could better assist their specific learning needs. Inspired by Hove and Anda's interview guidelines [65], we also asked follow-up clarification questions for responses that were unique, unclear, evasive, or inconsistent with earlier answers or our observations. As a token of appreciation, we made a donation of $1,191.30 (approximation after conversion from Indian Rupees) to both institutions, which would be used to support the education and medical care of BVIs in future programs.

4.3 Data Analysis

The primary data collected included researcher field notes from observations, informal interview memos, and audio recordings from the pre-study and post-study interviews. The first author transcribed the English interviews, and the second author, a native speaker, transcribed and translated the interviews conducted in Hindi and Kannada (regional languages in India). The transcriptions amounted to a detailed document of 617 single-spaced pages, with up to 50 lines per page. This qualitative dataset was analyzed using a hybrid thematic analysis approach [28, 189] that combined both inductive and deductive coding [86]. In the inductive phase, each researcher independently analyzed their assigned transcripts using open coding [154]. This process involved a close, line-by-line review to identify emergent patterns and concepts. Codes and themes were grounded in participants' experiences, and in-vivo codes were used to retain the original language of participants wherever possible. In the deductive phase, we systematically mapped emergent codes to specific theoretical constructs, including Bandura's Social Cognitive Theory [16], Vygotsky's notion of the zone of proximal development [165], and constructivist learning [203] perspectives, which address topics such as scaffolding, self-efficacy, peer learning (social persuasion), and motivation to learn (mastery and physiological arousal). This allowed us to situate our findings within the broader HCI and education literature. No apriori codebook was used at the start of the data analysis; instead, codes were generated inductively through iterative comparison of the data and then systematically mapped to relevant theoretical concepts. Finally, all authors collaboratively reviewed the codes, refined the codebook, and reached a consensus on the final themes presented in this paper.

4.4 Researcher Positionality

This study was conducted by five authors representing different national backgrounds: the first, second, and fifth authors are from India, the third author is from Sri Lanka, and the fourth author is from South Korea. The first, second, third, and fifth authors identify as male, while the fourth author identifies as female. All authors are sighted and specialize in human-centered computing with a focus on accessible technologies. The research team has extensive experience in developing non-visual interfaces, including assistive tools for BVIs (e.g., SR-accessible interfaces and AI-driven usability enhancement systems). We approach this work through the lens of the social model of disability, viewing disability as a product of environmental and systemic barriers rather than individual deficits [63, 166]. Consequently, our analysis focuses on the socio-technical gaps in the training ecosystem, such as curriculum misalignment and a lack of contextual scaffolding, rather than on the limitations of the BVI learners themselves. The second author, a multilingual researcher, has a long-term collaborative relationship with BVI communities in India and participated throughout the research process. The lead author coordinated data collection with support from the second and third authors. The first, second, and third authors led the qualitative data analysis, while the fourth author contributed to refining the theoretical foundations. The fifth author participated in interpreting findings and identifying future research directions. Throughout the study, the team employed reflexive strategies to mitigate bias, including documenting our initial assumptions and revisiting these reflections at each stage to ensure the findings remained grounded in the participants' experiences.

5 Findings

In this section, we report the findings from the contextual inquiry and semi-structured interview studies.

5.1 Misaligned Curricula and Unstructured Pedagogical Practices (RQ1)

5.1.1 ***Ocularcentric, Certification-Oriented Curricula Overlook BVI Needs.*** Computer trainers at the urban center described the goal of training as *"getting certified by 'KEONICS' (Karnataka State Electronics Development Corporation Limited),"* a government IT certification provider [1] that enlists critical in-demand IT skills for the general population (e.g., Call Center Operator and Data Entry). They added that some ISO 9001–certified organizations also adapted and provided their *"own syllabus."* The program began with basic keyboard shortcuts (e.g., using Tab to move between elements, opening and closing files) and quickly advanced to routine tasks in MS Office applications (Word, Excel, PowerPoint). Then they proceeded to web browsing and *"advanced networking tasks [collaborative editing]."* The curriculum remained focused on job-oriented computer skills, with no inclusion of smartphone-specific training. An urban trainer noted,

> *"Our training program lasts for one year. The first six months are dedicated to helping students become comfortable with computers and develop a proper understanding of how they work. After that, we follow the official schedule of KEONICS."*

While the curriculum offered promising job certifications, it was fundamentally misaligned with non-visual learning and lacked accessibility-focused pedagogical guidelines for BVI trainers. As a result, trainers improvised teaching practices on the fly, relying on personal experience and developing their *"own teaching style."* Our inquiry also shed light on another critical dilemma: given differing backgrounds and prior experiences (Section 5.2), trainees' learning outcomes varied significantly. Some trainees progressed to more complex applications (e.g., Excel), while others were still learning basic navigation. However, trainers attributed this to *"different capabilities."* A trainer explained,

> *"If their qualification is acceptable, only then can we go for advanced concepts like HTML; otherwise, we focus on typing, sending mails... It also depends on the subjects they learned before. If someone is starting from scratch or if someone is older, the learning process is different. It is up to them."*

The gap between students' procedural skills and conceptual knowledge was also evident in their self-assessments. For instance, some students confidently claimed to *"know Java programming"* because they could type a memorized code snippet to produce a specific output. This reflected the program's instructional focus; when asked why foundational concepts such as data structures or loops were excluded, one trainer replied they were *"not required for the certificate."* He added that such topics were very difficult for *"blind students"* to learn and that *"they learn the theory in school" [trainees attend regular K–12 schools in addition to computer training].*

A central challenge for trainees was the steep learning curve of the SR itself, yet the curriculum provided no pedagogically well-structured, formal instruction or skill evaluation, treating it merely as an auxiliary add-on. A trainer explained,

> *"Screen readers cannot be certified by the government because they are not responsible for them. Screen readers are only for personal use. Only if it is for general population, they will give a certificate."*

Across both training centers, the trainers primarily taught JAWS SRs, typically installed as a pirated copy on institution-owned computers (resonating with McCarthy et al. [106]'s observations). However, in the urban site, five of the seven machines also had NVDA installed, reflecting one trainer's preference as it was *"free to use"*, making it a viable option for professional use. Trainers reported that while computers were procured through donations, they themselves installed the SR software.

The exams did not assess practical SR skills, relying instead on theoretical questions (e.g., *"What do you press to save a file?"*). Even when shortcuts were included, they were generic (e.g., Ctrl+S to save) rather than SR-specific (e.g., Insert+F7 to list links). Additionally, while many developed personalized navigation strategies, their skills were brittle and context-bound. This lack of transferability was evident when one trainee, proficient in MS Word, avoided Google Docs because she *"did not know how to use Docs."*

In the rural center, computer instruction was embedded within the general K-12 curriculum. The primary goal was not to provide an employment-oriented certificate but to help students pass their 10th and 12th-grade state exams. This academic focus meant that computer science content was largely theoretical and often outdated: students learned concepts like *"what is a CPU?"* or the function of a floppy disc. BVI students received leeway during practical lab activities. Their computer use was not formally structured, becoming task-driven and incidental. It was often confined to routine activities like typing, navigating simple websites, or using the computer as a tool for information consumption (e.g., reading digital books or listening to music). Consequently, rural students who aspired for employment-oriented computer competencies inevitably required supplemental training at specialized urban centers to acquire job-necessary computer skills.

5.1.2 ***Technical Proficiency is the Only Teaching Qualification.*** While HCI literature positions trainers with disabilities as invaluable 'experts by experience', our findings revealed a critical flaw in applying this model to vocational computer training for BVIs in India [21, 57, 102]. At both the urban and rural centers, trainers were hired almost solely for their technical proficiency as SR users, with no formal credentials in pedagogy or computer science. This hiring practice, though pragmatic given the shortage of specialist trainers, produced a pedagogical ecosystem ill-equipped to meet diverse learning needs. An urban trainer described his career path:

[1] https://www.keonics.in/english/courses

> *"I have done my B.A. in Kannada literature...I have like 10-12 years of experience, so I volunteered to teach computers here initially. Then, later, they hired me as a trainer. In between for 1-2 years, I have also taught in another school for intellectually disabled students who could see...I used to teach theory mainly there".*

Additionally, computer trainers at the urban center themselves did not have any prior industry experience, even though teachers covering other subjects had such exposure, underscoring a disconnect between who held industry-relevant skills and who was formally responsible for teaching computing. For example, the center's English teacher had previously worked as a data entry operator, gaining industry-relevant computer skills before losing her job when the project ended. She later sought advanced training in accessibility testing from fellow computer trainers while simultaneously teaching English and informally assisting students with application tasks whenever *"time permitted."* The rural school reflected similar dynamics. The computer trainer there described himself as a *"senior student"* who had first learned computers at an urban training center and was now teaching computers at the school for a living.

5.1.3 *Trainer-Centric Pedagogy and the Reliance on Rote Demonstration.*

Urban trainers largely followed the prescribed curriculum, moving from typing in MS Word to what they described as *"complex software like Excel."* They emphasized the difficulty of keeping pace with software updates, often avoiding new versions. As one trainer noted, *"We use Office 2007 only, because the new one, like 2025, is very complex and I am not confident in that."* Lacking formal pedagogical training, trainers defaulted to direct transfer of their own expertise through rote demonstration of tasks within their own comfort zone. A common method involved the trainer and trainee sharing earphones, each using one earbud to monitor SR feedback as the trainer performed shortcut-based tasks. The trainer then explained how to interpret the feedback, asked questions, and prompted the trainee to repeat the sequence, correcting as needed while observing practice.

However, one-on-one guided demos proved logistically unscalable given the number of trainees. Trainers often asked students to *"come back when he [trainer] was free"*, noting they could only teach each student two or three times before directing them to peers. In many cases, students requested lessons that the instructors themselves did not know well enough to teach. As one trainer recalled, *"one student wanted to learn PowerShell, so I learnt it from Google myself...tested and then taught her."* Trainers were also often unaware of the rationale behind using specific shortcuts in different contexts. Additionally, trainers seldom tracked individual progress, leaving learning largely dependent on students' own *"interest to learn."* In the absence of personalized support, students at both centers often turned to senior peers who *"had more computer experience."*

5.2 Impact of Socio-Technical Factors on Learning Self-Efficacy (RQ2)

5.2.1 *Delayed Access to Computers Creates Accelerated Learning Needs.*

India has invested heavily in bridging the digital divide, often through the widespread adoption of smartphones among marginalized BVI groups [77, 163, 190]. Yet this form of digital literacy did not translate into desktop computer skills, which remain essential for ICT employment. Our findings revealed a digital double bind; the delayed and resource-constrained nature of learners' first encounters with desktop computers shaped their goals and created compounded learning challenges that undermined self-efficacy from the outset. Most participants came from economically disadvantaged backgrounds, many holding BPL (Below Poverty Line) cards and described a desktop computer as a *"big investment."* For most, nonprofit training centers provided their first meaningful access to computers, along with free accommodation, meals, and instruction, reducing financial barriers and enabling them to focus on skill development. Reliance on late-stage specialized training was inevitable, as teachers in regular schools, though familiar with computers, had little understanding of SRs or accessibility. Participants reported that instruction in the regular schools had been largely theoretical, leaving them far behind their sighted peers in terms of computer literacy. One trainee explained:

> *"My friends told [me] about Narrator, I tried to use it...But I was lost, my teachers or friends did not know like what shortcuts to use or anything...In labs, I would randomly hit different keys, and my friends would explain what was happening on the screen. Sometimes they would open and give me notepad to type...Later I thought if I study more, I can get a typing job or something and joined this computer class."*

Consequently, many BVI trainees were introduced to computers for the first time at the center, yet they were still expected to acquire skills within a short span of 6 months, motivated by the allure of office employment. Many trainees specifically aspired to learn Excel, PowerPoint, and internet skills as prerequisites for a *"computer job at SBI [government bank in India]."* Few reported examining the adequacy of the curriculum; admission decisions were more often shaped by word-of-mouth credibility and linguistic fit than by evidence of post-training employment success or alignment with personal learning goals beyond employment. This reliance on hearsay often produced narrow, specific ambitions that overlooked both the program's curriculum and the complexity of the learning process, as one trainee explained:

> *"My [sighted] friends were making money from trading, and I thought, if they can do it, I can too. See, for that I need to learn how to use the computer, right? Like, to read those graphs and understand the trends ... So, that's the reason I'm here. But none of my trainers know how to do these things, I have no idea where else to go and learn".*

In contrast, rural trainees arrived with no fixed learning goals, enrolling mainly for general education with practical computer training offered in an unstructured format. They had limited, shared access to campus computers and little time for hands-on practice. Learning goals were set by the trainer, who focused on basic tasks such as typing in Notepad or using SR shortcuts for file management. Yet, even this rudimentary training had a profound impact on students. Successfully completing simple tasks built foundational self-efficacy and, for some, sparked new ambitions. As one student noted, *"thinking I'll go to Bangalore [city]...I am very confident in this computer and gadgets...want to learn more."*

5.2.2 ***Lack of Transitional Support Undermines Learning Self-Efficacy.*** We observed that the domain-specific self-efficacy (computer and AT use) was shaped collectively by the support BVI learners received at the onset of disability, the quality of training available, and the time elapsed since vision loss. Many low-vision participants reported that, initially, they often avoided mainstream computer classes because using computers was *"painful"*, requiring constant zooming and panning with screen magnifiers (SM). When their vision deteriorated substantially, they were forced to adapt to audio-based SR navigation to preserve employability, catching up on tasks that were no longer manageable with magnification or managing everyday communication. One trainee described:

> *"I was born with partial blindness, but my parents didn't fully acknowledge my condition and enrolled me in regular schools. Since I had some residual vision, I was able to read and write without needing a screen reader at that time. However, when my vision deteriorated at the age of 15, I could no longer write on paper or read as I used to. That's when I had no choice but to learn how to use screen readers to get a job."*

Such delayed support among late blind participants created significant cognitive load, which they reported *"was difficult to adjust to quickly."* They first had to unlearn the mouse and icons paradigm before they could begin to internalize auditory feedback. One trainee whose vision declined only four years ago admitted, *"I don't know, now also I don't know Braille,"* having attended school as a sighted student. For learners like him, SR commands felt like abstract jargon rather than familiar tools. Many participants with residual vision reported that they continued to rely on visual memory and guesswork to predict screen contents rather than fully adapting to audio-only navigation. Low vision learners at both centers received no tailored support; they were grouped with congenitally blind peers and expected to adapt right away to SR-based computer interaction. Trainers, all of whom were blind SR users, did not teach SM use. Consequently, several low vision learners adopted a hybrid strategy: they relied on SMs to navigate simple tasks on their smartphones while learning to use SRs on desktop computers, which were taught by the trainers.

Although the training centers offered minimal transitional support, they nonetheless *"helped bring back confidence and gave hope"* by reconstructing a sense of normalcy for learners with acquired blindness. Several participants described how vision loss and the fear of being dependent on others had taken a heavy emotional toll. Joining the centers, where peers used computers and produced documents in MS Word, provided renewed motivation (vicarious experience). While the initial transition to audio-based interaction was overwhelming, participants emphasized that peer support was crucial in helping them adapt gradually over time, bolstering their *"confidence to use computers over time."*

5.2.3 ***Subjective Norms Shape Motivation to Learn.*** A learner's perception of the shared expectations from 'important others' such as instructors, peers, employers, or family (subjective norms or normative beliefs) [5], and the desire to meet them, shaped by collective knowledge and domain self-efficacy, influences how students approach complex learning tasks (social persuasion) [16]. Many rural students reported a complete lack of information about blind schools or accessible computer education until later in life. Some families and local peers *"didn't even know this type of [specialized] computer school for blind and jobs even exists."* Participants reflected that while their parents were *"very supportive"* and enrolled them in sighted schools to study alongside normal kids, families lacked *"the knowledge of computers and how to use screen readers."* Families often celebrated any *"respectful office job"* that provided a basic independent income.

A powerful motivation for learning among BVIs was the desire to resist societal perceptions of dependence. While their immediate circles often held limited belief in their capabilities and offered little support for accessible computer education, computer proficiency was celebrated as a badge of pride that encouraged students to pursue training in computers. Trainees explained that they were often regarded with sympathy and positioned primarily as beneficiaries of charity. Computers helped them resist this construct, enabling even simple acts such as writing an exam without hiring a sighted person to transcribe. Participants described how others reacted with surprise, *"Oh, even without vision, he's able to operate a computer,"* and how this recognition fueled their hopes of building a career in computer fields.

5.3 Contextual Learning Challenges and Learning Behaviors (RQ2)

5.3.1 ***Compounded Cognitive Load of Simultaneous Learning.*** For BVI learners, acquiring computer proficiency involves simultaneous mastery of several distinct cognitive layers: memorizing a vast array of keyboard shortcuts, building detailed mental maps for each new software application, and developing critical debugging and recovery skills to handle frequent navigational errors [139]. This already steep learning curve is exponentially amplified when guidance to build tactile 'muscle memory' is scarce, and learners must operate an assistive technology (e.g., SRs) narrating in less-familiar language, using a physical keyboard whose layout, keys, and functions are themselves new concepts to be learned. These challenges manifested in our context as explained next.

Learning an English Keyboard, User Interface Semantics, and Mental Mappings: The key to effective non-visual navigation for BVIs lies in mastering coherent use of SR and application-specific keyboard shortcuts while constructing mental maps of software applications through repeated exploration and memorization of platforms' structure [26, 211]. For our participants, the initial learning step was building a mental map and proprioceptive understanding of the Western-designed, English QWERTY keyboard. Trainees at both centers used standard (non-Braille) keyboards, usually provided through charitable donations, with little to no accessibility enhancements. Since many had only basic exposure to spoken and written English, learning key functions and screen symbols was tedious. One trainer described how he *"holds their fingers and points to what each key is and tells them... for example, I tell press shift and 2 for typing at-the-rate (i.e., '@') when typing email address,"* providing contextual explanations for keystrokes. Students initially had little conceptual understanding of the meaning or use of symbols; instead, learning them incidentally over time. Trainers often assigned the first two weeks to typing in Notepad for practice, but in reality, this often extended to several weeks for many beginners. As one trainer reflected, *"it was not just about pressing keys but also remembering where the keys are on the keyboard, decoding what the SR has narrated, and remembering how to respond,"* usually by recalling demonstrations. For our participants, typing was not merely a motor skill but also a cognitively demanding challenge: they had to mentally map a keyboard that was not designed for their linguistic or accessibility context in real time, while also understanding and building a virtual mental model of the software structure.

Additionally, at both centers, most participants began training with little understanding of what computer UI elements meant, which made it difficult to map keyboard shortcuts to digital actions. Trainees often asked questions such as, *"What is a toolbar?"* or *"What is a filter?"* One student explained, *"In the beginning I didn't know what is filter. Normally I know water filter and coffee filter... but I didn't know that filter can like give selected items only on website... in such cases I need more explanation."* Participants also struggled to differentiate user interface elements, often confusing toggles with dropdowns and expecting them to behave differently. Even in application-specific training, participants mapped keyboard shortcuts to surface-level outcomes (e.g., selecting items) rather than to underlying technical actions (e.g., moving through a list). This shallow understanding made it difficult to transfer SR navigation skills across unfamiliar applications, forcing learners to relearn each action in isolation instead of generalizing it as part of a broader digital grammar. Participants also developed their own ways of describing application elements, often using vague or context-specific terms and analogies. For example, they referred to headings as *"title jump,"* highlighting their navigational purpose rather than their structural role in a document.

While students at both centers gradually developed navigation proficiency, their skills remained confined to the applications they were trained on. For example, one rural trainee admitted, *"I only use Internet Explorer and not Google Chrome as I was not used to that."* Trainers seldom offered structured instruction on approaching unfamiliar platforms and were themselves often limited to routine applications (and versions) they originally trained on. By memorizing and executing routine tasks, participants gained confidence and a sense of expertise. A senior student explained, *"I know how to use full MS Word and HTML...So next I need to start looking for job in a company."* Yet this confidence did not always translate into adaptability to new applications. As one trainer cautioned, *"Main problem is when they give new applications or different versions, we struggle because we did not learn that, again the companies will have to retrain us, which makes it harder for them to hire us."*

Learning Transliteration and Multi-Linguistic Keyboard Mappings: While BVIs gradually built an understanding of the English keyboard, they soon faced another challenge: *"they have to also learn typing Kannada using the keyboard as most government jobs needed it,"* one trainer explained. At the urban training center, where the focus was strongly on job placement, mastering this mapping was treated as essential. A trainer elaborated:

> *"For some jobs you need to learn how to type the Inscript [Indian Script keyboard layout] which students need to practice... in this keyboard if I type like A it becomes Aa [Kannada letter] or S means Sa [Kannada letter] and we need to use like shift for Svara [vowels]. And if they don't install the Kannada screen reader package, it will announce keys in English... So we need to hold two systems in your memory at once: the English keyboard layout for navigation, like normal[English] websites, and then Kannada Inscript mapping to type... This gets very confusing."*

This challenge was greater for participants who had moved from neighboring states for training. While they spoke Tamil or Telugu at home and conversational Kannada socially, they had limited knowledge of the written scripts of either Kannada or English. As one student noted, *"I gave up on government jobs here because learning multiple typing is complex... so I prefer corporate or banking... but there they ask advanced stuff."* Even at the rural center, where students were only beginning to learn basic English, this process created an overwhelming cognitive load. As participants explained, they were *"juggling two languages, two mapping systems, and the screen reader's feedback all at once."* By contrast, participants described how mobile devices felt easier, since many simply used voice input: *"we just use the microphone and speak."*

Ambiguity Between Platform Inaccessibility and User Navigational Errors: As novice BVI learners began using SRs or exploring unfamiliar platforms, they frequently made navigational errors, making debugging skills (e.g., restarting or returning to a checkpoint) crucial for progress. Yet students received little instruction on managing such errors. During classes, participants often lost control of navigation. Trainers typically asked them to retry the task, without explaining why they got lost or how else the issue might be resolved. Consequently, most students adopted the same strategy of restarting rather than developing alternative debugging techniques. Learners also struggled to distinguish between platform inaccessibility and their own mistakes. For example, they often assumed they had erred when unexpected pop-ups disrupted their flow. Furthermore, they received little guidance on navigating cluttered government websites, which often lacked accessibility features. As a result, students committed frequent errors. Since these sites were not used routinely, many avoided them altogether, relying instead on mobile devices or help from others.

Decoding Rapid and Monotonic English Feedback: For effective non-visual digital navigation, BVI users must dynamically interpret SR output and construct a mental structure in real-time, i.e., a predictive expectation of where elements are located using the structure SRs announce (e.g., headings, links, and buttons). Over time, as users build proficiency, SR users can infer element details from partial output, skip unnecessary details, and familiarize themselves with new applications more quickly [10, 140]. For our BVI students, this already complex task was even more difficult because they had to get used to a fast, monotonic English voice and often needed to think, ask others, and then decipher what was spoken, even at the lowest reading speeds. Novice students noted:

> *"it [SR] speaks very fast and sounds robotic... it says like you are now on group, press control shift x or something... I can't remember all of that now... now I have to go back and try to remember what it is... sometimes I try to ask Google, but it cannot understand what I am asking about... it's not only about speed, I need like more explanation and step by step guidance... till I get used to it."*

Participants described anxiety about missing or mishearing SR output due to incomplete understanding. Many asked for *"a slow emotional like voice"* at the learning phase, whereas trainers preferred faster speech because of their own proficiency.

5.3.2 ***Self-Learning is Inaccessible for Novice BVI Users.*** Accessibility literature shows that self-training is the primary way BVIs learn computers and ATs, including SRs [86, 153, 205]. In the absence of formal instruction, they often transition to self-regulated learning through peer support. Our participants, however, were limited in this process due to restricted access to computers (most did not own one) and a lack of foundational knowledge. Many were proficient smartphone users but had little understanding of desktop operation. Urban trainees spent their academic session working on center-provided computers under trainer guidance. Many avoided independent exploration; one explained she *"was scared to try navigating something... like if something breaks or gets deleted then I do not know how to fix it or buy [afford] a new computer."* Over time, longer-term trainees began exploring tasks independently, most often only within the applications they had been taught. Rural students followed a similar trajectory but with fewer opportunities. Their classes lasted only three to four hours per week, and while computers were technically available outside class hours, few chose to use them. In practice, learning remained limited to following trainers' instructions.

For most students, trainers, or peers were the first point of contact for doubts or information. They seldom consulted software documentation or online tutorials, describing them as overly technical, filled with unfamiliar terms, or too abstract to address their immediate tasks. Students lacked the vocabulary to articulate problems in technical terms or break them into building blocks. As a result, they relied on explanations that mirrored trainer methods, using informal task-to-action sequences. These included guidance such as locating keys on the keyboard or basic debugging steps. For instance, while shortcuts like 'Ctrl + Escape' were listed, documentation rarely clarified that the '+' symbol meant pressing the two keys simultaneously. Documentation also lacked accessibility-specific explanations for individual platforms. Participants were unfamiliar with terms like 'ARIA' or actions such as 'Toggle', making it difficult to connect content to their problems. At the rural center, students seldom explored beyond routine tasks, as their computer textbook rarely included practical, non-visual instructions until the trainer provided a translation.

5.3.3 ***Confusion in Peer Learning.*** With limited trainer availability and largely inaccessible self-learning tools, BVI students often relied on their friends and seniors, with whom they spent most of their day in computer classes, schools, and hostel rooms. Many students described that their first introduction to computers (before joining the training center) was through sighted friends at school or, in rare cases, through BVI family or peers who had already acquired some training. For example, one student recalled:

> *"My first trainer was my brother only... who is also a visually impaired and learned computer before me. But he cannot teach the advanced skills like programming... so I joined here... much of what they teach here is what I already know like basics MS Office... I want to learning like HTML and building website kind of things."*

However, for most students, entry into formal training came with minimal prior knowledge or family support. In these cases, senior users acted as ad-hoc trainers. Students also recalled support from sighted peers in school, who taught basic theory and navigation despite limited understanding of SR. One participant explained that friends shared application-specific shortcuts and would *"search and tell me what shortcuts to use"* when SR support was needed. Such help was useful mainly for basic navigation. Over time, most BVIs reported gravitating toward peer learning with other BVIs, feeling *"more comfortable with friends who explain more clearly."* At the training centers, these interactions often unfolded in mixed, multilingual conversations, with English terms used for technical vocabulary and local languages for explanations. Informal curricula also emerged. For instance, one student aspired to learn Excel and use a calculator and finance tools like her senior, so she could also become a chartered accountant. She therefore chose not to pursue programming certifications, instead prioritizing *"accounting tools."* However, peer knowledge was limited by incomplete training and inconsistent instruction. Students often received different shortcut sequences for the same action, leading to confusion. In such cases, participants typically tried each version and stuck with the one that was easiest to remember or worked first.

5.3.4 ***Computer Learning Stops at the Training Center.*** BVI students at the urban training center completed the program with varying levels of computer proficiency. Only a few attempted the KEONICS certification exam, while many stayed an extra month or two. At least 11 participants, according to the trainer, transferred to other non-profit blind schools during the course, even when those schools did not offer computer training. This movement was often driven by perceptions that *"the trainers were strict with respect to learning"* or by personal reasons such as word-of-mouth recommendations from peers. These patterns reflected the absence of structured academic accountability compared to computer education for sighted students in regular schools. Admissions were informal, and participation was often inconsistent. In contrast, students at the rural center seldom dropped out. The organization provided a complete K–12 education and functioned as *"home"* for many, which fostered consistent participation.

Although urban students did not complete the training with formal certifications, many expressed high self-efficacy by the end of training, stating they could now *"use a computer and can apply for bank or IT... government clerk type jobs."* Yet graduates soon faced structural barriers. They explained that *"reserved jobs in government sectors for PWD [people with disabilities] are very few and they prefer some other disabled people who can see, like physical handicap, because they don't need screen reader or anything, even in corporate [ICT industry]."* One graduate reflected that many students gave up after initial rejection and returned home. In such cases, they lost access to computers, or if access remained, they did not practice enough to reach industry-level proficiency. By contrast, a graduate who eventually secured a position in an IT firm noted,

> *"After I graduated the training... I was there for like 2-3 months trying to learn and practice computer more... I also built connections and got some referral by one the donor [philanthropist who supports the NGO] in a startup company where I work as accessibility testing engineer... he also bought one laptop. First few months I practiced a lot and like with checking in internet I became a expert user... the thing is we have to keep practicing and build skills... not every company will take new visually impaired people and train no."*

Trainees who were unable to secure employment after training described how they *"lost confidence after giving the first few interviews."* Although the centers never explicitly promised jobs, students widely believed that learning computers and SR would enable them to compete with sighted peers. In interviews, however, they were often asked advanced concepts like coding or *"even in Word they would ask if we know how to use collaboration."* The training had not prepared them for such tasks, particularly collaborative functions. Graduates noted that even when they wanted to learn these skills, they did not know who to ask. After repeated rejections, many returned to their permanent residences, often in rural areas with their families, as they could not sustain themselves without immediate employment opportunities.

6 Discussion and Future Work

Our findings illuminate key challenges in BVI computer training in resource-constrained Indian contexts. The programs relied on a borrowed, ocularcentric, certification-oriented IT curriculum that largely overlooked the accessibility needs of BVIs. Trainers were hired primarily for their computer proficiency and lacked pedagogical expertise, so they relied on demonstrative, task-centric teaching. The training further failed to account for learners' diverse life experiences, including unequal access to computers, limited transitional support for people with acquired blindness, and local subjective norms surrounding disability. Together, these factors undermined learners' self-efficacy and contributed to compressed training timelines. Trainees were required to manage a compounded cognitive load arising from poorly scaffolded multifaceted learning demands. In response, many turned to peer support, yet peer learning was often inconsistent and ambiguous, which deepened confusion rather than resolving it. Taken together, these findings raise a broader question of how computer literacy education and AT ecosystems in the Global South can be reimagined to distribute expertise, reduce cognitive and linguistic burdens, and support long-term, transferable skill development beyond the training center. Situated in these findings, we unpack: (i) how vocational computer training in resource-constrained contexts shapes BVI learners' trajectories; (ii) how culturally sensitive pedagogy can promote higher self-efficacy; and (iii) design suggestions for EdTech for BVI computer training that can complement ongoing systemic efforts.

6.1 Understanding Inclusive Computer Training in Resource-Constrained, Multicultural Contexts

Despite growing digital inclusion efforts in India [80, 126, 162, 190], computer training centers expect BVIs from multicultural and economically marginalized backgrounds to appropriate Western-designed computer applications and ATs without sufficient attention to how adoption unfolds or what forms of scaffolding it requires. In the Global North, computer training is widely recognized as a core component of vocational rehabilitation for BVIs and is often delivered through dedicated state-funded and non-profit programs [15, 31, 121, 145]. Programs such as Helen Keller National Center's (HKNC) Technology, Employment, Achievement & Mastery (TEAM) explicitly center BVI learning needs in their curriculum design, foregrounding accessibility and long-term digital independence rather than only credentialing, and are structured around disability-specific pedagogies and extended timelines [1, 2]. By comparison, Indian training centers often orient toward certification exams originally designed for sighted learners, or toward locally created in-house curricula whose credibility and recognition remain opaque to global ICT employers (Section 5.1). SR training was treated as an 'assistive add-on' that was not formally supported or certified *"because it is not for general people"*, which normalized BVIs being structurally positioned outside mainstream curricular design. Our findings suggest that simply importing a single BVI-specific curriculum modeled on Global North initiatives would be unlikely to succeed in India, given the sheer diversity of languages, schooling experiences, and baseline digital exposure, and the absence of a long-term rehabilitation pipeline.

Additionally, trainers in our study, hired solely for their personal computer proficiency, were positioned primarily as proficient device operators rather than as professionals equipped with pedagogical know-how tailored to BVI learners. By comparison, Global North educators of BVI students are typically trained in pedagogy and special education, preparing them to both use and teach ATs effectively [27, 48, 172, 200, 215]. While broad accessibility literature rightly values the role of 'expert by experience' [21, 57, 102], our findings highlight the risks of conflating user expertise with teaching expertise. Trainers struggled to bridge gaps in foundational concepts and relied on idiosyncratic analogies to teach core digital terms, which fractured shared understanding and made it harder for BVIs to build robust mental models that transfer across application contexts. Learners' varied experiences and personal preferences were frequently overlooked, with the burden of slow progress placed on the student instead of the teaching model, a stark contrast to inclusive approaches such as Universal Design for Learning (UDL) [150], which are central to Global North practices.

The temporal and structural organization of learning further differentiated the resource-constrained Indian computer training centers from the affluent Global North vocational training programs. We found that many BVIs in our study progress through schooling with predominantly theoretical content and limited access to AT or computers, then encounter intensive, one-year vocational computer courses only after high school. This compressed timeline contrasts with multi-stage models in the Global North, where exposure to AT and digital tools is often introduced earlier and scaffolded across formal education and rehabilitation services [7]. Instead of developing cognitive layers of computer use over the years [118, 210], BVI learners in India encounter a single, overwhelming learning experience at training centers, which often encourages reliance on procedural mimicry rather than conceptual understanding.

Prior work on vocational training in western contexts also proposes multimodal methods (e.g., tangible interfaces and vibro-tactile feedback) to strengthen understanding of UI concepts, hardware, and programming beyond audio-only SR [15, 152, 177], shifting effort from memorizing many shortcuts to leveraging spatial and tactile memory. In contrast, BVIs in our study sites relied on one-dimensional audio-only interaction via SR without any multimodal references to conceptualize digital structures. Furthermore, they often lacked the technical vocabulary to describe navigational errors, which rendered online tutorials and help documents ineffective, thereby reflecting missing instructional scaffolds to connect Western-designed guidance to their situated problems [128, 204].

We argue that closing these gaps requires reimagining the broader ecosystem of inclusive computer training rather than focusing on specialized centers alone. Because many BVIs attend a small number of government-supported schools due to financial constraints, targeting teachers in these schools for specialized training in accessibility support and SR use, for example, as a dedicated subject or module, could establish foundational digital skills earlier and reduce cognitive overload in later vocational programs [27, 172, 215]. This, in turn, demands investment in trainer preparation across languages and regions and in shared, locally-adaptable curricula designed through participatory collaboration between accessibility and HCI researchers and proficient BVIs [44, 132, 202]. Rather than rebuilding solutions in isolation, cross-regional partnerships can examine which elements of Global North disability-centered curriculum and AT training models can be transferred, and how they should be adapted to accommodate linguistic diversity, infrastructural constraints, and different educational trajectories in the Global South [9, 46, 202]. Our findings also show that learning often ended at the training center and that fragile self-efficacy collapsed after graduation and repeated job rejections, reflecting shallow conceptual understanding and acquisition of computer skills. Research in the Global North has recognized this problem and addressed post-training collapse in self-efficacy by coupling centre-based courses with comprehensive 'adjustment to blindness' programs, higher-education pathways, and sustained engagement with consumer organizations, an ecosystem that is associated with substantially higher employment and earnings for BVI adults [19]. Future work should explore how similarly holistic, contextually grounded ecosystems can be designed for BVIs in India to support sustained skill development and favorable employment outcomes.

6.2 Culturally Responsive Pedagogy for Higher Self-efficacy

Within the Global South, BVIs face structural barriers including limited access to computers and licensed SRs, weak collective understanding of accessibility, and limited belief in their ability to succeed in computer-dominated fields, and persistent linguistic barriers [72, 86]. Together, these factors erode self-efficacy in navigating the cognitively complex task of computer learning and often push BVIs toward alternative careers. Inclusive computer education in such multicultural, resource-constrained contexts requires more than 'functionally accessible' instructional materials or software tools. It demands a pedagogy rooted in students' cultural references, lived experiences, customs, and prior knowledge to create meaningful learning (social accessibility). Building on Ladson-Billings' concept of culturally relevant pedagogy [92, 113], we ask: what contextual scaffolds can inform a culturally responsive computer pedagogy that improves learning outcomes and self-efficacy for BVI learners in the Global South?

Beyond the narrative of an 'inaccessible curriculum,' our findings raise a deeper question about how ATs are positioned within computer pedagogy. When computer training programs adopt an ocularcentric, certification-oriented curricula, they discount the cognitive demands and locally-adaptable instructional support needed to adopt Western technologies in contexts for which they were not designed. This raises a broader question: what is it about the fundamental design of computers and SRs, developed in affluent Global North contexts, and computer training programs that imposes such a steep learning curve on BVI students in India?

First, is the challenge primarily the lack of support for local languages? A simplistic solution poses a paradox: even if these technologies fully support local languages, how can learners be prepared for an English-dominated ICT job market if their technology learning is in another language? Simply augmenting SR instruction to existing curricula also ignores the cognitive load of mastering a computer and an SR at the same time. Perhaps the real challenge is not a binary choice between full localization and the status quo, but rather finding a more nuanced tradeoff. Sweller's Cognitive Load Theory [179] suggests minimizing 'extraneous cognitive load' (mental effort imposed by the interface or language) and optimizing 'germane load' so learners can focus on the intrinsic load of computer concepts. In practice, educators can use students' native language or simpler representations to introduce new ideas [45], i.e., first teaching SR navigation with familiar terminology or local analogies before gradually introducing standard English commands. Sequencing instruction in this way can distribute cognitive burden over time rather than compounding it all at once. The critical task is to identify analogies that resonate with learners' lived experiences or 'funds of knowledge' [100].

Second, pedagogy often mis-categorizes learners by imposing a uniform 'blind' identity on a spectrum of visually impaired individuals. For those who acquired blindness later in life, being *"treated as normal"* meant they were denied the re-adoption scaffolds needed at the onset of vision loss. Placed alongside congenitally blind peers, they were expected to start from the same point despite lacking the native non-visual mental models developed over a lifetime. This abrupt re-categorization led many to struggle, internalize systemic shortcomings as personal failure, and experience diminished self-efficacy. Educators must therefore create assistive learning profiles grounded in contextual factors such as onset of disability and prior familiarity with ATs. These profiles can enable learner-centered AT selection and customized adoption processes. The K–12 curriculum should also anticipate potential vision loss in students with low-vision conditions, such as Stargardt disease [64]. While complex auditory navigation can be overwhelming during early literacy and comprehension development [185], research has shown that multi-sensory learning more effectively supports cognitive growth at this stage [52].

Finally, what scaffolding do current and incoming BVI trainers need to implement a personalized teaching model that provides contextually rooted support and enables BVI students to move beyond application-specific tasks toward the self-efficacy required for advanced computer navigational skills? Our findings show that BVI trainers, often hired for experience but without pedagogical or AT training, struggled to meet individual needs and sometimes attributed student difficulties to *"lower capabilities."* To address the challenges we observed, we advocate for a training-of-trainers program that: (i) equips BVI trainers with conceptual knowledge of computers and SRs, (ii) incorporates learner preferences through data-informed approaches [108, 164, 182] to provide personalized scaffolds that strengthen their learning self-efficacy. Trainers should also practice a pedagogical mirror, i.e., reflecting on their own tasks, articulating the rationale behind specific actions, and then transferring that understanding to students. Technologies could also support such training, as discussed in the next section.

6.3 Designing EdTech for BVI-Inclusive Computer Learning

Our findings show that BVI learners in India navigate computer training in environments where pedagogical support is thin, peer help is uneven, and self-learning resources are largely inaccessible. The digital divide in this context is less about devices or connectivity and more about limited teacher capacity [89, 131, 143], as overextended trainers rarely have the time or preparation to offer slow, stepwise explanations, and scaffolding often ends once learners leave the training center. In such cases, HCI and education researchers have explored locally adaptable, culturally responsive AI tools that complement rather than replace teachers by offering continuous, individualized, context-aware support at scale (e.g., Squirrel AI [97] and Shiksha Copilot [40]), which current teaching capacity cannot sustain in such low-income, resource-constrained societies. AI-mediated learning experiences such as educational robotics and audio games have also improved engagement and collaboration between BVI and sighted peers, surfacing capabilities that remain hidden in resource-constrained classrooms [114, 184, 207]. Moreover, AI tutoring systems can reason over interaction histories to infer cognitive load and confusion, provide personalized, just-in-time scaffolding, and maintain patience and consistency in ways that are difficult for overburdened trainers [18, 173]. Building on this work, we argue that AI-based EdTech could help both BVI learners and trainers manage the cognitive load of learning computers by providing patient, stepwise, and personalized instruction, and we next propose design directions that foreground such contextual support [18, 55, 147, 173].

6.3.1 ***Personalized Computer Learning.*** To meet individual learning needs at scale, we propose an artificial intelligence (AI)-driven BVI computer training EdTech that integrates Large Language Models (LLM) that maintain individual learner profiles and adapt support over time [193, 198]. Through targeted questions and brief diagnostic tasks, such EdTech can elicit background, preferences, and current skills, including prior experience with computers and SRs [17, 58], then use these profiles to select individualized scaffolds that keep learners within their Zone of Proximal Development [78]. Interaction traces such as response times and error patterns can drive real-time adaptation, helping the AI tool decide when and what hints to provide, when to fade guidance, and when to increase task complexity [3, 120, 160]. Pedagogically, the tool can follow cognitive apprenticeship principles [22, 34], making expert reasoning visible and prompting reflection [209], while coaching learners step by step in a friendly, peer-like tone that our participants preferred. To support safe exploration, the tool can also provide audio-based sandbox simulations (for instance, a virtual desktop where commands always work or reset) that let learners practice without fear of 'breaking' anything [157, 207].

More broadly, the design must recognize that novice BVI learners in India lack foundational computer training or early guided access, and therefore must navigate a multifaceted learning process (refer to Section 5.3.1). This creates a fundamental design challenge: if a person has not yet mastered an SR or other AT, they are poorly positioned to learn a software platform that assumes exactly that proficiency. Prior work on technology adoption among disabled digital novices highlights 'learnability', arguing for multi-layered interfaces that progressively reveal functionality as users gain experience [32, 32, 51, 95]. Following this principle, software platforms could offer novice BVIs a tutorial mode with guided onboarding, where simplified interfaces, audio prompts (for example, *"Press the Down Arrow to hear the next menu item"*) and proprioceptive guidance (for example, *"slide your right hand down three rows and two keys to the right"*) introduce basic concepts such as arrow keys and their use.

Additionally, our findings also highlight that BVI trainers occupy a learner role: they are hired for personal computer proficiency but lack preparation in advanced concepts and pedagogy. Inclusive education in the Global North often relies on training-of-trainers workshops [8, 175], but directly transplanting these models to India is challenging due to linguistic diversity, limited baseline AT expertise and infrastructure in schools, and weak professional incentives for teachers to specialize in accessibility [71, 161]. Building on research on AI-supported virtual simulations to support teachers' responsive teaching [214] and LLM-mediated teacher support in low-resource Indian schools [40], we advocate for EdTech that treats BVI trainers as learners with their own scaffolding needs, rather than just neutral conduits of a fixed curriculum. Instead of only delivering content to students, trainer-facing interfaces could embed stepwise guidance, for example, by letting trainers rehearse lessons with a simulated novice BVI learner and then providing targeted feedback on their explanations and demonstrations [98, 214]. Such systems could encode principles for SR and computer instruction, such as LaPlante's guidelines [93], and use them to flag lessons that skip concepts, vocabulary, or patterns, giving trainers a concrete pedagogical mirror on their own practice.

6.3.2 ***Multi-lingually Assisted Learning.*** In Section 6.2, we proposed reducing extraneous cognitive load by using cross-language analogies for technical terms. This approach supports BVI learners through their zone of proximal development, gradually building capacity to interpret the English output of SRs. However, relying solely on BVI trainers for this support is not scalable. Self-learning

EdTech can instead provide these linguistic scaffolds by leveraging multimodal large language models (MLLMs). With the ability to interpret visual screen layouts and generate linguistic explanations, MLLMs offer powerful resources for reducing learning barriers [197]. HCI research shows that such tools can simulate human-like interactions [35, 67], while linguistics scholarship advocates translanguaging, where learners fluidly draw on all their linguistic resources. A self-learning tool built on these principles could act as a bilingual coach: 'shadow-interpreting' SR output in the learner's native language with brief expansions, giving embodied bilingual instructions for keyboarding (e.g., *"Find the home row: touch the bumps on F and J"*), and offering contextualized, analogy-based explanations for software terminology.

6.3.3 ***Responsible-AI Integration.*** Deploying AI-driven learning systems, especially among marginalized disabled groups in the Global South, must confront biases in their training data, which are often collected in affluent Global North settings and shaped by normative, ableist, and ocularcentric assumptions [103, 135, 156]. Phutane et al. [134, 135] showed that LLMs in simulated Indian hiring dialogues routinely reproduced infantilizing, techno-ableist, and tokenizing portrayals of disabled candidates, especially at intersections of disability, caste, and gender. Because LLMs are trained on predominantly ocularcentric data, they often produce feedback that presumes visual access [99, 148], so a computer learning system for BVIs risks describing interfaces only in spatial terms (for example, *"click the button on the left"*) instead of semantic or structural ones (for example, *"navigate to the third child in the DOM hierarchy"*). Without explicit intervention, this can push BVI learners to 'think visually', which is cognitively inefficient and reinforces ableist interaction norms. To mitigate these harms, we advocate culturally responsive, bottom-up design with BVI students, including systematic audits for ableist language, lowered expectations, and one-size-fits-all depictions of blindness, followed by retraining or filtering before using such systems as learning scaffolds [99, 104]. Our findings also reveal a structural bias in which BVI learners are channeled into clerical roles, so developers must treat this as a property of the training environment rather than ground truth. Developers of AI-based tutoring systems must treat this as a bias in the training environment, not as a neutral ground truth to be replicated [134, 135]. If an AI tutor simply optimizes learning for existing certificates, reproduces trainers' task lists, or models 'success' as rapid execution of routine office workflows, it will inherit and entrench the same clericalization of BVI learners that we document, reinforcing a normative view of BVI workers as only suited to low-status, repetitive roles. Instead, AI tutoring systems should be deliberately designed to disrupt this pattern, for example, by scaffolding conceptual understanding alongside procedural mastery, exposing learners to a broader range of computer tasks and career paths, and valuing exploration and transfer across applications rather than rote proficiency in a single software version.

6.3.4 ***Designing for Interdependence.*** Current paradigms exploring technology design in community-focused Global South societies, such as India, advocate an interdependence framework that contrasts with Western independence-focused models where users are expected to operate technology alone [23, 74]. Interdependence, introduced by Bennett et al. [20], foregrounds relational dynamics; it (1) focuses on relations, (2) makes sense of simultaneous forms of assistance, (3) highlights the often invisible work and contributions of disabled people in co-creating access, and (4) challenges ability-based hierarchies that treat disabled people as passive recipients of help. In India, this has motivated calls to design away from forced independence toward technologies that balance autonomy with community reliance [23, 74]. Our findings highlight how, despite substantial governmental and philanthropic efforts to route resources toward making BVIs 'computer literate,' policy makers, funders, and implementers remain disconnected from learners' situated needs. This results either in forced independence, where learners are expected to master opaque SR-based systems alone, or in a narrow form of interdependence that is confined within BVI-only circles. In such configurations, knowledge circulation becomes insular, learning remains ambiguous and piecemeal, and BVIs are kept at the periphery of both technology design and mainstream education. At the same time, family, peers, and teachers are often eager to help but are locked out because SRs and other ATs function as black boxes; many participants, for instance, first encountered computers through sighted friends who *"did not know what shortcuts to use."* We argue that AT and educational technologies should treat learning as a collaborative process among BVIs, sighted peers, teachers, and AI-mediated supports. AI systems should make learning needs visible, help allies understand how to assist BVI learners, and act as shared infrastructure that connects, rather than replaces, existing human support networks.

6.4 Study Limitations

Our participant pool consisted of BVIs from a single region of India. Given the diversity across states in literacy levels, socioeconomic backgrounds, spoken languages, state education boards, and degrees of urbanization [79, 136], training curricula for BVIs may vary, and further studies are needed to validate the generalizability of our findings. Most participants in our study were either blind or had extremely low vision, excluding those with residual vision who may combine assistive technologies such as screen magnifiers and SRs. Their learning strategies and challenges may differ, and future research could examine their experiences in more depth. In addition, while our study included visually impaired trainers at the partnered organizations, we did not examine sighted teachers' instructional practices. Students briefly recounted their experiences of computer instruction in mainstream schools, but we did not study these directly. Future research should explore how sighted teachers in India impart computer literacy education to BVI students in inclusive school environments. Finally, our work focused primarily on desktop SRs, with limited attention to mobile SRs. Future studies should investigate how BVI learners engage with mobile SRs across different life stages, from early schooling to adulthood.

7 Conclusion

Considering the pivotal role of computers in enabling access and employment for BVI individuals, we examined how they learn to use computers and SRs in resource-constrained, multicultural contexts like India. Our study revealed a deep misalignment between standardized, Global North-centric technologies and inclusive computer literacy pedagogies, and the diverse linguistic realities, lived experiences, and personal goals of BVI learners in India. Specifically, we found that a rigid, visually oriented curriculum, combined with trainers lacking advanced computer knowledge and pedagogical preparation, imposed a one-size-fits-all approach on a heterogeneous group of learners. This systematically eroded their learning self-efficacy and pushed many toward alternative career paths. To address this gap, we propose culturally responsive pedagogies and smart self-learning tools that provide the contextual scaffolds necessary to improve computer learning for BVIs in India. This work contributes to inclusive computer literacy education by offering rich empirical insights into the computer learning experiences of BVIs in the Global South.

Acknowledgments

We sincerely appreciate the invaluable assistance of Arun Kumar Nayak, Aditya Vishal S, Shine C Simmy, and Sagar Nampally in data collection and setting up the user study.

References

[1] 2025. Helen Keller National Center. https://www.helenkeller.org/hknc/. Comprehensive vocational rehabilitation services for DeafBlind individuals.
[2] 2025. TEAM Program - Helen Keller Services for the Blind. https://www.helenkeller.org/hksb/team-program/. Advanced computer skills and customer service training program for blind and visually impaired job seekers.
[3] Mahmoud MS Abdallah. 2025. How Conversational AI Chatbots Support and Reinforce Self-Regulated Language Learning. *Online Submission* (2025).
[4] Ali Abdolrahmani, Ravi Kuber, and Stacy M Branham. 2018. " Siri Talks at You" An Empirical Investigation of Voice-Activated Personal Assistant (VAPA) Usage by Individuals Who Are Blind. In *Proceedings of the 20th international ACM SIGACCESS conference on computers and accessibility*. 249–258.
[5] Icek Ajzen. 1991. The theory of planned behavior. *Organizational behavior and human decision processes* 50, 2 (1991), 179–211.
[6] Rahaf Alharbi, John Tang, and Karl Henderson. 2023. Accessibility barriers, conflicts, and repairs: Understanding the experience of professionals with disabilities in hybrid meetings. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–15.
[7] Khalid A Alshamrani, Marla C Roll, Matt P Malcolm, Aryn A Taylor, and James E Graham. 2024. Assistive technology services for adults with disabilities in state-federal vocational rehabilitation programs. *Disability and Rehabilitation: Assistive Technology* 19, 4 (2024), 1382–1391.
[8] Vassilios Argyropoulos, Magda Nikolaraizi, Thomai Tsiakali, Polychronis Kountrias, Sofia-Marina Koutsogiorgou, and Aineias Martos. 2014. Collaborative action research approach promoting professional development for teachers of students with visual impairment in assistive technology. *Journal of International Special Needs Education* 17, 1 (2014), 33–43.
[9] Alfredo J Artiles. 2020. Inclusive education in the 21st century disruptive interventions. In *The Educational Forum*, Vol. 84. Taylor & Francis, 289–295.
[10] Vikas Ashok, Yury Puzis, Yevgen Borodin, and IV Ramakrishnan. 2017. Web screen reading automation assistance using semantic abstraction. In *Proceedings of the 22nd International Conference on Intelligent User Interfaces*. 407–418.
[11] Catherine M Baker, Cynthia L Bennett, and Richard E Ladner. 2019. Educational experiences of blind programmers. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*. 759–765.
[12] Catherine M Baker, Lauren R Milne, and Richard E Ladner. 2015. Structjumper: A tool to help blind programmers navigate and understand the structure of code. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*. 3043–3052.
[13] Catherine M Baker, Lauren R Milne, and Richard E Ladner. 2019. Understanding the impact of TVIs on technology use and selection by children with visual impairments. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.
[14] Jan Balata and Zdenek Mikovec. 2016. Why visually impaired people resist to adopt touchscreen smartphones in the Czech Republic?. In *2016 7th IEEE International Conference on Cognitive Infocommunications (CogInfoCom)*. IEEE, 000049–000054.
[15] Mark S Baldwin, Gillian R Hayes, Oliver L Haimson, Jennifer Mankoff, and Scott E Hudson. 2017. The tangible desktop: a multimodal approach to nonvisual computing. *ACM Transactions on Accessible Computing (TACCESS)* 10, 3 (2017), 1–28.
[16] Albert Bandura. 2001. Social cognitive theory: An agentic perspective. *Annual review of psychology* 52, 1 (2001), 1–26.
[17] Russell Beale. 2025. Dialogic Pedagogy for Large Language Models: Aligning Conversational AI with Proven Theories of Learning. *arXiv preprint arXiv:2506.19484* (2025).
[18] E Becker, J Wünsche, JM Veith, J Schrader, and P Bitzenbauer. 2025. From Cognitive Relief to Affective Engagement: An Empirical Comparison of AI Chatbots and Instructional Scaffolding in Physics Education. *arXiv preprint arXiv:2508.06254* (2025).
[19] Edward C Bell and Natalia M Mino. 2013. Blind and visually impaired adult rehabilitation and employment survey: Final results. *Journal of blindness Innovation and Research* 3, 1 (2013), 1–35.
[20] Cynthia L Bennett, Erin Brady, and Stacy M Branham. 2018. Interdependence as a frame for assistive technology research and design. In *Proceedings of the 20th international acm sigaccess conference on computers and accessibility*. 161–173.
[21] Cynthia L Bennett and Daniela K Rosner. 2019. The promise of empathy: Design, disability, and knowing the" other". In *Proceedings of the 2019 CHI conference on human factors in computing systems*. 1–13.
[22] Sue E Berryman. 1991. Designing Effective Learning Environments: Cognitive Apprenticeship Models. *IEE Brief* (1991).
[23] Tigmanshu Bhatnagar, Vikas Upadhyay, PV Madhusudhan Rao, Nicolai Marquardt, Mark Miodownik, and Catherine Holloway. 2023. Brilliance and Resilience: A New Perspective to the Challenges, Practices and Needs of University Students with Visual Impairments in India. In *IFIP Conference on Human-Computer Interaction*. Springer, 67–88.
[24] Ananya Bhattacharjee, Yuchen Zeng, Sarah Yi Xu, Dana Kulzhabayeva, Minyi Ma, Rachel Kornfield, Syed Ishtiaque Ahmed, Alex Mariakakis, Mary P Czerwinski, Anastasia Kuzminykh, et al. 2024. Understanding the role of large language models in personalizing and scaffolding strategies to combat academic procrastination. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–18.
[25] Jeffrey P Bigham, Maxwell B Aller, Jeremy T Brudvik, Jessica O Leung, Lindsay A Yazzolino, and Richard E Ladner. 2008. Inspiring blind high school students to pursue computer science with instant messaging chatbots. In *Proceedings of the 39th SIGCSE technical symposium on Computer science education*. 449–453.
[26] Jeffrey P Bigham, Anna C Cavender, Jeremy T Brudvik, Jacob O Wobbrock, and Richard E Ladner. 2007. WebinSitu: a comparative analysis of blind and sighted browsing behavior. In *Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility*. 51–58.
[27] Gwendolyn Charlene Blue. 2017. *Teachers of students with visual impairments in five North Carolina rural school districts and barriers to assistive technology implementation: An examination of their experiences and perceptions*. North Carolina State University.
[28] Virginia Braun and Victoria Clarke. 2021. Thematic analysis: a practical guide. (2021).
[29] Audun Brunes, Marianne B. Hansen, and Trond Heir. 2021. General Self–Efficacy in Individuals with Visual Impairment Compared with the General Population. *PLoS ONE* 16, 7 (2021), e0254043. doi:10.1371/journal.pone.0254043
[30] Kevin Shing-Chi Chan, Allan HK Yuen, Patcy PS Yeung, and Fay Wong. 2020. Utilising Screen Reader to Support the Transitions of Learners with Visual Impairment. *Careers for Students with Special Educational Needs: Perspectives on Development and Transitions from the Asia-Pacific Region* (2020), 283–299.
[31] Chung-Yi Chiu, Fong Chan, Malachy Bishop, Elizabeth da Silva Cardoso, and John O'Neill. 2013. State vocational rehabilitation services and employment in multiple sclerosis. *Multiple Sclerosis Journal* 19, 12 (2013), 1655–1664.
[32] Andy Cockburn, Carl Gutwin, Joey Scarr, and Sylvain Malacria. 2014. Supporting novice to expert transitions in user interfaces. *ACM Computing Surveys (CSUR)* 47, 2 (2014), 1–36.
[33] Code.org. 2025. Code.org: Free K–12 Curriculum for Computer Science and AI. https://code.org/en-US
[34] Allan Collins, John Seely Brown, Ann Holum, et al. 1991. Cognitive apprenticeship: Making thinking visible. *American educator* 15, 3 (1991), 6–11.
[35] Helen Crompton, Mildred V Jones, and Diane Burke. 2024. Affordances and challenges of artificial intelligence in K-12 education: A systematic review. *Journal of Research on Technology in Education* 56, 3 (2024), 248–268.
[36] CSforALL. 2025. CSforALL Official Website. https://csforall.org/en-US
[37] Meenakshi Das, Daniela Marghitu, Mahender Mandala, and Ayanna Howard. 2021. Accessible block-based programming for k-12 students who are blind or low vision. In *International Conference on Human-Computer Interaction*. Springer, 52–61.
[38] S. Das. 2019. An Overview on the E-governance Initiatives taken by the ... *Library Philosophy and Practice (E-Journal)* 6921 (2019). https://digitalcommons.unl.edu/libphilprac/6921/
[39] Melissa Dawe. 2006. Desperately seeking simplicity: how young adults with cognitive disabilities and their families adopt assistive technologies. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. 1143–1152.
[40] Deepak Varuvel Dennison, Bakhtawar Ahtisham, Kavyansh Chourasia, Nirmit Arora, Rahul Singh, Rene F Kizilcec, Akshay Nambi, Tanuja Ganu, and Aditya

Vashistha. 2025. Teacher-AI Collaboration for Curating and Customizing Lesson Plans in Low-Resource Schools. *arXiv preprint arXiv:2507.00456* (2025).
[41] Supriya Dey, Y Vidhya, Suprgya Bhushan, Mounika Neerukonda, and Amit Prakash. 2019. Creating an accessible technology ecosystem for learning science and math: A case of visually impaired children in Indian schools. In *Workshop on Being (more) Human in a Digitised World, Association of Information Systems–India Chapter Workshop, Kolkata*.
[42] Paramveer S Dhillon, Somayeh Molaei, Jiaqi Li, Maximilian Golub, Shaochun Zheng, and Lionel Peter Robert. 2024. Shaping human-AI collaboration: Varied scaffolding levels in co-writing with language models. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–18.
[43] Tawanna R Dillahunt and Joey Chiao-Yin Hsiao. 2020. Positive feedback and self-reflection: features to support self-efficacy among underrepresented job seekers. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.
[44] Shi Ding, Jason Brent Smith, Stephen Garrett, and Brian Magerko. 2024. Redesigning EarSketch for Inclusive CS Education: A Participatory Design Approach. In *Proceedings of the 23rd Annual ACM Interaction Design and Children Conference*. 720–724.
[45] Emma R Dodoo, Tamara Nelson-Fromm, and Mark Guzdial. 2025. The Teacher's Dilemma: Balancing Trade-Offs in Programming Education for Emergent Bilingual Students. *arXiv preprint arXiv:2506.14147* (2025).
[46] Yakhuluntu Dubazana. 2025. Equity-Driven Curriculum Design: Blended Learning for Inclusive Education in the Global South. In *Enablers, Barriers, and Challenges for Inclusive Curriculum*. IGI Global Scientific Publishing, 227–250.
[47] EmpowerTech. [n. d.]. EmpowerTech. https://www.empowertech.org/.
[48] European Agency for Special Needs and Inclusive Education. 2018. Teacher education for inclusive education – Switzerland. https://www.european-agency.org/country-information/switzerland/teacher-education-for-inclusive-education European Agency for Special Needs and Inclusive Education.
[49] European Commission. 2021. European accessibility act. https://commission.europa.eu/strategy-and-policy/policies/justice-and-fundamental-rights/disability/union-equality-strategy-rights-persons-disabilities-2021-2030/european-accessibility-act_en
[50] Isabela Figueira, Yoonha Cha, and Stacy M Branham. 2024. Intersecting Liminality: Acquiring a Smartphone as a Blind or Low Vision Older Adult. In *Proceedings of the 26th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–14.
[51] Helen Forsey, David Leahy, Bob Fields, Shailey Minocha, Simon Attfield, and Tom Snell. 2025. Designing for Learnability: Improvement Through Layered Interfaces. *Ergonomics in Design* 33, 3 (2025), 135–141.
[52] Mustafa Gazioğlu and Neslihan Karakuş. 2023. The impact of multisensory learning model-based tale-telling on listening skills and student opinions about it. In *Frontiers in Education*, Vol. 8. Frontiers Media SA, 1137042.
[53] Neveen I Ghali, Omar Soluiman, Nashwa El-Bendary, Tamer M Nassef, Sara A Ahmed, Yomna M Elbarawy, and Aboul Ella Hassanien. 2012. Virtual reality technology for blind and visual impaired people: reviews and recent advances. *Advances in Robotics and Virtual Reality* (2012), 363–385.
[54] Nicholas A Giudice. 2018. Navigating without vision: Principles of blind spatial cognition. In *Handbook of behavioral and cognitive geography*. Edward Elgar Publishing, 260–288.
[55] Evgenia Gkintoni, Hera Antonopoulou, Andrew Sortwell, and Constantinos Halkiopoulos. 2025. Challenging cognitive load theory: The role of educational neuroscience and artificial intelligence in redefining learning efficacy. *Brain Sciences* 15, 2 (2025), 203.
[56] Ricardo Gomez. 2014. When you do not have a computer: Public-access computing in developing countries. *Information Technology for Development* 20, 3 (2014), 274–291.
[57] Joseph K Gona, Charles R Newton, Sally Hartley, and Karen Bunning. 2018. Persons with disabilities as experts-by experience: using personal narratives to affect community attitudes in Kilifi, Kenya. *BMC international health and human rights* 18, 1 (2018), 18.
[58] Alex Goslen, Yeo Jin Kim, Jonathan Rowe, and James Lester. 2025. Llm-based student plan generation for adaptive scaffolding in game-based learning environments. *International journal of artificial intelligence in education* 35, 2 (2025), 533–558.
[59] Government of India. 2016. The Rights of Persons with Disabilities Act, 2016. https://www.indiacode.nic.in/bitstream/123456789/15939/1/the_rights_of_persons_with_disabilities_act,_2016.pdf.
[60] Granthaalayah - Arts Journal. 2024. Visual Disability in India: A Literature Review of Challenges and Opportunities. https://www.granthaalayahpublication.org/Arts-Journal/ShodhKosh/article/download/5768/5275/30509
[61] Laxmi Gunupudi, Maryam Bandukda, Giulia Barbareschi, Tigmanshu Bhatnagar, Aanchal Singh, Satish Mishra, Amit Prakash, and Catherine Holloway. 2024. Scaffolding Digital Literacy Through Digital Skills Training for Disabled People in the Global South. In *Proceedings of the 26th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–14.
[62] Alex Hadwen-Bennett, Sue Sentance, and Cecily Morrison. 2018. Making programming accessible to learners with visual impairments: a literature review. *International Journal of Computer Science Education in Schools* 2, 2 (2018), 3–13.
[63] Joy Hammel, Susan Magasi, Allen Heinemann, David B Gray, Susan Stark, Pamela Kisala, Noelle E Carlozzi, David Tulsky, Sofia F Garcia, and Elizabeth A Hahn. 2015. Environmental barriers and supports to everyday participation: A qualitative insider perspective from people with disabilities. *Archives of physical medicine and rehabilitation* 96, 4 (2015), 578–588.
[64] Aditya T Hernowo, Doety Prins, Heidi A Baseler, Tina Plank, Andre D Gouws, Johanna MM Hooymans, Antony B Morland, Mark W Greenlee, and Frans W Cornelissen. 2014. Morphometric analyses of the visual pathways in macular degeneration. *Cortex* 56 (2014), 99–110.
[65] Siw Elisabeth Hove and Bente Anda. 2005. Experiences from conducting semi-structured interviews in empirical software engineering research. In *11th IEEE International Software Metrics Symposium (METRICS'05)*. IEEE, 10–pp.
[66] HT Correspondent. 2017. Number of blind to come down by 4m as India set to change blindness definition. *Hindustan Times* (2017). https://www.hindustantimes.com/india-news/india-to-change-definition-of-blindness-reduce-number-of-blind-by-4-million/story-HxHKeH3XpfPBEtSr2moerO.html
[67] Runke Huang, Yanan Bao, Yinkuo Wang, and Jiameng Wei. 2024. Exploring AI Tools in Early Childhood Education: Usage Patterns, Functions, and Developmental Outcomes. (2024).
[68] Earl W Huff Jr. 2022. Designing and Evaluating Accessible E-Learning for Students with Visual Impairments in K-12 Computing Education. (2022).
[69] Earl W Huff Jr, Kwajo Boateng, Makayla Moster, Paige Rodeghero, and Julian Brinkley. 2021. Exploring the perspectives of teachers of the visually impaired regarding accessible k12 computing education. In *Proceedings of the 52nd acm technical symposium on computer science education*. 156–162.
[70] HumanWare. [n. d.]. Victor Reader Stream — Handheld Media Player. https://store.humanware.com/hus/victor-reader-stream-handheld-media-player.html.
[71] Matthew Hunt, Ramasubramanian Ponnusamy, Anik Goulet, Chamila Anthonypillai, Sankar Sahayaraj Muthukaruppan, Aravind Bharathwaj, Aliki Thomas, Philippe S Archambault, Crystal Garnett, Caroline Storr, et al. 2021. An integrated knowledge translation project to develop, implement, and evaluate a train-the-trainer program at a community rehabilitation program in Tamil Nadu, India. *Disability and Rehabilitation* 43, 26 (2021), 3868–3877.
[72] Gesu India, Aishwarya O, Nirmalendu Diwakar, Mohit Jain, Aditya Vashistha, and Manohar Swaminathan. 2021. Teachers' perceptions around digital games for children in low-resource schools for the blind. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–17.
[73] Gesu India, Geetha Ramakrishna, Joyojeet Pal, and Manohar Swaminathan. 2020. Conceptual learning through accessible play: Project Torino and computational thinking for blind children in India. In *Proceedings of the 2020 international conference on information and communication technologies and development*. 1–11.
[74] Gesu India, Simon Robinson, Jennifer Pearson, Cecily Morrison, and Matt Jones. 2025. Exploring the Experiences of Individuals Who are Blind or Low-Vision Using Object-Recognition Technologies in India. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*. 1–11.
[75] Shari L Jackson, Joseph Krajcik, and Elliot Soloway. 1998. The design of guided learner-adaptable scaffolding in interactive learning environments. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 187–194.
[76] K Jafar, Kripa Ananthpur, and L Venkatachalam. 2023. Digital divide and access to online education: new evidence from Tamil Nadu, India. *Journal of Social and Economic Development* 25, 2 (2023), 313–333.
[77] Mohit Jain, Nirmalendu Diwakar, and Manohar Swaminathan. 2021. Smartphone usage by expert blind users. In *Proceedings of the 2021 CHI conference on human factors in computing systems*. 1–15.
[78] James A Jaramillo. 1996. Vygotsky's sociocultural theory and contributions to the development of constructivist curricula. *Education* 117, 1 (1996), 133–141.
[79] Niraja Jayal. 2006. *Representing India: Ethnic diversity and the governance of public institutions*. Springer.
[80] Vaishnav Kameswaran. 2024. *Help Facilitates Accessibility: Understanding the Social and Technology-mediated Experiences of People with Visual Impairments in India*. Ph. D. Dissertation.
[81] Vaishnav Kameswaran and Megh Marathe. 2023. Advocacy as Access Work: How People with Visual Impairments Gain Access to Digital Banking in India. *Proceedings of the ACM on Human-Computer Interaction* 7, CSCW1 (2023), 1–23.
[82] Shaun K Kane and Jeffrey P Bigham. 2014. Tracking@ stemxcomet: teaching programming to blind students via 3D printing, crisis management, and twitter. In *Proceedings of the 45th ACM technical symposium on Computer science education*. 247–252.
[83] Amy J Kesterton, John Cleland, Andy Sloggett, and Carine Ronsmans. 2010. Institutional delivery in rural India: the relative importance of accessibility and economic status. *BMC pregnancy and childbirth* 10, 1 (2010), 30.

[84] Kalpana Kharade and Hema Peese. 2012. Learning by E-learning for visually impaired students: Opportunities or again marginalisation? *E-learning and Digital Media* 9, 4 (2012), 439–448.

[85] Hyung Nam Kim. 2021. Characteristics of technology adoption by older adults with visual disabilities. *International Journal of Human–Computer Interaction* 37, 13 (2021), 1256–1268.

[86] Akshay Nayak Kolgar, Yash Prakash, Sampath Jayarathna, Hae-Na Lee, and Vikas Ashok. 2025. Insights in Adaptation: Examining Self-reflection Strategies of Job Seekers with Visual Impairments in India. *arXiv preprint arXiv:2506.22741* (2025).

[87] Julian Kreimeier, Pascal Karg, and Timo Götzelmann. 2020. BlindWalkVR: formative insights into blind and visually impaired people's VR locomotion using commercially available approaches. In *Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments*. 1–8.

[88] Mukta Kulkarni. 2019. Digital accessibility: Challenges and opportunities. *IIMB Management Review* 31, 1 (2019), 91–98.

[89] Arjun Kumar, Priya Sharma, Ravi Patel, Ananya Gupta, and Vikram Singh. 2024. Educational Inequality and Its Impact on Social and Economic Opportunities in Rural India. *International Journal of Humanities, Management and Social Science (IJ-HuMaSS)* 7, 2 (2024), 87–96.

[90] Pawan Kumar and Sunil Kumar. 2022. ICT and employment in India: An analysis of organized sector. *The Indian Journal of Labour Economics* 65, 2 (2022), 373–395.

[91] Richard E Ladner and Andreas Stefik. 2017. AccessCSforall: making computer science accessible to K-12 students in the United States. *ACM SIGACCESS Accessibility and Computing* 118 (2017), 3–8.

[92] Gloria Ladson-Billings. 2021. *Culturally relevant pedagogy: Asking a different question*. Teachers College Press.

[93] Cody M. LaPlante. 2023. Introduction to Screen Reader Instruction. https://www.pathstoliteracy.org/resource/introduction-screen-reader-instruction/

[94] Jean Lave and Etienne Wenger. 1991. *Situated learning: Legitimate peripheral participation*. Cambridge university press.

[95] Chien-Sing Lee and John H Hughes. 2019. Refocusing on cognitive load design through a meta-analysis on learnability, goal-based intentions and extensibility: towards personalized cognitive-social-affective engagement among seniors. In *Advancing Technology Industrialization Through Intelligent Software Methodologies, Tools and Techniques*. IOS Press, 456–469.

[96] Franklin Mingzhe Li, Michael Xieyang Liu, Shaun K Kane, and Patrick Carrington. 2024. A Contextual Inquiry of People with Vision Impairments in Cooking. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*. 1–14.

[97] Haoyang Li, Xing Fan, and Jing Liang. 2025. The squirrel AI adaptive learning system accompanying millions of children in their growth. In *Digital transformation of regional education in China*. Springer, 51–53.

[98] Mingfeng Li, Changfan Pan, Wanlu Zhang, Jianxia Ling, Jiewen Sun, Xin Liu, Qingyu Niu, and Jia Zhu. 2025. Enhancing pre-service teachers training with AI-simulated students: providing realistic classroom experiences without impacting real learners. *Interactive Learning Environments* (2025), 1–18.

[99] Rong Li, Ashwini Kamaraj, Jing Ma, and Sarah Ebling. 2024. Decoding ableism in large language models: An intersectional approach. In *Proceedings of the Third Workshop on NLP for Positive Impact*. 232–249.

[100] Mariona Llopart and Moisès Esteban-Guitart. 2018. Funds of knowledge in 21st century societies: Inclusive educational practices for under-represented students. A literature review. *Journal of curriculum studies* 50, 2 (2018), 145–161.

[101] Kathryn Locke, Leanne McRae, Gwyneth Peaty, Katie Ellis, and Mike Kent. 2022. Developing accessible technologies for a changing world: understanding how people with vision impairment use smartphones. *Disability & society* 37, 1 (2022), 111–128.

[102] Kelly Mack, Emma J McDonnell, Leah Findlater, and Heather D Evans. 2022. Chronically under-addressed: Considerations for HCI accessibility practice with chronically ill people. In *Proceedings of the 24th international ACM SIGACCESS conference on computers and accessibility*. 1–15.

[103] Jennifer Mankoff, Devva Kasnitz, L Jean Camp, Jonathan Lazar, and Harry Hochheiser. 2024. AI Must Be Anti-Ableist and Accessible. *Commun. ACM* 67, 12 (2024), 40–42.

[104] Marta Marchiori Manerba. 2025. Fairness Auditing, Explanation and Debiasing in Linguistic Data and Language Models. (2025).

[105] Ted McCarthy, Joyojeet Pal, and Edward Cutrell. 2013. The "voice" has it: screen reader adoption and switching behavior among vision impaired persons in India. *Assistive Technology* 25, 4 (2013), 222–229.

[106] Ted McCarthy, Joyojeet Pal, Tanvi Marballi, and Edward Cutrell. 2012. An analysis of screen reader use in India. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*. 149–158.

[107] Sean Mealin and Emerson Murphy-Hill. 2012. An exploratory study of blind software developers. In *2012 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*. IEEE, 71–74.

[108] Gonzalo Mendez, Xavier Ochoa, Katherine Chiluiza, and Bram De Wever. 2014. Curricular design analysis: A data-driven perspective. *Journal of Learning Analytics* 1, 3 (2014), 84–119.

[109] Lauren R Milne and Richard E Ladner. 2018. Blocks4All: overcoming accessibility barriers to blocks programming for children with visual impairments. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–10.

[110] Ministry of Electronics and Information Technology, Government of India. 2025. Digital India. https://www.digitalindia.gov.in/

[111] Ministry of Skill Development and Entrepreneurship, Government of India. 2024. Skill India Digital Hub. https://www.skillindiadigital.gov.in/home

[112] Ashutosh Mishra, Anamika Mishra, and Govind Pandey. 2023. Spatial inequality and education: unraveling the geographical dimensions of educational disparities. (2023).

[113] Jessica Morales-Chicas, Mauricio Castillo, Ireri Bernal, Paloma Ramos, and Bianca L Guzman. 2019. Computing with relevance and purpose: A review of culturally relevant education in computing. *International Journal of Multicultural Education* 21, 1 (2019), 125–155.

[114] Cecily Morrison, Edward Cutrell, Martin Grayson, Elisabeth RB Becker, Vasiliki Kladouchou, Linda Pring, Katherine Jones, Rita Faia Marques, Camilla Longden, and Abigail Sellen. 2021. Enabling meaningful use of AI-infused educational technologies for children with blindness: Learnings from the development and piloting of the PeopleLens curriculum. In *Proceedings of the 23rd International ACM SIGACCESS Conference on Computers and Accessibility*. 1–13.

[115] Cecily Morrison, Nicolas Villar, Alex Hadwen-Bennett, Tim Regan, Daniel Cletheroe, Anja Thieme, and Sue Sentance. 2021. Physical programming for blind and low vision children at scale. *Human–Computer Interaction* 36, 5-6 (2021), 535–569.

[116] Aboubakar Mountapmbeme, Obianuju Okafor, and Stephanie Ludi. 2022. Accessible blockly: An accessible block-based programming library for people with visual impairments. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–15.

[117] National Association for the Blind, India. 2024. National Association for the Blind, India. https://nabindia.org.in/

[118] Carmen del Rosario Navas-Bonilla, Julio Andrés Guerra-Arango, Daniel Alejandro Oviedo-Guado, and Daniel Eduardo Murillo-Noriega. 2025. Inclusive education through technology: a systematic review of types, tools and characteristics. In *Frontiers in Education*, Vol. 10. Frontiers Media SA, 1527851.

[119] Jyothi Neeli, MK Pushpanjali, Ayushman Shivam, Raja Anand, Romsha Sengar, et al. 2023. Wingman-Virtual Assistant for Visually Impaired. In *2023 IEEE 3rd Mysore Sub Section International Conference (MysuruCon)*. IEEE, 1–6.

[120] Michael Nickl, Daniel Sommerhoff, Anika Radkowitsch, Sina A Huber, Elisabeth Bauer, Stefan Ufer, Jan L Plass, and Tina Seidel. 2024. Effects of real-time adaptivity of scaffolding: Supporting pre-service mathematics teachers' assessment skills in simulations. *Learning and Instruction* 94 (2024), 101994.

[121] Royal National Institute of Blind People. [n. d.]. RNIB – Royal National Institute of Blind People. https://www.rnib.org.uk/.

[122] Washington State Department of Services for the Blind. [n. d.]. Washington State Department of Services for the Blind. https://www.wsblind.org/.

[123] Patrick Emeka Okonji. 2018. Use of computer assistive technologies by older people with sight impairment: Perceived state of access and considerations for adoption. *British Journal of Visual Impairment* 36, 2 (2018), 128–142.

[124] Patrick Emeka Okonji and Darlinton Chukwunalu Ogwezzy. 2019. Awareness and barriers to adoption of assistive technologies among visually impaired people in Nigeria. *Assistive Technology* 31, 4 (2019), 209–219.

[125] Juliana Damasio Oliveira and Rafael H Bordini. 2019. A survey on the needs of visually impaired users and requirements for a virtual assistant in ambient assisted living. In *16th International Conference on Information Technology-New Generations (ITNG 2019)*. Springer, 449–453.

[126] Joyojeet Pal and Meera Lakshmanan. 2012. Assistive technology and the employment of people with vision impairments in India. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*. 307–317.

[127] Hariprasath Palani, Uro Giudice, and Nicholas A Giudice. 2016. Evaluation of non-visual zooming operations on touchscreen devices. In *International Conference on Universal Access in Human-Computer Interaction*. Springer, 162–174.

[128] Maulishree Pandey. 2023. *Accessibility of Collaborative Programming for Blind and Visually Impaired Developers*. Ph. D. Dissertation.

[129] Carolyn Pang, Zhiqin Collin Wang, Joanna McGrenere, Rock Leung, Jiamin Dai, and Karyn Moffatt. 2021. Technology adoption and learning preferences for older adults: evolving perceptions, ongoing challenges, and emerging design opportunities. In *Proceedings of the 2021 CHI conference on human factors in computing systems*. 1–13.

[130] Parliament of India. 2016. The Rights of Persons with Disabilities Act, 2016. https://www.indiacode.nic.in/bitstream/123456789/15939/1/the_rights_of_persons_with_disabilities_act%2C_2016.pdf

[131] PD Parthasarathy and Swaroop Joshi. 2024. Teaching Digital Accessibility in Computing Education: Views of Educators in India. In *Proceedings of the 2024 ACM Conference on International Computing Education Research-Volume 1*. 222–232.
[132] William Payne. 2022. Sounds and (Braille) cells: co-designing music technology with blind and visually impaired musicians. In *Proceedings of the 19th International Web for All Conference*. 1–3.
[133] Jamie Payton, Tiffany Barnes, Kim Buch, Audrey Rorrer, Huifang Zuo, Kinnis Gosha, Kristine Nagel, Nannette Napier, Ebrahim Randeree, and Lawrence Dennis. 2016. Stars computing corps: Enhancing engagement of underrepresented students and building community in computing. *Computing in Science & Engineering* 18, 3 (2016), 44–57.
[134] Mahika Phutane, Hayoung Jung, Matthew Kim, Tanushree Mitra, and Aditya Vashistha. 2025. ABLEIST: Intersectional Disability Bias in LLM-Generated Hiring Scenarios. *arXiv preprint arXiv:2510.10998* (2025).
[135] Mahika Phutane and Aditya Vashistha. 2025. Disability Across Cultures: A Human-Centered Audit of Ableism in Western and Indic LLMs. In *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society*, Vol. 8. 2000–2014.
[136] Prabhu Pingali and Anaka Aiyar. 2018. Diversity in Development: Inter-state Differences in the India Growth Story. *World Food Policy* 4, 2 (2018), 57–77.
[137] Roshni Poddar, Tarini Naik, Manikanteswar Punnam, Kavyansh Chourasia, Rajeswari Pandurangan, Rajesh S Paali, Nagarathna R Bhat, Bhagyashree Biradar, Venkatesh Deshpande, Devidatta Ghosh, et al. 2024. Experiences from Running a Voice-Based Education Platform for Children and Teachers with Visual Impairments. *ACM Journal on Computing and Sustainable Societies* 2, 3 (2024), 1–35.
[138] Yash Prakash, Pathan Aseef Khan, Akshay Kolgar Nayak, Sampath Jayarathna, Hae-Na Lee, and Vikas Ashok. 2024. Towards Enhancing Low Vision Usability of Data Charts on Smartphones. *IEEE Transactions on Visualization and Computer Graphics* (2024).
[139] Yash Prakash, Akshay Kolgar Nayak, Mohan Sunkara, Sampath Jayarathna, Hae-Na Lee, and Vikas Ashok. 2024. All in One Place: Ensuring Usable Access to Online Shopping Items for Blind Users. *Proceedings of the ACM on Human-Computer Interaction* 8, EICS (2024), 1–25.
[140] Yash Prakash, Mohan Sunkara, Hae-Na Lee, Sampath Jayarathna, and Vikas Ashok. 2023. AutoDesc: Facilitating Convenient Perusal of Web Data Items for Blind Users. In *Proceedings of the 28th International Conference on Intelligent User Interfaces*. 32–45.
[141] E. Prema. 2021. *India's visually impaired face several hurdles in race for jobs*. https://mediaindia.eu/society/visually-impaired-jobs/
[142] Pune Blind School. 2025. Top 10 NGOs for Blind in India. https://www.puneblindschool.org/top-ngos-for-blind-in-india/ Accessed: 2025-09-08.
[143] Debyani Mukherjee Rawal. 2024. Mapping of school teachers' digital competency in the context of digital infrastructure: a systematic review and empirical study of India. *Journal of Professional Capital and Community* 9, 3 (2024), 173–195.
[144] Rehabilitation Council of India. 2023. Diploma in Computer Education & Assistive Technology (Visual Impairment) - 2023. https://rehabcouncil.nic.in/sites/default/files/DCE_AT_VI_2023.pdf
[145] Grant Revell, Frank Smith, and Katherine Inge. 2009. Report: An analysis of self-employment outcomes within the Federal/State Vocational Rehabilitation System. *Journal of Vocational Rehabilitation* 31, 1 (2009), 11–18.
[146] Jacquie Ripat and Roberta Woodgate. 2011. The intersection of culture, disability and assistive technology. *Disability and Rehabilitation: Assistive Technology* 6, 2 (2011), 87–96.
[147] Giuseppe Riva. 2025. The Architecture of Cognitive Amplification: Enhanced Cognitive Scaffolding as a Resolution to the Comfort-Growth Paradox in Human-AI Cognitive Integration. *arXiv preprint arXiv:2507.19483* (2025).
[148] Naba Rizvi, Harper Strickland, Saleha Ahmedi, Aekta Kallepalli, Isha Khirwadkar, William Wu, Imani NS Munyaka, and Nedjma Ousidhoum. 2025. Beyond Keywords: Evaluating Large Language Model Classification of Nuanced Ableism. *arXiv preprint arXiv:2505.20500* (2025).
[149] André Rodrigues, Kyle Montague, Hugo Nicolau, and Tiago Guerreiro. 2015. Getting smartphones to talkback: Understanding the smartphone adoption process of blind users. In *Proceedings of the 17th international acm sigaccess conference on computers & accessibility*. 23–32.
[150] David Rose. 2000. Universal design for learning. *Journal of Special Education Technology* 15, 4 (2000), 47–51.
[151] Royal National Institute of Blind People. [n. d.]. Curriculum Framework for Children and Young People with Vision Impairment (CFVI). https://www.rnib.org.uk/professionals/education-professionals/cfvi/.
[152] Rami Saarinen, Janne Järvi, Roope Raisamo, Eva Tuominen, Marjatta Kangassalo, Kari Peltola, and Jouni Salo. 2006. Supporting visually impaired children with software agents in a multimodal learning environment. *Virtual Reality* 9, 2 (2006), 108–117.
[153] Abir Saha, Darren Gergle, and Anne Marie Piper. 2023. Understanding peer-to-peer instructional support in an online community for blind audio producers. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–15.
[154] Johnny Saldaña. 2021. The coding manual for qualitative researchers. (2021).
[155] Ron Salden, Vincent Aleven, Rolf Schwonke, and Alexander Renkl. 2008. Are worked examples and tutored problem solving synergistic forms of support?. In *Proceedings of the 8th international conference on International conference for the learning sciences-Volume 3*. 119–120.
[156] Nithya Sambasivan. 2021. Seeing like a dataset from the global south. *Interactions* 28, 4 (2021), 76–78.
[157] Sergio Álvarez Sánchez, Laura Delgado Martín, Miguel Ángel Gimeno-González, Teresa Martín-Garcia, Fernando Almaraz-Menéndez, and Camilo Ruiz. 2016. Augmented reality sandbox: A platform for educative experiences. In *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality*. 599–602.
[158] Shruti Sannon and Dan Cosley. 2022. Toward a more inclusive gig economy: Risks and opportunities for workers with disabilities. *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW2 (2022), 1–31.
[159] Sarah Scott and Annemarie Palincsar. 2013. Sociocultural theory.
[160] Karim Sehaba, Benoît Encelle, and Alain Mille. 2009. Adaptive TEL based on interaction traces. In *AIED 2009: 14 th International Conference on Artificial Intelligence in Education Workshops Proceedings*. 33.
[161] Suraj Singh Senjam, Allen Foster, and Covadonga Bascaran. 2022. Assistive technology for visual impairment and trainers at schools for the blind in Delhi. *Assistive Technology* 34, 4 (2022), 418–422.
[162] Suraj Singh Senjam, Souvik Manna, Praveen Vashist, Vivek Gupta, Sumit Grover, Vikas Ajeet Kumar, and Jeewan Singh Titiyal. 2023. Improving assistive technology access to students with low vision and blindness in Delhi: A school-based model. *Indian Journal of Ophthalmology* 71, 1 (2023), 257–262.
[163] Suraj Singh Senjam and Susan A Primo. 2022. Challenges and enablers for smartphone use by persons with vision loss during the COVID-19 pandemic: A report of two case studies. *Frontiers in Public Health* 10 (2022), 912460.
[164] Muhamad Ario Setiawan and Zaitun Qamariah. 2023. A Practical Guide in Designing Curriculum for Diverse Learners. *PUSTAKA: Jurnal Bahasa Dan Pendidikan* 3, 3 (2023), 260–275.
[165] Karim Shabani, Mohamad Khatib, and Saman Ebadi. 2010. Vygotsky's zone of proximal development: Instructional implications and teachers' professional development. *English language teaching* 3, 4 (2010), 237–248.
[166] Tom Shakespeare. 2006. The social model of disability. In *The disability studies reader*. Routledge, 16–24.
[167] Priya Sharma and Michael J Hannafin. 2007. Scaffolding in technology-enhanced learning environments. *Interactive learning environments* 15, 1 (2007), 27–46.
[168] Fact Sheet. [n. d.]. Visual impairment and blindness. ([n. d.]).
[169] Kristen Shinohara and Josh Tenenberg. 2007. Observing Sara: a case study of a blind person's interactions with technology. In *Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility*. 171–178.
[170] Kristen Shinohara and Jacob O Wobbrock. 2016. Self-conscious or self-confident? A diary study conceptualizing the social accessibility of assistive technology. *ACM Transactions on Accessible Computing (TACCESS)* 8, 2 (2016), 1–31.
[171] Sightsavers India. 2023. Learning Assessment of Children with Visual Impairment and Knowledge Attitude and Practices of Teachers Under Sambalam Project. https://www.sightsaversindia.org/wp-content/uploads/2023/10/LA-KAP-Report-Sightsavers-Final.pdf
[172] Derrick W Smith and Pat Kelley. 2007. A survey of assistive technology and teacher preparation programs for individuals with visual impairments. *Journal of Visual Impairment & Blindness* 101, 7 (2007), 429–433.
[173] Robert A Sottilare, Arthur Graesser, Xiangen Hu, and Heather Holden. 2013. *Design recommendations for intelligent tutoring systems: Volume 1-learner modeling*. Vol. 1. US Army Research Laboratory.
[174] Andreas Stefik and Richard Ladner. 2017. The quorum programming language. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*. 641–641.
[175] Andreas Stefik, Richard E Ladner, William Allee, and Sean Mealin. 2019. Computer science principles for teachers of blind and visually impaired students. In *Proceedings of the 50th ACM technical symposium on computer science education*. 766–772.
[176] Andreas Stefik, Susanna Siebert, Kim Slattery, and Melissa Stefik. 2011. Toward intuitive programming languages. In *2011 IEEE 19th International Conference on Program Comprehension*. IEEE, 213–214.
[177] Andreas M Stefik, Christopher Hundhausen, and Derrick Smith. 2011. On the design of an educational infrastructure for the blind and visually impaired in computer science. In *Proceedings of the 42nd ACM technical symposium on Computer science education*. 571–576.
[178] Mohan Sunkara, Akshay Kolgar Nayak, Sandeep Kalari, Satwik Ram Kodandaram, Sampath Jayarathna, Hae-Na Lee, and Vikas Ashok. 2024. Assessing the Accessibility and Usability of Web Archives for Blind Users. In *International Conference on Theory and Practice of Digital Libraries*. Springer, 203–221.
[179] John Sweller and Paul Chandler. 1991. Evidence for cognitive load theory. *Cognition and instruction* 8, 4 (1991), 351–362.

[180] Sarit Felicia Anais Szpiro, Shafeka Hashash, Yuhang Zhao, and Shiri Azenkot. 2016. How people with low vision access computing devices: Understanding challenges and opportunities. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility*. 171–180.

[181] Xiaohang Tang, Sam Wong, Marcus Huynh, Zicheng He, Yalong Yang, and Yan Chen. 2025. SPHERE: Supporting Personalized Feedback at Scale in Programming Classrooms with Structured Review of Generative AI Outputs. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. 1–17.

[182] Mohammadreza Tavakoli, Abdolali Faraji, Mohammadreza Molavi, Stefan T. Mol, and Gábor Kismihók. 2022. Hybrid human-AI curriculum development for personalised informal learning environments. In *LAK22: 12th International Learning Analytics and Knowledge Conference*. 563–569.

[183] Inc. The Lighthouse for the Blind. [n. d.]. The Lighthouse for the Blind, Inc. https://lhblind.org/.

[184] Yong-Joon Thoo, Maximiliano Jeanneret Medina, Jon E Froehlich, Nicolas Ruffieux, and Denis Lalanne. 2023. A large-scale mixed-methods analysis of blind and low-vision research in ACM and IEEE. In *Proceedings of the 25th international ACM SIGACCESS conference on computers and accessibility*. 1–20.

[185] Stella Timotheou, Ourania Miliou, Yiannis Dimitriadis, Sara Villagrá Sobrino, Nikoleta Giannoutsou, Romina Cachia, Alejandra Martínez Monés, and Andri Ioannou. 2023. Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and information technologies* 28, 6 (2023), 6695–6726.

[186] United Nations Department of Economic and Social Affairs. [n. d.]. Convention on the Rights of Persons with Disabilities (CRPD). https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd.

[187] U.S. Department of Education. [n. d.]. Section 504 — Laws & Policy. https://www.ed.gov/laws-and-policy/individuals-disabilities/section-504.

[188] U.S. Department of Justice Civil Rights Division. 2024. Americans with Disabilities Act. https://www.ada.gov/

[189] Mojtaba Vaismoradi, Jacqueline Jones, Hannele Turunen, and Sherrill Snelgrove. 2016. Theme development in qualitative content analysis and thematic analysis. (2016).

[190] Aditya Vashistha and Richard Anderson. 2016. Technology use and non-use by low-income blind people in India. *ACM SIGACCESS Accessibility and Computing* 116 (2016), 10–21.

[191] Aditya Vashistha, Edward Cutrell, Nicola Dell, and Richard Anderson. 2015. Social media platforms for low-income blind people in India. In *Proceedings of the 17th International ACM SIGACCESS conference on computers & accessibility*. 259–272.

[192] Aditya Vashistha, Pooja Sethi, and Richard Anderson. 2018. BSpeak: An accessible voice-based crowdsourcing marketplace for low-income blind people. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–13.

[193] Riti Verma, Ingmar Weber, and Vikram Kamath Cannanure. 2025. Exploring AI in Education: Child-Computer Interaction in the Global South. *ACM Journal on Computing and Sustainable Societies* (2025).

[194] Vision-Aid. 2024. Project Springboard. https://visionaid.org/project-springboard/

[195] Violeta Voykinska, Shiri Azenkot, Shaomei Wu, and Gilly Leshed. 2016. How blind people interact with visual content on social networking services. In *Proceedings of the 19th acm conference on computer-supported cooperative work & social computing*. 1584–1595.

[196] Alexandra Vtyurina, Adam Fourney, Meredith Ringel Morris, Leah Findlater, and Ryen W White. 2019. Bridging screen readers and voice assistants for enhanced eyes-free web search. In *The world wide web conference*. 3590–3594.

[197] Shen Wang, Tianlong Xu, Hang Li, Chaoli Zhang, Joleen Liang, Jiliang Tang, Philip S Yu, and Qingsong Wen. 2024. Large language models for education: A survey and outlook. *arXiv preprint arXiv:2403.18105* (2024).

[198] Xinyu Jessica Wang, Christine P Lee, and Bilge Mutlu. 2025. LearnMate: Enhancing Online Education with LLM-Powered Personalized Learning Plans and Support. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. 1–10.

[199] Nathaniel Weinman, Armando Fox, and Marti A Hearst. 2021. Improving instruction of programming patterns with faded parsons problems. In *Proceedings of the 2021 chi conference on human factors in computing systems*. 1–4.

[200] Carmen Willings. 2025. Professional Preparation Programs for the Visual Impairment Field. https://www.teachingvisuallyimpaired.com/professional-preparation-programs.html teachingvisuallyimpaired.com.

[201] Rainer Winkler, Sebastian Hobert, Antti Salovaara, Matthias Söllner, and Jan Marco Leimeister. 2020. Sara, the lecturer: Improving learning in online education with a scaffolding-based conversational agent. In *Proceedings of the 2020 CHI conference on human factors in computing systems*. 1–14.

[202] R Michael Winters, E Lynne Harden, and Emily B Moore. 2020. Co-designing accessible science education simulations with blind and visually-impaired teens. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*. 1–4.

[203] David Wood, Jerome S Bruner, and Gail Ross. 1976. The role of tutoring in problem solving. *Journal of child psychology and psychiatry* 17, 2 (1976), 89–100.

[204] Iris Xie, Rakesh Babu, Tae Hee Lee, Shengang Wang, and Hyun Seung Lee. 2021. Coping tactics of blind and visually impaired users: Responding to help-seeking situations in the digital library environment. *Information Processing & Management* 58, 5 (2021), 102612.

[205] Iris Xie, Wonchan Choi, Shengang Wang, Hyun Seung Lee, Bo Hyun Hong, Ning-Chiao Wang, and Emmanuel Kwame Cudjoe. 2024. Help-Seeking Situations Related to Visual Interactions on Mobile Platforms and Recommended Designs for Blind and Visually Impaired Users. *Journal of Imaging* 10, 8 (2024), 205.

[206] Shuchang Xu, Xiaofu Jin, Huamin Qu, and Yukang Yan. 2025. DanmuA11y: Making Time-Synced On-Screen Video Comments (Danmu) Accessible to Blind and Low Vision Users via Multi-Viewer Audio Discussions. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*. 1–22.

[207] Crystal Yang and Paul Taele. 2025. AI for Accessible Education: Personalized Audio-Based Learning for Blind Students. *arXiv preprint arXiv:2504.17117* (2025).

[208] Kexin Yang, Junyi Wu, Haokun Xin, and Jiangtao Gong. 2024. " I see it as a wellspring for my positive and upward journey in life.": Understanding Current Practices of Assistive Technology's Customized Modification in China. *Proceedings of the ACM on Human-Computer Interaction* 8, CSCW2 (2024), 1–42.

[209] Matin Yarmand, Chen Chen, Kexin Cheng, James Murphy, and Nadir Weibel. 2024. " I'd be watching him contour till 10 o'clock at night": Understanding Tensions between Teaching Methods and Learning Needs in Healthcare Apprenticeship. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. 1–19.

[210] Aitkul Yersultanova, Nursaule Karelkhan, and Pavol Jurik. 2022. PROJECT-ORIENTED COMPUTER SCIENCE TEACHING IN INCLUSIVE EDUCATION. *REVIEWED PROCEEDINGS* (2022), 161.

[211] Dongsong Zhang, Lina Zhou, Judith O Uchidiuno, and Isil Y Kilic. 2017. Personalized assistive web for improving mobile web browsing and accessibility for visually impaired users. *ACM Transactions on Accessible Computing (TACCESS)* 10, 2 (2017), 1–22.

[212] Lotus Zhang. 2024. Designing accessible content creation support with blind and low vision creators. *ACM SIGACCESS Accessibility and Computing* 137 (2024), 1–1.

[213] Lotus Zhang, Simon Sun, and Leah Findlater. 2023. Understanding Digital Content Creation Needs of Blind and Low Vision People. In *Proceedings of the 25th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–15.

[214] Nuodi Zhang, Fengfeng Ke, Chih-Pu Dai, Sherry A Southerland, and Xin Yuan. 2025. Seeking to support preservice teachers' responsive teaching: Leveraging artificial intelligence-supported virtual simulation. *British Journal of Educational Technology* 56, 3 (2025), 1148–1169.

[215] Li Zhou, Paul M Ajuwon, Derrick W Smith, Nora Griffin-Shirley, Amy T Parker, and Phoebe Okungu. 2012. Assistive technology competencies for teachers of students with visual impairments: A national study. *Journal of Visual Impairment & Blindness* 106, 10 (2012), 656–665.

[216] Kathryn Zyskowski, Meredith Ringel Morris, Jeffrey P Bigham, Mary L Gray, and Shaun K Kane. 2015. Accessible crowdwork? Understanding the value in and challenge of microtask employment for people with disabilities. In *Proceedings of the 18th ACM conference on computer supported cooperative work & social computing*. 1682–1693.