Understanding Experiences, Attitudes and Perspectives towards Designing Interactive Creative Tools for Teachers of Visually Impaired Students

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ABSTRACT

Many academic subjects are inaccessible for students who are blind or have low vision (BLV) due to the prevalence of visual aids to represent concepts. Interactive devices offer promise as creative tools for teachers of the visually impaired (TVIs) as they can support real-time iteration of adapted learning materials, display changing information, and provide embodied learning experiences for BLV students. We conducted semi-structured interviews with 5 educators (all have TVI experience) and identified their considerations when creating adaptations, attitudes towards technology, and perspectives on existing barriers to access. Our findings reveal and reaffirm unresolved challenges in the adaptation process as well as offer insights into key factors that must be considered when selecting the type of adaptation. From these findings, we formulate design recommendations for interactive tools that support TVIs in creating effective adaptations for BLV students.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in accessibility**.

KEYWORDS

Accessibility, visual impairments, interactive creative tools for education

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1 INTRODUCTION AND RELATED WORK

In many academic subjects, learning materials are often inaccessible to students who are blind or have low vision (BLV) due to the prevalence of visual aids to represent concepts [6]. For example, in STEM subjects like biology, mathematics, and chemistry, teachers will often use visual representations of human anatomy, graphs and charts, or images of the structure of an atom as instructional tools [31]. Teachers of the visually impaired (TVIs) are responsible for adapting learning materials so that they are accessible to BLV students. They use a variety of materials and techniques to adapt visual learning materials. Common methods include using tactile materials, such as tactile graphics, 3D models, and real world objects [28, 32]. While these adaptations offer several benefits, including being readily accessible and affordable, many are static and cannot display dynamic information.

There are significant challenges when adapting visual materials, including the labor and time cost to create new materials, issues of information over- or undershoot, difficulties representing scale changes, and representing 3D and other perspectives [33]. Another challenging task for sighted TVIs is adapting visual information for non-visual consumption. This process aims to facilitate sensory substitution, which is when BLV individuals use other sensory modalities in the place of vision [2, 3, 11]. Prior work urges researchers to begin by assessing target user needs to ensure the design of useful and effective sensory substitution devices [25].

Interactive devices have many educational benefits. They can facilitate Embodied Learning [14], which is beneficial to the motor, cognitive, and academic achievement of students with disabilities [21–23, 30]. Common interactive devices for BLV people are haptic and auditory displays. Some haptic displays are designed to provide students with rich, embodied learning opportunities [12, 41–43] by allowing them to manipulate virtual objects and perceive force and tactile information, thereby reducing conceptual barriers [5]. Audio-haptic displays provide cross-modal integration, which use multiple senses to establish meaning [38] and have been used successfully to teach computer science and engineering activities [17]. Audio displays have made dynamic information featured in interactive science simulations accessible to BLV students [27, 29, 36, 44] and promote sensemaking [37]. In general, interactive devices are promising tools for TVIs as they are capable of real-time iteration of adapted learning materials and information display. Despite this, prior work is sparse in considering the insights of TVIs when designing these new technologies.

In this work, we conducted semi-structured interviews to understand experiences, attitudes, and perspectives on creating adaptations with existing methods. Our work contributes design recommendations and considerations for interactive tools that support TVIs in creating adaptations for BLV students.

2 INTERVIEW STUDY

We performed semi-structured interviews with 5 participants (see Table 1), all of whom were sighted educators with TVI experience. Each interview lasted approximately 1 hour and was hosted using the Zoom videoconferencing platform. Four participants were TVIs, and the fifth was an accessible technology specialist who assists TVIs in obtaining assistive technology for BLV students. All participants were employees at a regional education agency that provides special education services to over 40 school districts. The study took place in a metropolitan area within a mid-size county in the USA. The interviews explored 7 research questions: (1) educators' professional experience, (2) challenging academic subjects for BLV students and for TVIs to adapt, (3) general adaptation strategies, (4) adaptation strategies for courses with highly visual materials, (5) adaptation strategies for non-static information, (6) technology used in the classroom, and (7) the challenges using it. The study procedure was approved by the university's Institutional Review Board. All interviews were performed and transcribed by the first author with the use of automatic transcription software. Two authors performed thematic analysis by conducting iterative affinity diagramming and identifying themes [10, 16].

3 FINDINGS

3.1 Considerations when creating Adaptations

3.1.1 ***Academic Subjects.*** Participants noted several challenges in making adaptations, including: (1) the prevalence of visual representations, (2) the complexity of a subject, (3) specific syntax use and formatting of the information, and (4) inaccessible hands-on tools. They noted struggles when encountering unfamiliar, difficult concepts in subjects that rely on visual representations because they are not subject matter experts, along with the added challenge of adapting the information tactually. The TVIs emphasized that STEM curricula are incredibly visual and challenging to adapt. However, STEM subjects are not the only ones with significant reliance on visual learning materials: they also mentioned that certain humanities subjects, such as geography, are challenging because of the significant use of images.

Our participants described several specific instances in which they faced challenges adapting materials. For example, Harper discussed the challenge of representing the multidimensional concepts in geometry succinctly in tactile form. The participants also generally cited difficulties with adapting subjects that require specific syntax and formatting. For chemistry, Addison noted that the materials are complex and loaded with symbols. They shared that they chose to reduce the amount of information provided at one time to a student to make it more manageable. Harper also shared that the large number of symbols used in chemistry required significant time to adapt. Participants mentioned the challenges for Braille-reading students with Nemeth Code, a special type of Braille used for math and science notation that can result in longer representations. Addison and Casey both described challenges in teaching algebra, where presenting long, multi-step problems and solutions can place high demands on auditory processing and working memory.

Participants also shared that academic subjects with hands-on labs often lack accessible lab tools. Jaimie described the challenge of making a science activity accessible for their student by pre-teaching key concepts and providing additional verbal descriptions during the activity. Furthermore, Jaimie shared that the dangerous nature of some lab activities impact whether a student can safely work independently or have limits placed on certain higher risk tasks.

3.1.2 ***Student Needs.*** TVIs must consider varied student needs when making adaptations. Harper mentioned that they consider the degree of visual impairment and whether the student's vision has changed during their lifetime. TVIs also mentioned that they account for whether their students have any other disabilities. Additionally, they shared that a student's individual preferences for various adaptation types are considered. Quinn mentioned that their students' preferences influenced whether they chose to listen to descriptions or use Braille materials. Furthermore, Harper noted that they consider a student's level or desire for independence. Jaimie noted that a student's age also impacts the amount of pre-teaching that they require as they may not have had certain experiences yet. Finally, the TVIs mentioned that a student's motivation to learn new technology impacts whether technology can be used to create access.

3.1.3 ***Adaptation Strategies.*** The type of adaptation strategy is influenced by the topics covered in an academic subject and a student's individual needs (see 3.1.1 and 3.1.2). Participants mentioned using a range of "low-tech" and "high-tech" strategies to create adaptations. Low-tech solutions include using craft materials to adapt learning materials. High-tech solutions include using tactile graphics software and embossers to design and create tactile graphics as well as existing assistive technology features of computing devices, such as screen reading software and magnification. They also mentioned acquiring materials from resources like The American Printing House for the Blind. During pre-teaching, TVIs mentioned using techniques of grounding new knowledge in students' lived experiences and sensory feedback, including auditory descriptions and haptic modalities, such as vibrations, to deliver dynamic concepts.

3.2 Perspectives on Technology

3.2.1 ***Technology and its (Many) Challenges.*** The TVIs noted that increased technology use in classrooms did not always result in more accessibility. TVIs reported that the use of online resources and materials as part of instruction posed an issue when websites failed to follow web accessibility standards. Addison and Quinn shared that inaccessibility of online materials sometimes requires finding an alternative resource than what the classroom teacher selected. There were also difficulties in using adaptation technologies.

Table 1: Participant Information

Pseudonym	Role	Additional Experience	Student Grade Level
Harper	Teacher of Visually Impaired	Accessible Materials Specialist & graphic design	1-12
Jaimie	Teacher of Visually Impaired	-	K-12
Addison	Teacher of Visually Impaired	Orientation & Mobility	K-12 (mostly 6-12)
Quinn	Teacher of Visually Impaired	Orientation & Mobility	K-12, adults
Casey	Accessible Technology Specialist	TVI, O&M	all

Harper noted the limitations of tactile graphics software, citing the inability to use this software beyond specific embossers. Furthermore, Jaimie discussed the time cost of using tactile graphics software, including editing the image to reduce or eliminate visual clutter and add Braille labels. Available assistive tools may be unable to correctly display adapted materials. Jaimie noted the struggle of formatting charts used in mathematics courses because screen readers often fail to read them successfully.

Learning curves can also be a formidable challenge. For TVIs, Harper shared that they felt that their graphic design background enhanced their ability to use tactile graphics software, an advantage they did not think their peers had. Furthermore, Addison shared the struggle of learning new technologies without sufficient instruction. For students, Harper noted that the growing use of the Canvas learning management system causes unique issues for BLV students.

Assistive technology devices, such as Braille displays, also have limitations. Addison mentioned that students who can read Braille quickly are limited by the output speed of Braille displays. Addison also described that Braille displays induce laborious parsing issues for long mathematical expressions.

3.2.2 ***TVI Attitudes Towards Technology.*** While technology can be a powerful tool in the classroom, the many hurdles TVIs encounter when helping BLV students also inform their attitudes towards it. When discussing preferences for classroom technology, Quinn shared concerns about advertising that overpromises utility and perpetuates ableist claims: "*There are a few technologies out there that claim to be 'almost like seeing' or a 'cure to blindness'…for a device that can't really do all that much.*" Moreover, Quinn mentioned their gripes with technologies that are "*one-trick ponies*". Quinn noted that technology directed at BLV students may be encouraged by caregivers or parents despite being unsuitable for the needs of that particular student. Harper shared a nuanced perspective on the presence of technology in the classroom, noting that while there is utility of technology in the classroom, "*Technology should not be taking the place of actual instruction and learning.*" Finally, Harper noted that reliance on technology in the place of quality instruction "*has allowed people to become a little lazy in their teaching*".

3.3 Perspectives on Barriers to Access

Once a student's needs are identified, the time must be allotted and the resources must be requested to ensure that they are able to access learning materials. The participants noted that adapting learning materials has a substantial time and material cost and requires significant forewarning to prepare and deliver materials to their BLV students.

TVIs mentioned that they have to make adaptations "*on the fly*" when teachers do not provide learning materials ahead of time or deviate from the agreed upon lesson plan. However, it is not always possible to make adaptations in real time. Addison shared that if this happens, TVIs have to ensure that a student will get the same access to the information through a one-on-one session later. However, a TVI may not be a certified teacher of a given subject and cannot ensure equitable instruction. Addison notes that this puts pressure on TVIs to fill in the gaps, remarking: "*You can see them falling behind … and it sometimes feels like it's your fault because you should have known, but it's not.*"

Sometimes course instructors stand in the way of BLV students being able to take classes with a prevalence of visual materials. Harper shared that a course instructor told her that their BLV student would not be able to take a class with significant presence of visual information. TVIs also mentioned that sometimes BLV students will be told that they can skip questions on an exercise or will be exempt entirely if the materials have not been made accessible to them. To this, Harper remarked, "*Ultimately, we're not providing that equal opportunity for learning.*"

4 DISCUSSION

We sought to understand the various factors that shape how TVIs adapt visual materials for BLV students. We reaffirmed prior findings indicating that inaccessible hands-on tools [24, 39, 40] and the required time to create or secure adapted materials are challenges for TVIs [1, 28]. Furthermore, we reiterate the importance of considering student's additional disabilities [15, 28] and independence [28, 45]. In novel findings, we revealed that a student's motivation to learn new technology and age are important factors when deciding on the adaptation. We also uncovered that subject complexity, specific syntax and formatting are hurdles impacting the adaptation process. Finally, we learned that TVIs face resistance from course instructors in supporting BLV students in courses with highly visual content. In this work, we observed that TVIs' experiences, including witnessing the barriers that BLV students face, shape their attitudes towards current technology. We outline important considerations and design recommendations for future interactive creative tools.

4.1 Important Design Considerations

Visual Impairment of Student and TVI. There is diversity in the type and degree of visual impairment of a student. While some students may have no functional vision, a significant number of students are low vision [19]. Thus, making adaptations for students must take into account the variations between BLV students. We attend to prior work [25] by assessing TVIs' needs, which are grounded in their experiences, perspectives, and attitudes, while considering perception and information processing differences in BLV students due to degree and duration of disability. One limitation of this work is that all of the TVI participants were sighted, influencing their approaches to creating adaptations for visual learning materials [8, 20, 25]. Insights from TVIs with visual impairments would be valuable to consider when designing future interactive tools.

Additional Disabilities. Prior work has shown the importance of supporting BLV students with additional disabilities [9, 18, 28, 34, 35], demonstrating the need to design for diversity of disability amongst BLV students. For example, some BLV students may have tactile defensiveness, which is common in children with developmental disabilities [4]. The type of haptic modality provided by an interactive haptic display would need to be alterable [13] for a student like this.

4.2 Design Recommendations for Future Interactive Tools

Real-Time Adaptation. The classroom is a dynamic environment where students and TVIs often have to keep up with the decisions of the course instructor. Occasionally, course instructors deviate or go beyond the lesson plan they provided to the TVI. Thus, it is important that interactive systems enable the ability to quickly iterate upon adaptations.

Multiple Functions and Conveying Distinct Meaning. Interactive creative tools should be able to provide multiple functions [7, 28]. Designers should ensure the balance between a system that offers multiple capabilities without sacrificing the intuitive design qualities and sufficient documentation to reduce the learning curve. Furthermore, TVIs discussed the use of sensory experiences such as tactile, auditory, visual (for LV students), and, to a lesser extent, olfactory and thermal feedback to make concepts accessible to their students. Interactive systems that leverage sensory feedback should support rich experiences [28] that support sensemaking [26]. Furthermore, the quality of feedback should enable users to differentiate between sensations (e.g., textures, pitches) to convey distinct meanings [45].

Unrealistic Claims and Reinforcing Ableism. Designers should focus on supporting the TVIs' adaptation process and enabling students to have equitable access. They should be wary of purporting to solve or "cure" visual impairment or overpromising the utility of their systems.

5 CONCLUSIONS AND FUTURE WORK

In this work, we aimed to understand the various factors considered when adapting visual learning materials for BLV students. We uncovered factors that impact creating adaptations and outlined key considerations and recommendations for designing interactive tools to support TVIs in this process. Future work should take into account the insights that TVIs with visual impairments have on adaptation strategies towards designing interactive creative tools. Designers should also employ participatory design methods to explore how TVIs and BLV students could co-create adaptations with these interactive tools.

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