Lessons Learned from Training Developers to Consider Accessibility in Cultural Heritage

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Abstract

The emergence of 3D scanning and 3D printing technologies has created new opportunities to enhance the engagement of visually impaired individuals, particularly blind visitors, in cultural heritage sites. Despite growing research in this area, the design of accessible museum experiences remains complex, as participation is affected by multiple factors, including awareness of available technologies, user preferences, abilities, and existing barriers. To address these challenges, this study adopts a hands-on training-oriented approach, focusing on educating developers through a multidisciplinary graduate course that actively involves museum professionals and visually impaired participants. Based on universal design principles, the course facilitated the development and demonstration of a range of accessibility-oriented prototypes. Recognizing the exploratory nature of these initial outcomes, the study further extends to iterative development and evaluation with 60 real users. The findings contribute to a deeper understanding of user needs and highlight emerging technological opportunities for inclusive cultural heritage design, while demonstrating the complexity of the challenges.

Keywords

Accessibility in cultural heritage, enhancing the museum visit experience for visitors with visual impairment, Accessibility, Cultural Heritage,

1. Introduction

Museum exhibitions are predominantly visual, which makes visiting museums challenging for visually impaired individuals in terms of engagement and participation. Exhibits are typically displayed in glass cases and are not meant to be touched, presenting a primary barrier for these visitors. However, recent technological advancements, particularly in 3D scanning and 3D printing, offer new opportunities to improve accessibility. Over the years, significant research has focused on making museums more inclusive for visually impaired audiences. [1] and [2] provide comprehensive surveys of assistive technologies designed to enhance museum experiences. Their work outlines the key challenges faced by visually impaired visitors and explores how such technologies can address these barriers. They emphasize the need for further research to better understand user needs and expectations across the entire museum experience. This includes areas such as collection digitization, multi-sensory interaction with exhibits, access to contextual information beyond Braille and audio, navigation within museum spaces, and remote access to collections. Building on similar ideas, we aimed to train student developers to collaborate in multidisciplinary teams within a graduate-level course focused on making archaeological heritage in museums accessible to blind visitors, inspired by the work of [3]. As part of the process, students from the information systems department and from the occupational therapy department (balanced groups, with complementary skills) engaged directly with two completely blind individuals. This collaborative approach proved essential for developing accessible and inclusive solutions that genuinely address the needs of the target audience. In partnership with museum staff, several thematic areas were defined, and corresponding sets of museum objects were selected, 3D

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scanned, and printed. Each student group then designed interactive experiences for these artefacts, constructing narratives in which the 3D-printed replicas could be explored through touch as part of a holistic, multisensory engagement. Although the outcomes were highly successful, this initiative marked only the beginning of a longer journey. In this paper, we present the conceptual framework of the course, the technologies employed, the implementation process, and the resulting prototypes, as well as how these prototypes evolved.

2. Background and Related Work

Recent technological innovations offer new opportunities to enhance the museum experience for visually impaired visitors. In particular, 3D scanning and 3D printing have attracted significant attention within the research community, as they enable the creation of immersive and engaging experiences through tactile, and often instrumented, replicas. [4] explore the application of these technologies in archaeology, with a focus on the accuracy and realism of 3D models. Cavazos el al. [2] describe a participatory design process in which an interactive, multimodal guide was developed to improve accessibility to art for blind visitors. Similarly, Vaz et al. [5], Asakawa et al. [6], and Meliones and Sampson [7] present systems that support independent and interactive museum experiences, enabling visually impaired visitors to navigate and follow curated paths through museum spaces autonomously. Vaz et al. [8] review a wide range of projects that apply state-of-the-art technologies and techniques to enhance museum experiences for visually impaired visitors. These approaches include haptic systems, which provide kinesthetic force feedback, enabling users to perceive properties such as shape, weight, texture, and material; digitally augmented touch replicas, which rely on 3D scanning and printing technologies to create accurate physical reproductions of artifacts; gesture-based interactive tactile reliefs, which use computer vision or other non-intrusive tracking systems to enrich tactile exploration with audio and additional multisensory information; and assistive navigation systems for self-guided tours, supporting independent movement across galleries without reliance on guides. In addition, hybrid solutions combine multiple approaches to create more comprehensive and engaging experiences. As we can see, in recent years, there has been a growing interest in exploring the potential of such advanced technologies to enhance museum accessibility for visually impaired visitors. Research findings demonstrate their capacity to bridge the gap between individuals' abilities and the demands of engaging with museum environments. In this context, our work aims to train developers to design and implement such systems, equipping them with the skills needed to create inclusive and accessible museum experiences.

3. Conceptual Framework and Technologies

As our goal, as defined in [9], was to train a multidisciplinary team of students (developers to be) to design and develop an accessible environment for blind people by exploring the potential of advanced technologies (intelligent user interfaces) using a user-centered design approach. We defined a multidisciplinary graduate course, involving students with technological background and experience (from the information systems department) and students with therapy experience and background (from the department of occupational therapy - faculty of social welfare and health sciences). The course was designed to combine theoretical and practical aspects and to develop several experiential kits (for specific cultural heritage topics) for visually impaired visitors. The course followed a co-creation approach where the students were introduced to a human centered design approach, design thinking methodologies and interaction design principles, as well as to the Human Activity Assistive Technology (HAAT) model [10]; the Matching Person and Technology (MPT) model [11] and the 7 universal design principles focusing on User-Centered Design (UCD) approach to ensure that the product or prototype meets the needs, wants, and expectations of its intended users [12] and [13]. Based on all these models and principles, the students worked with blind people and the museum staff to better understand the challenges and opportunities, to design the experience, to create 3D models of museum artifacts, to print 3D replicas, and to augment them with audio commentary, in which they selected different interaction

techniques.

4. Implementation

The course began with an introductory session, after which the students were divided into four groups of four participants. The museum staff defined four thematic areas and selected several artefacts for each: ancient warfare, writing, mythology and religion, and the story of Late Bronze Age anthropomorphic sarcophagi. Each theme was designed to be presented as a cohesive narrative, represented by three to four artefacts from the museum's collection. To ensure that the proposed concepts effectively addressed the needs of blind users, the development process incorporated all stages of the Design Thinking methodology:

- Empathy: The students generate empathy and familiarity with the field of development by talking with the museum staff, experiencing the museum blindfolded, and accompanying blind visitors during a visit in the museum, and finally, reviewing relevant literature (Figure 1). Then they had a guided tour at the museum, to familiarize them with the museum itself and the topics selected for designing the experience.

Figure 1: Visiting the Hecht Museum with their eyes covered, accompanying two blind visitors and learning about the specific museum topics.

- Define and Ideate: The teams were asked to present their concepts based on literature reviews and user interviews while producing quick prototypes (such as a video prototype and a cardboard prototype) to better communicate and refine their concepts (Figure 2).

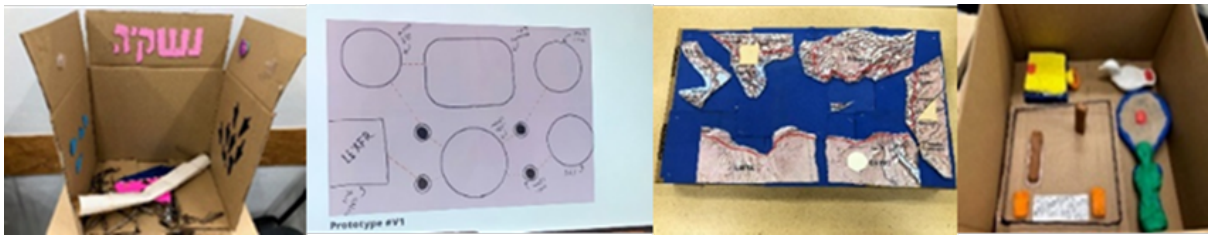

Figure 2: Ideation process using cardboard prototyping, 2D sketches and video prototypes. Left to right: ancient weapons, writing, mythology and religion, and the story of late Bronze Age anthropomorphic sarcophagi.

- Prototyping: the teams were asked to produce semi-working prototypes that could be tested with actual users. For that matter, replicas were produced using 3D scanning and 3D printing, audio files were recorded, and primary code was written. All groups faced the same questions regarding interaction design and each of them chose to solve them in a different way (interaction techniques varied, and included push buttons, RFID readers, and micro switches.

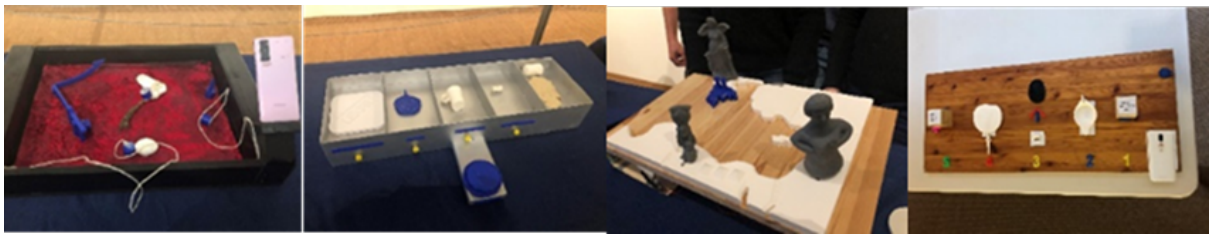

Figure 3: The four concepts developed as thematic kits and initially tested with two blind users. Left to right: ancient weapons, writing, mythology and religion, and the story of late Bronze Age anthropomorphic sarcophagi.

- Testing and Evaluation: For the first usability test, the students used the Wizard of Oz testing technique – a method of testing a system that does not yet exist and which has yet been found to be a very efficient tool for evaluating interactions and performance [14]. The 3D artifacts and audio files were produced, but the activation of the interactive artifacts was controlled by "a hidden wizard". The students could test the concepts with the two blind users, although it was not fully working, and improvements would be implemented in the final projects.

The final prototypes (Figure 3) were developed and refined according to the observations of the intermediate tests. The interactive sets were presented at the end of the course, but had not yet undergone additional testing with blind users.

The course was highly appreciated by the museum staff, and the group work generated a wide range of innovative suggestions for improving accessibility for blind visitors. The end users also evaluated the final projects positively, highlighting their potential to enhance participation and engagement within the museum environment.

5. Beyond a Graduate Course

The success of the course led us to think that we should not stop here – the idea of training the developers was highly appreciated and it has been repeated two more times (next time, this summer) – once again, with blind users and then with people with intellectual and developmental disabilities (IDD). However, we realized that while the course was highly successful, this is only the beginning. Hence, we went on, this time, the work was carried out by a master student who converted the initial prototypes into working systems (see Figures 4-6) [14].

Following a pilot study, three kits representing different interaction techniques were selected for further experimentation (there were two kits that applied RFID scanning based interaction so one was removed). Each prototype was subsequently developed into a robust system (as illustrated in Figures 4, 5, 6). In addition, each kit included an introductory overview, a structured opening, and a concluding summary to support user engagement and comprehension. A user study involving 30 blind participants was conducted to identify the preferred mode of interaction. The findings indicated a clear preference for the simplest interaction technique, push buttons, which were favored for their intuitive interface and the sense of control they provided. The micro-switch autoplay mechanism was ranked second, while the RFID-based solution was the least preferred. General feedback collected during the study highlighted several key issues. The most prominent was the need for audio control, particularly regarding volume and playback speed. Participants also emphasized the importance of tailoring audio descriptions more effectively to blind visitors. Additionally, concerns were raised about the material authenticity of the 3D replicas, as plastic models were perceived as less representative compared to original materials such as metal or ceramics. In response to this feedback, a second study was conducted by a master student to examine the extent to which blind visitors could independently operate improved versions of the kits [15]. The revised systems incorporated audio controls and updated descriptions adapted to user feedback. The study was repeated with additional 30 blind participants using the same three interaction techniques. The results were consistent with those of the initial study: the push-button

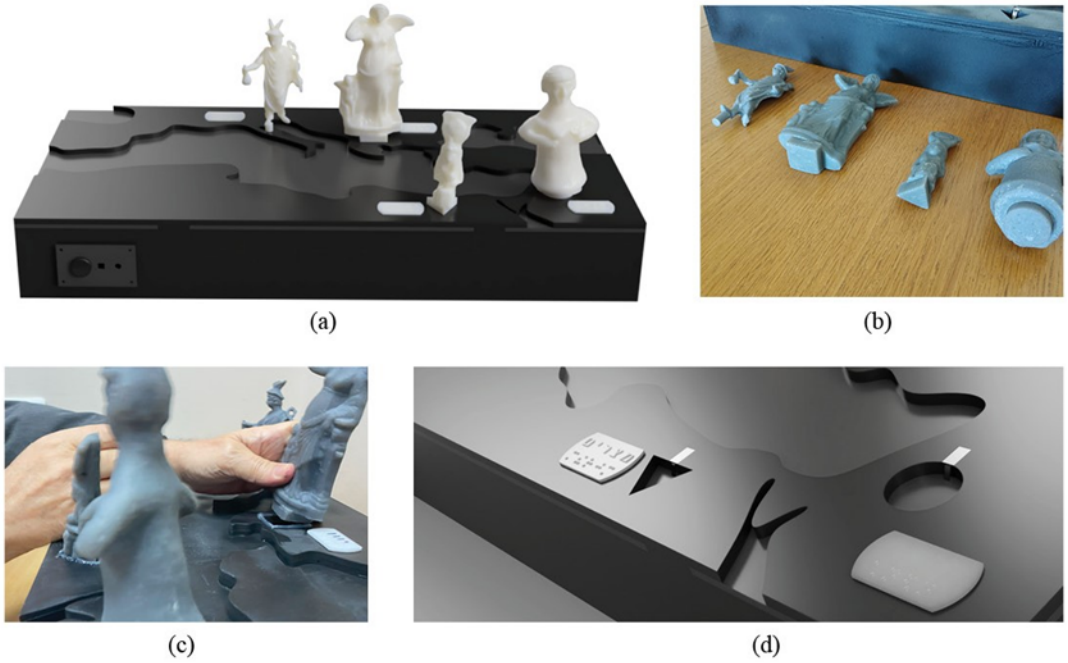

Figure 4: Micro switch – auto play interaction. The theme of the kit is religion around the Mediterranean. A set of figurines of goddesses placed in a Mediterranean map. Audio commentary is activated when the figurine is picked up and stops when placed back in place.

Figure 5: Push button-based interaction. The theme of the kit is writing and the user may pick up an item and then push a button to hear a commentary.

interface remained the most preferred, and was also perceived as providing the highest levels of control and autonomy.

6. Discussion and conclusion

What began as an initiative to develop a multidisciplinary graduate course to train developers in designing accessible museum experiences evolved into an ongoing and expanding endeavor. We would like to note especially the empathy phase, as it became a pivot point in our design cycle. By prioritizing human connection and lived experience over purely technical specifications early on, the methodology provides a stronger foundation for the subsequent ideation and prototyping stages. The creativity and dedication of the multidisciplinary teams resulted in high-quality prototypes that demonstrated diverse approaches to supporting interaction between blind visitors and museum artifacts. The success of the course led to its repetition, as well as to more advanced studies that provided deeper insights into the complexity of designing accessible museum experiences for visually impaired visitors. The course highlighted both the necessity and the potential of multidisciplinary collaboration

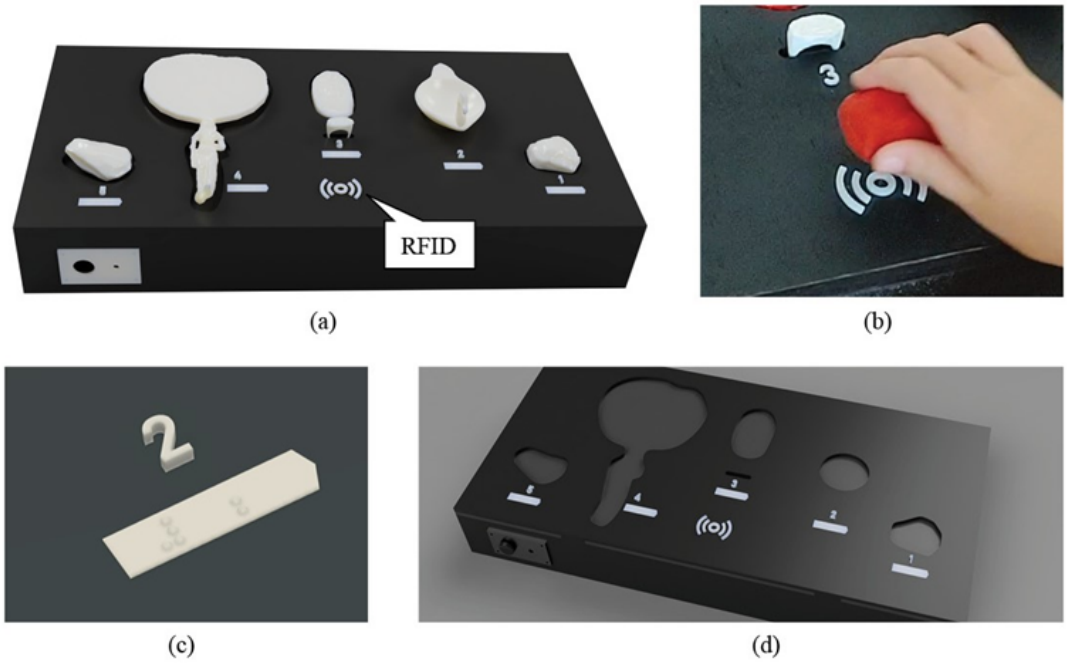

Figure 6: RFID-based interaction. The user picks up an object and places it momentarily over the RFID icon (can be touched) to start the audio commentary.

in generating innovative solutions tailored to the needs of the target population. Subsequent studies further emphasized the multifaceted nature of this challenge, underscoring the importance of adopting a structured, methodological approach while attending to a wide range of design considerations and user needs. Building on these findings, ongoing research is focused on developing a comprehensive framework to guide the design and implementation of accessible museum experiences for individuals with visual impairments.

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Declaration on Generative AI

During the preparation of this work, the author(s) used Chat-GPT-4 in order to: Grammar and spelling check. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the publication's content.

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