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Accessible E-Learning Through Story-Based Participatory Design for Persons With Vision Impairments

Earl W. Huff Jr.

The University of Texas at Austin, Austin, TX 78701, USA

ABSTRACT

Electronic or online learning (e-learning) has created opportunities for education and skill development through digital technology. As society continues to build more innovations for enhancing the online learning experience, we must raise questions about who has access to e-learning. More importantly, are the digital technologies designed for e-learning, such as learning management systems (LMS), accessible for persons with disabilities? We present a case study using participatory design (PD) with blind and visually impaired (BVI) learners and K-12 teachers to design an LMS usable and accessible to BVI users. We implemented storytelling to engage our codesigners, given that visual stimuli typically used in PD may not be effective with BVI participants. Through three design workshops, we learned about the challenges faced by BVI users in online courses and collaboratively produced design and interaction features to improve accessibility in LMS platforms. This research addresses a critical need for incorporating the input of persons with disabilities into the educational technology design.

Keywords: Exemplary paper, Human systems integration, Systems engineering, Systems modeling language

INTRODUCTION

The rapid emergence of information and communication technologies (ICT) for remote education has shifted how people approach learning and skill development. While remote learning is nothing new, it has existed since the 18th century (Kentnor, 2015), it has since evolved to provide ICT for synchronous and asynchronous communication and interaction between teachers and learners and persistent access to information. This form of remote learning, called "E-learning," introduced an alternative to traditional in-classroom instruction. However, the widespread adoption of e-learning technologies rests on consumers' perceived user experience (UX).

While usability is often a criterion in evaluating online learning technology, accessibility is often not considered. As a result, persons with visual impairments may find them more challenging to use than sighted users. Research suggests that current designs of online learning platforms may not provide a fully accessible learning experience for persons with disabilities (Johnson & Ruppert, 2002). As a result, the learning gap may widen for BVI learners and negatively impact their self-efficacy in e-learning.

Within the HCI community, researchers and designers apply participatory methods to create space for future consumers to lend their experience and voice to the design of interactive technologies. Participatory design (PD) solicits user requirements from end-users by including them as codesigners throughout the design process (Pascual et al., 2015). However, when working with BVI end users, traditional approaches in PD (i.e., storyboards, physical prototypes) may not be suited to facilitate an accessible experience. In our study, we describe an approach to PD using storytelling to engage BVI codesigners in designing a prototype LMS. We provide an account of the process and discuss takeaways from the study to advise researchers and designers on some guidelines for facilitating PD with BVI codesigners using stories.

BACKGROUND

E-Learning and People With Disabilities

E-learning offers several benefits over traditional classroom instruction: flexibility of teaching and learning, accessibility (in terms of accessing learning content and communication), and the asynchronous nature of the learning, allowing students to control the pace of their learning. Online education is also supported by a variety of electronic tools such as video conferencing (i.e., Zoom or Google Meet), online discussion forums (i.e., Piazza), and collaboration tools (i.e., Google Jamboard, Notion). Some notable disadvantages to e-learning include potential technology issues, students becoming less attentive while on the internet, reduced student-teacher interaction, and a lack of student feedback (Andrews, 2014; Buskermolen & Terken, 2012; Gautuam, 2020). Research also suggests that collaborative learning and teacher rating perceptions are lowered in online learning (Andrews, 2014).

Additional concerns about e-learning may impact people with disabilities more than others. For BVI students, switching to electronic platforms and materials raises questions about whether they are accessible with screen readers and assistive technologies that read visual displays; this is a significant concern for educators, especially when comparing the needs of blind vs. visually impaired students (Huff et al., 2021). Prerecorded videos can also be detrimental for BVI students without context for describing specific topics. For example, in a programming course, if the teacher references a line of code, pointing to the line on a whiteboard or slide without mentioning the line number or position, it will make it difficult for BVI students to understand where the code exists in the codebase. Using non-descriptive images in materials can also disadvantage BVI students and those with learning disabilities such as Dyslexia. Live teaching formats can be challenging for the deaf or hard of hearing if no live captioning is provided (Anderson, 2020). Even with live captioning, language barriers from the teachers may affect captioning accuracy.

Participatory Design Using Storytelling

Research has shown how using stories may help stakeholders define the design and context of using a product or service (Christensen, 2012).

Storytelling often uses visual cues such as storyboards to tell stories; however, stories can be presented verbally, suggesting that it may be an accessible form of PD for participants with disabilities (Andrews, 2014). Frauenberger et al. (2011) argued that storytelling effectively engages codesigners' sense of creativity in the design process, especially when working with children with disabilities. For our study, we used a method called co-constructing stories.

Co-constructing stories is a PD technique for eliciting in-depth feedback and suggestions (Buskermolen & Terken, 2012). This method is based on the idea that users are best suited to judge a new concept and offer helpful feedback when they think about past experiences. The technique uses two phases: sensitization and elaboration. During the sensitization phase, participants are introduced to an initial story that introduces the product's context and prepares them for dialogue. The designer asks questions to evoke past experiences from the participants. During the elaboration phase, the designer introduces a story with the product within the context introduced in the sensitization phase. At the end of the story, the designer elicits feedback from the participants. Then, the participants are tasked to envision themselves as the story's main character, thinking aloud about how they envision future experiences and aspirations of the product. The outcome of this technique is a series of co-constructed stories about the use of the product.

METHOD

Overview

We present a case study of the participatory design of a learning management system (LMS) with blind and visually impaired (BVI) codesigners using co-constructing stories. We detail participant selection and demographics, the stories constructed for each group, and the process for the three design sessions.

Participants

There were two design groups: one group for BVI students and one for K-12 teachers of visually impaired students (TVI). For the TVI group, there were two codesigners. One teacher identified as blind and uses a screen reader as their assistive technology; the other was sighted. On average, both codesigners have taught seven blind or visually impaired students a year. The participants have six years of experience teaching K-12 CS and 2.5 years teaching visually impaired students. Between the two teachers, the group has taught six fully online courses. Languages used by the group include Java, HTML/CSS, and Swift.

In the student group, two identified as blind and used screen readers and braille displays as assistive technologies. One student identified has low vision and uses magnification (i.e., ZoomText). Two students were undergraduates (one sophomore and one junior), and one was pursuing a graduate certificate. The students have taken 42 fully-online courses combined (mean = 14).

Stories

One part of conducting co-constructing stories is the narratives that facilitate discussions around the system's design. Two stories are required for each phase (sensitization, elaboration). We created two sets of stories for each group for the design sessions. We drew on the informative literature and research conducted on accessibility in computer science education (CSEd) to craft stories that reflect the experiences of taking an online course from the teachers' and students' points of view (POV). The first story, called the context story, introduces the context in which the proposed system will be used, setting the background for the story's main characters as they prepare to use the proposed technology. The second story, called the concept story, introduces the actual technology conceptually used by the main character. This story is incomplete intentionally, allowing codesigners to build on the story as part of the activity to inform the system's design and functionality. We developed the stories in a way that would not guide the codesigners to specific responses or thoughts.

Procedure

The study procedure was similar for both groups. We conducted three design sessions with each group, scheduled bi-weekly, over six weeks. All sessions were conducted over video conferencing using Zoom as it is a popular and accessible platform for people with visual impairments, and all participants were familiar with using Zoom and its functionalities. Each design session lasted between 30–60 mins. Figure 1 provides an overview of the design sessions' progression and prototype development.

DESIGN SESSIONS

This section details the interactions in each design session and the findings from the teachers' and students' sessions.

Design Session 1

The goal of the first design workshop was to introduce the concept of the LMS to the groups by using stories introducing the context of using an online learning platform. We used co-constructing stories as a medium to provoke participant reflections on their teaching/learning journeys in online learning and think about early design and feature suggestions. The procedure was similar for both groups. The session began with introductions and an icebreaker exercise for members to become acquainted with one another. Afterward, we read the informed consent document explaining the study's objectives, the codesigners' role in the study, and other relevant information. After consent, we began video recording the session and explained the session's agenda and the stories to be used. The sensitization phase begins with the contextual story to introduce the context in which the proposed LMS would be used. The perspective of the story differed based on the group. After reading the story, we asked the codesigners questions regarding the story and what thoughts came to mind after hearing it. After the group exhausted their responses to the

questions, we moved to the elaboration phase, introducing the conceptual story. The story introduces the concept of the LMS as a continuation of the contextual story. After reading the conceptual story, we asked the codesigners what they liked and did not like about the story. In the last part of the phase, we tasked the codesigners to reconstruct the story with themselves as the main character and describe how the story would be similar or different from their perspectives, including the design and functionality of the LMS. At the end of the phase, we allowed codesigners to ask questions or comment on the workshop.

Findings – Teachers

After reading the contextual story, we asked teachers if any part of it was relatable to their experiences. Both teachers said they related strongly to the story and talked about their first-time teaching a course entirely online to blind or visually impaired students. The teachers confessed to needing time to adjust to the dynamics of a virtual learning environment, such as making digital versions of learning content, communication tools, and available code editors suitable for web-based coding.

When discussing institutional support, the teachers had two different levels of support and resources. T1 provided his own curriculum, learning materials, and tools. He used the curriculum from Code.org for teaching HTML and CSS, using the Web Lab code editor. T1 used the Google Suite of technology to support online learning, including Google Classroom for managing course content, Google Meet for synchronous lectures, and Google Docs for code editing.

On the other hand, T2 had more institutional support. T2 was provided a curriculum for the course with materials predesigned to be accessible for the BVI students. Additionally, T2 was supported by teaching assistants who would help plan the lectures and facilitate communication with BVI students. For her class, T2 used JGrasp, an integrated development environment (IDE) that automatically generates code visualizations, and JCreator, an IDE for writing code in Java, which students found accessible.

After reading the conceptual story, we asked teachers about their opinions of the story and how they would envision it as different from being the main character. Due to internet connectivity issues, T2 could not participate in the conceptual story activity. T1 found the story relatable to his experience using similar learning platforms and working with inaccessible course materials. T1 provided some suggestions as he imagined himself in the story. He wanted to view the platform's user interface from the student's point of view. He reflected on his experience using Google Classroom in having to create a dummy student account to view the created web pages from the student's side. Another suggestion was communicating with students through the platform using a live chat or messaging feature.

Findings – Students

After reading the contextual story to the students, we asked them what to aspects they could relate. S3 did not feel he related to the story because the main character was blind, and he did not feel the challenges they faced were

similar to that of that character. S1 related somewhat to the experience in the story; they reflected on their experience in a primarily in-person classroom but included an option for online lectures. The time he used the online option, S1 found the platform to be reasonably accessible. However, S1 mentioned that the lecture materials were not accessible.

After the conceptual story, we asked students their thoughts about the story—S1 related strongly to finding media inaccessible to screen readers. S1 recalled when he was taking a self-paced course in which the content the creators provided were not accessible, and he discontinued the course as a result. S1 also recalled the times during college when professors transitioned their courses from in-person to virtual but did not provide their content in a way BVI students could use them. The most significant issues during the discussions were graphics, images, or other illustrations without descriptive text. All three students concluded that instructors did not make much effort to provide images with text to describe them. S3 recalls having come across code as an image, which frustrated him as he could not copy and paste it into an editor to see how it worked. S3 preferred for instructors to share the actual code with the class. S2's biggest frustration was the lack of accommodations from instructors. She recalled asking an instructor for the lecture materials prior to the start of class and was denied. It made her feel like she had to work harder than her sighted classmates to stay on par with them. They unanimously picked online learning when asked if they preferred online learning or traditional in-classroom instruction. The benefits of online learning included having access to digital content, which is more accessible than physical content, not being physically in the classroom, and being easier to schedule help from tutors or instructors. The one drawback brought up was that it was more challenging to make friends in a virtual environment.

Design Session 2

We continued with the co-constructing stories for the second design workshop but focused on the conceptual story (elaboration phase). For this workshop, we reread the concept story, stopping at critical junctures in the story where the main character is using the proposed learning platform and asking questions to the group. Group members would collaboratively discuss the functions or actions in question and how they may change to best fit the needs of BVI students or teachers. This phase would generate more concrete design and functionality requirements through the discussions.

Findings – Teachers

One of the first suggestions from the teachers was user accounts. The teachers agreed that, at minimum, all user accounts should allow for the user's name, username, email address, password, and profile picture. T2 expressed a desire for students to add other attributes that would help teachers better understand them, such as their preferred pronouns, likes/dislikes, and preferred name. Additionally, T2 wanted the ability to add notes to the student's profile, visible to only the teacher, to keep specific information about a student's needs on hand.

Another critical area of discussion was the layout and navigation of the platform. The group elaborated on several critical aspects for making each page on the platform accessible. Such considerations included legible typography, large buttons, high color contrast, and placement of buttons closer to the side or bottom of the page (this is so that the buttons do not disappear when someone zooms in on the page). Customizing specific page aspects such as background color, font size, and button colors were mentioned as valuable features. The group thought multimodal output for describing page content would be helpful for students. An example would be a built-in page reader that would enable users to press a button, and the page's content would be read by an internal text-to-speech (TTS) synthesizer, thus increasing consistency in how the content is read. T2 explains that the reader would benefit BVI students and those who suffer from learning disabilities such as Dyslexia.

Findings – Students

The suggestions from the students centered around the user interface (UI) and platform navigation. Students recalled having difficulty navigating existing LMSs such as Blackboard because of the heavy nesting of menus and buttons to traverse to find the course and related content. They stressed a simpler and cleaner UI to reduce the time it takes to find course materials. Additionally, keyboard shortcuts will help navigate a screen reader faster than cycling through the controls. S1 mentions that HTML headings (i.e., <h1>, <h2>) and the appropriate leveling of headings are critical in identifying different sections of a page. HTML5 introduced semantic elements in replacement of an existing method in which web designers often create DIV ( ) elements and apply the id attribute with the name of the element (example:).

Discussions regarding lecture materials hosted on LMSs revolved around images without text descriptions. Students mentioned it is not an issue if the lecture is primarily text-based as the text may describe the images; however, lectures containing many images may make the lecture more challenging to comprehend. Students wish instructors could add alt text to images they upload to their lectures to improve the accessibility of their content. Another complaint is the difficulty of navigating from the course home page to the lecture content, reflecting on their experience using Blackboard. The students wanted a more straightforward method to reach the lectures without having to find the correct menus or buttons.

Design Session 3

Using the input from the first two design sessions, we developed a first-iteration prototype of a learning management system for groups to evaluate in the final design sessions. We engaged with group members in one-on-one sessions where each participant had the opportunity to use the platform and complete tasks. Participants engaged in think-aloud sessions, speaking their thoughts about the platform's various features as they completed the assigned tasks. At the end of the session, we asked participants for final feedback regarding the LMS.

Findings – Teachers

In both sessions, teachers had trouble creating an account for the system due to the unclear error message for creating a password for the account. There was a disconnect between what users thought were the requirements for a complex password and the system's expectations. They were able to eventually create an account and enter the home page of the LMS. Teachers had to navigate the page to get a feel of the layout and UI. Both teachers found navigation to be straightforward; they liked the simplicity of the layout and minimalist design. T2 suggested making the page elements responsive to the screen's width as she noticed the main section of the home page did not adjust when moved from a small screen to a larger screen. Teachers liked adding a profile picture but would like the ability to add alt text. The teachers felt that creating and managing the course roster and creating courses, modules, and lectures seemed straightforward, and they had little difficulty completing these tasks. T1 (blind) liked the inclusion of keyboard shortcuts to make navigating the text editor easier. They found the ability to manage the course roster, adding courses, modules, and lectures easy and without much guidance. The group complimented the minimalist design of the UI and believed that BVI users would appreciate the more straightforward controls and menus. Teacher T1 admitted that he does not have much experience with LMS but believes it would be a valuable and accessible tool for hosting course materials for students.

Findings – Students

For the student evaluation portion, student accounts were made for them to log into the platform and access courses assigned to them. Walking through the LMS home page, all the students were consistent in their thoughts that navigating the UI was easy. They found the UI simple, clean, and free of unnecessary controls. Student S2 found that the course list's layout makes traversing the list straightforward. Student S3 suggested that the top bar on the home page remain fixed to remain at the top of the page and not scroll down with the page. Another suggestion was to allow the sidebar navigation to be collapsible. Additionally, the sidebar should automatically disappear as the screen width decreases (i.e., viewing the page on a mobile device).

While navigating their user profiles, the students liked the ability to add a profile picture. Student S1 mentioned they would like more explicit labeling of buttons for uploading photos and adding alt text to their photos. The students could navigate through the course assigned to them and follow the controls and menus to find the lectures. The students were tasked with reading over the lecture, which contained an image with alt text. Additionally, they had to summarize the lecture and the image description. All three students were able to summarize the lecture content and image accurately.

DISCUSSION

Supporting Instructors in Online Learning

Ensuring an equitable learning experience for students starts with the institution having the necessary infrastructure in place and the instructors having

the appropriate training to conduct online classes. From the first design workshop, the teachers discussed their own teaching experiences in an online setting that contrasted with one another. While the blind teacher could run their web design course fully online successfully, it was not without challenges in using the available tools and creating their own curriculum. On the other hand, the sighted teacher was provided with the curriculum, editors, and staff to support their online course. The difference in preparation and support is evidence of the inconsistencies in educational institutions preparing their instructors for teaching online. Even more, evidence was the lack of support for teachers in transitioning to virtual instruction during the COVID-19 pandemic; instructors faced numerous pedagogical challenges in using new technologies to provide quality online lectures for students (Ferri et al., 2020; Holmes, 2013).

Engaging BVI Persons in Technology Design

Our work builds on existing literature regarding including persons with disabilities in technology design. In an effort to produce more equitable and inclusive products, devices, and services, society should focus on capturing a broader range of perspectives of its consumers. Applying user-centered design (UCD), including accessible design, can yield benefits, such as products being usable to a broader range of users, increasing the likelihood of adoption, and higher profits for companies (Ladner, 2015; Newell & Gregor, 2000). In engaging with BVI teachers and students in our study, we discovered various pain points in online learning and learning management systems and worked towards potential design ideas to address such pain points.

CONCLUSION

The study's goals were to examine the experiences of K-12 teachers and blind and visually impaired students using learning management systems to understand sources of frustration with existing platforms and to explore how learning platforms could be redesigned to be more accessible for BVI persons. Using co-constructing stories, a combination of participatory design and storytelling, we learned about the essential design requirements for improving usability in learning management systems. The next step is incorporating the feedback from the third workshop to improve the prototype further. We will then conduct a usability study with BVI and non-BVI students to evaluate the accessibility of the LMS and compare perceptions of usability between the groups. Our goal is to provide further evidence of how to design more accessible learning technologies for persons with visual impairments and improve the science of conducting participatory research with users with disabilities.

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