Immersive Cross-Cultural Journeys: Enhancing Museum Experiences Through Mixed Reality

Gayathri Ravichandran [1], SangHun Nam [2]

[1] *Department of Culture and Technology Convergence, Changwon National University, Korea*
[2] *Department of Culture and Technology, Changwon National University, Korea*

Abstract **– Mixed reality technology is employed to develop immersive experiences, enhancing visitor engagement within museum environments. There are challenges in interface design and sensory accuracy for such mixed-reality applications. This study explored integration of mixed reality technology in museums, emphasizing the enhancement of cross-cultural understanding and visitor engagement. Using advanced three-dimensional printing, significant artifacts from various cultures, including a notable Korean artifact from the Goryeo period, were replicated and digitized. These artifacts were the core of a mixed reality environment that was created using Unity and the MR Software Development Kit and experienced through a HoloLens 2 Head-Mounted Display. This immersive mixed reality experience, comprising three interactive segments, incorporated eye- and hand-tracking technologies to enable deeper engagement with cultural artifacts. The impact of mixed reality on visitor engagement and cross-cultural comprehension was evaluated, revealing a significant increase in visitor involvement and appreciation of cultural diversity.**

Notably, this study contributes to the evolving narrative of digital cultural heritage by highlighting the role of mixed reality in fostering a cross-cultural understanding and shaping future museum experiences.

Keywords **– Cross-culture, eye-tracking, hand-tracing, immersive system, mixed reality.**

DOI: 10.18421/TEM132-37
https://doi.org/10.18421/TEM132-37

Corresponding author: Sang-Hun Nam,
Department of Culture and Technology, Changwon National University, Korea
Email: *sanghunnam@changwon.ac.kr*

Received: 28 December 2023.
Revised: 12 March 2024.
Accepted: 28 March 2024.
Published: 28 May 2024.

© 2024 Gayathri Ravichandran & SangHun Nam; published by UIKTEN. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 License.

The article is published with Open Access at https://www.temjournal.com/

1. Introduction

In the digital era, there is an increasingly evident transformation of museums from traditional artifact repositories to dynamic spaces of engagement. Once primarily seen as the custodians of tangible cultural and historical treasures, museums are now embracing digital innovations to meet the changing expectations of globally connected audiences. This transition is marked by a shift toward interactive and immersive experiences that enrich the understanding and appreciation of cultural heritage.

Museums increasingly adopt MR technology to create immersive environments where physical artifacts and digital augmentations coexist, offering visitors a more engaging and interactive way of learning about cultural narratives [1], [2]. Examples of MR applications in museums include the virtual restoration of ancient artifacts, reconstruction of historical sites, and interactive holograms of historical figures, which provide a more dynamic and engaging experience than that offered by traditional exhibits [3],[4],[12],[13].

Despite the potential of MR, its integration into museums poses several challenges. Technical issues such as interface design, sensory accuracy, and user accessibility can significantly affect the effectiveness and reach of the MR experience [5]. Furthermore, there is a crucial need to balance technological innovation with culturally and educationally meaningful content to ensure that MR experiences in museums are not only visually immersive but also enriching and informative [6], [7].

This study examines the role of MR technology in enhancing visitor interactions and fostering a cross-cultural understanding of museums. By exploring the current applications of MR in museum environments, assessing its impact on visitor engagement, and identifying the challenges and opportunities for its broader implementation, it seeks to offer insights into its effectiveness as a tool for cultural education and heritage preservation. Through an analysis of visitor feedback from MR-enhanced museum experiences, this study evaluates the potential of MR to revolutionize museum experiences and contribute to the evolving landscape of digital cultural heritage [8]. The rest of the manuscript is organized as follows. Section 2 reviews existing literature related to the proposed study, and Section 3 describes the MR experiment conducted to assess the experience of people interacting with MR. Then, Section 4 presents the results of the experiment and discusses them concerning the aim of the study. Finally, Section 5 provides the concluding remarks and provides the scope for future research.

2. Literature Review

The transition of museums into digitally enhanced cultural spaces is marked by the adoption of MR technology, which reshapes interactions between visitors and cultural heritage. Existing literature indicates a trend toward immersive technologies, such as MR and virtual reality (VR) in museums. Studies by Kiourt *et al.* [9] and Kersten *et al.* [10] demonstrated how 3D reconstruction and VR could contribute to facilitating interactions between people and virtual archaeological exhibitions, aligning with the goal of our study to enhance visitor engagement through immersive experiences.

Central to the transformative impact of MR in museums is its ability to blend the real and digital realms [3], [4]. This aspect is vital to our hypothesis that eye-tracking interactions within MR environments can significantly enhance cross-cultural understanding. The potential of MR to support immersive and interactive experiences aligns with our objective of exploring how these technologies impact visitor perceptions and cultural appreciation.

Existing research underscores the importance of tailoring the MR experience to accommodate diverse cultural narratives. Zhao *et al*. [6] and Wang and Kim [7] emphasized the necessity of inclusivity in MR applications, resonating with our focus on how personalized interactions, such as eye tracking, can deepen the cultural appreciation of visitors.

Furthermore, the incorporation of advanced features such as eye and hand tracking in MR, as displayed in systems such as MuseumEye and Microsoft HoloLens [11], [10], showcases the potential of MR to enrich visitor engagement. The work of Plecher *et al.* [11] on creating an MR-based museum further exemplifies how MR can offer authentic historical contexts informing our methodology and supporting our objective of investigating the influence of interactive MR on cultural understanding.

There are research gaps in applying MR technology within museum settings, particularly in adapting to varied cultural perspectives and integrating sophisticated interaction technologies. Bridging these gaps is essential to realize the full potential of MR in enhancing museum experiences and facilitating cross-cultural understanding, which aligns with our research objectives. Overall, our study addresses these issues and explores the role of MR in digital cultural heritage and cross-cultural education within the museum context.

3. Interactive Exhibit Design and User Engagement in the MR Experience

In this study, an MR experiment in the context of a museum was conducted. Both eye- and hand-tracking technologies were employed to create an interactive and intuitive visitor experience.

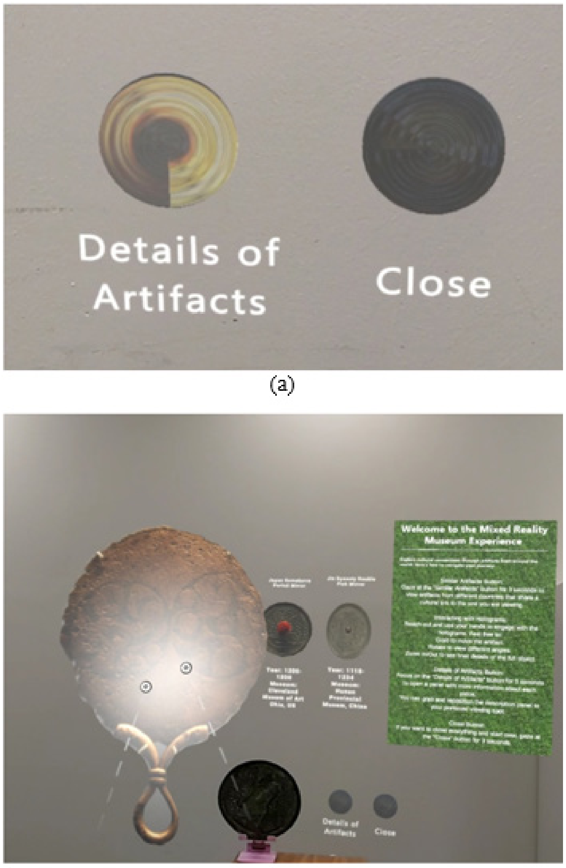

Figure 1. a. Eye gaze triggers the "Details of Artifacts" button.
b. Interaction of a pair of hands with a hologram

Regarding eye-tracking technology, it plays a critical role in navigating an MR environment [14]. A system can detect the focus and intent of a user by tracking where they are looking. For instance, when a visitor spends a specific amount of time looking at a specific area or button, like the "Artifact Details" button, the system interprets this sustained gaze as an engagement signal. This triggers a transition to a new scene or interaction without requiring physical inputs, simplifying and enhancing the user interface, as shown in Figure 1(a).

Regarding hand-tracking technology, it is employed to enable natural and intuitive interactions with digital content [15]. It captures and interprets hand and finger movements, allowing visitors to manipulate the holographic representations of cultural artifacts. Users can move, rotate, and interact with virtual objects using simple hand gestures to create a tactile and immersive experience, as shown in Figure 1(b). This combination of eye- and hand-tracking technologies ensures a seamless and engaging exploration of holographic artifacts, making this experience more widely accessible and appealing to a broad audience, including those unfamiliar with conventional digital interfaces.

In this study, the development process began with selecting culturally significant Korean artifacts from the Goryeo period, which were chosen for their historical and cultural value, as shown in Figure 2(a). Utilizing advanced 3D printing technology, a precise physical replica was created and meticulously colored to accurately mirror the appearance of the original artifact, ensuring authenticity and historical accuracy, as shown in Figure 2(b).

(a) (b)

Figure 2. a. 2D image and b. 3D print of a Korean artifact

In addition to Korean artifacts, high-resolution 2D images of culturally significant artifacts from five countries were obtained. These images, selected for their cultural and historical importance as shown in Figure 3(a), were converted into 3D models using advanced software such as Monster Mash [16].

Further refinements in terms of visual accuracy and detail were carried out in Blender, ensuring that these models would closely resemble the original artifacts shown in Figure 3(b).

The MR experience was developed using Unity 3D and an MR Software Development Kit (SDK). This powerful combination facilitated immersive content creation, integrating eye- and hand-tracking functionalities to enable natural interactions with holographic artifacts.

(a)

(b)

Figure 3. a. 2D and b. 3D images of various artifacts from various countries

Five participants in their 20s participated in our study. There was a balanced gender representation, and no participant had been previously exposed to MR and consent was obtained from all the participants before their involvement in the experiment. The interaction duration for each participant ranged from 9 to 10 min, allowing comprehensive engagement with the MR exhibit.

The experiment was structured into three distinct scenes, each designed to gradually introduce users to various facets of cultural artifacts and their historical contexts. This layered approach was facilitated using a HoloLens 2 head-mounted display (HMD).

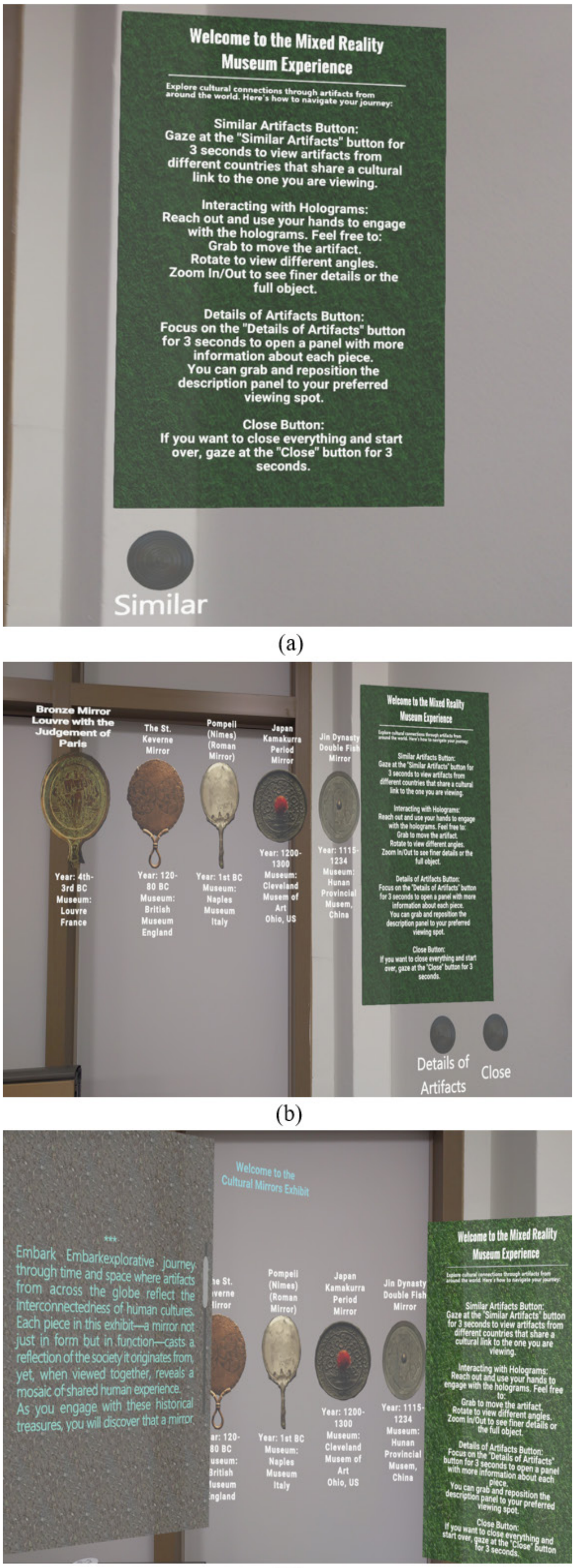

Figure 4. a. Introduction and orientation scene, b. artifact exploration scene, and c. informational and dynamic interaction scene

In the introduction and orientation scenes, each user wore a HoloLens 2 HMD. They were presented with an instructional board and holographic button next to a physical Korean artifact. Interaction with the board was enabled by hand tracking, which allowed users to navigate the presented information. The transition to the next scene was initiated by eye tracking, where focusing on the holographic button for 3 s triggered a change, as shown in Figure 4(a).

The interactive artifact exploration scene showcased the holograms of artifacts alongside eye-tracking-enabled buttons. Each hologram included details such as the name and origin of each artifact and the museum preserving it. Users interacted with these holograms through hand tracking, enabling them to zoom, rotate, and reposition artifacts as desired. Transitioning to the next scene was achieved by focusing on the "Artifact Details" button using eye-tracking for a set duration, as shown in Figure 4(b).

The informational and dynamic interaction scene was an interactive panel that users could manipulate using hand tracking. The text on the panel scrolled in response to the gaze direction of a user, and it was tracked using eye-tracking technology, as shown in Figure 4(c). The experience would conclude and return to the initial scene when the user focused on the "Close" button for 3 s via eye-tracking.

4. Results and Discussion

Through this experiment, users engaged with the MR environment in a novel manner by manipulating holographic representations of cultural artifacts around the world. Together, eye and hand-tracking technologies created a unique, interactive, and educational experience, bridging traditional cultural appreciation with cutting-edge technology. This approach not only enhanced the museum experience but also provided insights into user interaction and learning behaviors within an MR context.

In this study, participant feedback was crucial for assessing the impact of the MR experience. Open-ended feedback was solicited from participants to capture their subjective experiences and perceptions. The collected qualitative data were methodically analyzed using the QDA Miner Lite software; a thematic analysis approach was employed. This involved an iterative process of coding the data to identify patterns and themes that emerged consistently across the participant responses.

The thematic analysis results revealed significant enthusiasm among visitors toward the MR exhibit, particularly concerning the eye-tracking feature.

Approximately 35.7% of the comments expressed excitement regarding this feature, suggesting that integrating eye tracking in MR exhibitions could significantly enhance visitor engagement.

More importantly, 60% of participants demonstrated direct engagement with the cultural content presented in the MR experience. This theme, which accounted for 21.4% of the overall feedback, indicated an enhanced cross-cultural understanding among visitors. This result substantiated the hypothesis of our study and met the second objective, which focused on investigating how eye tracking within an MR environment could influence cultural appreciation.

Despite the overall positive reception, the analysis also highlighted technical challenges, such as hand recognition accuracy and screen brightness, which had been mentioned in 21.4% of the feedback. Additionally, 14.3% of the respondents provided suggestions for more user-friendly interfaces. Addressing these technical aspects is crucial for optimizing the MR experience and aligns with our third research objective: exploring the full potential of MR and eye-tracking technology in global cultural education.

Our exploration of MR technology in museum settings, particularly with advanced features such as eye and hand tracking, highlighted the potential of MR to significantly enhance visitor engagement and cross-cultural understanding. These findings aligned with advancements in MR technology that merge the real and virtual worlds for innovative interactions [17]. We also identified crucial technological and ergonomic challenges that aligned with the concerns noted in recent literature [18], emphasizing the need for continuous improvements in MR technology.

5. Conclusion and Future Work

Our study demonstrated that incorporating MR technology in museums would signify a pivotal shift in the realm of cultural heritage and education [8]. Our findings, which highlighted the positive reception and enhanced engagement achieved through MR, resonate with the current trajectory of leveraging digital technologies for preserving cultural heritage. Adopting advanced features, such as eye-tracking and hand-tracking, has not only enriched visitor experience but also highlighted MR as a key tool in redefining museum interactions. Our research also sheds light on the challenges, particularly the technical and ergonomic aspects, that are critical for addressing the seamless adoption of MR technology in museum environments [5].

Addressing these issues will not only enhance visitor experiences but also pave the way for more intuitive and accessible MR applications in cultural settings.

The implications of this study extend beyond visitor engagement. They underscore the transformative potential of MR in cultural education and global heritage preservation; MR is at the forefront of a new wave of technological integration in museums, offering unique opportunities for immersive storytelling and educational experiences. Its ability to make cultural heritage more accessible and engaging, particularly for diverse and digitally native audiences, is invaluable.

As we move further into the digital age, MR technology has emerged as more than a tool, becoming a medium for cultural connection and learning. Therefore, the ongoing development and optimization of MR technology in museum settings are not only imperative for enhancing visitor experiences but also crucial for the broader objectives of cultural preservation and education in our interconnected world.

Overall, our findings confirmed the effectiveness of MR in museum contexts and highlighted areas for future research and development. Optimizing MR technology and broadening its scope of application can further solidify its role as a transformative tool for cultural education and visitor engagement. This study extends the current literature by pinpointing specific areas of MR technology requiring enhancement, such as hand recognition and screen brightness. These insights offer directions for future technological developments in MR systems, intending to make these applications more intuitive and accessible.

Moreover, the focus on specific demographics underlines the importance of diversity in future MR research and echoes the call for inclusivity in cultural heritage technology. Future studies should delve deeper into how MR can foster nuanced cultural understanding, potentially integrating advanced technologies such as artificial intelligence for enhanced personalization.

Acknowledgments

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF2020R1I1A3051739).

References:

[1]. Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A survey of augmented, virtual, and mixed reality for cultural heritage. *Journal on Computing and Cultural Heritage (JOCCH)*, *11*(2), 1-36. Doi: 10.1145/3145534

[2]. Trunfio, M., Jung, T., & Campana, S. (2022). Mixed reality experiences in museums: Exploring the impact of functional elements of the devices on visitors' immersive experiences and post-experience behaviours. *Information & Management*, *59*(8), 103698. Doi: 10.1016/j.im.2022.103698

[3]. Trunfio, M., Campana, S., & Magnelli, A. (2020). Measuring the impact of functional and experiential mixed reality elements on a museum visit. *Current Issues in Tourism*, *23*(16), 1990-2008. Doi: 10.1080/13683500.2019.1703914

[4]. Hammady, R., Ma, M., & Strathearn, C. (2020). Ambient information visualisation and visitors' technology acceptance of mixed reality in museums. *Journal on Computing and Cultural Heritage (JOCCH)*, *13*(2), 1-22. Doi: 10.1145/3359590

[5]. Heyman, N. (2019) *Trends, Challenges and the Future of Museums*. Gilbane. Retrieved from: https://www.gilbaneco.com/blog/trends-challenges-and-the-future-of-museums/ [accessed: 14 January 2024]

[6]. Hutson, J., & Hutson, P. (2023). Museums and the Metaverse: Emerging Technologies to Promote Inclusivity and Engagement. *Faculty Scholarship*. Doi: 10.5772/intechopen.110044.

[7]. Llamazares De Prado, J. E., & Arias Gago, A. R. (2023). Education and ICT in inclusive museums environments. *International journal of disability, Development and Education*, *70*(2), 186-200. Doi: 10.1080/1034912x.2020.1856350

[8]. Okaro, I., & Vlachopoulos, D. (2020). Exploring the use of mixed reality (MR) in museum education: a systematic literature review. *INTED2020 Proceedings*, 6899-6908. Doi: 10.21125/inted.2020.1830

[9]. Kiourt, C., Koutsoudis, A., & Pavlidis, G. (2016). DynaMus: A fully dynamic 3D virtual museum framework. *Journal of Cultural Heritage*, *22*, 984-991. Doi: 10.1016/j.culher.2016.06.007

[10]. Kersten, T., Tschirschwitz, F., & Deggim, S. (2017). Development of a virtual museum including a 4D presentation of building history in virtual reality. In *TC II & CIPA 3D Virtual Reconstruction and Visualization of Complex Architectures, 1–3 March 2017, Nafplio, Greece*, 361-367. Copernicus. Doi: 10.5194/isprs-archives-XLII-2-W3-361-2017

[11]. Hammady, R., Ma, M., Strathern, C., & Mohamad, M. (2020). Design and development of a spatial mixed reality touring guide to the Egyptian museum. *Multimedia Tools and Applications*, *79*(5), 3465-3494. Doi: 10.1007/s11042-019-08026-w

[12]. Hammady, R., & Ma, M. (2021). Interactive Mixed Reality Technology for Boosting the Level of Museum Engagement. In *Augmented Reality and Virtual Reality: New Trends in Immersive Technology*, 77-91. Cham: Springer International Publishing.

[13]. Plecher, D. A., Wandinger, M., & Klinker, G. (2019). Mixed reality for cultural heritage. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 1618-1622. IEEE. Doi: 10.1109/VR.2019.8797846.

[14]. Lai, M. L. et al. (2013). A review of using eye-tracking technology in exploring learning from 2000 to 2012. *Educational research review*, *10*, 90-115. Doi: 10.1016/j.edurev.2013.10.001.

[15]. Park, Y. *What is Hand Tracking Input?* Mixed Reality Now AR/VR/MR/XR Stories by Yoon Park. Retrieved from: https://mixedrealitynow.com/what-is-hand-tracking-input [accessed: 20 January 2024]

[16]. *Monster Mash.* (n.d.). Monster Mash. Retrieved from: https://monstermash.zone/ [accessed: 20 January 2024]

[17]. Ranjan, A., & Chaturvedi, P. (2023). Digitally Sustaining: The Rural Intangible Cultural Heritage. In *Embracing Business Sustainability Through Innovation and Creativity in the Service Sector*, 14-30. IGI Global.

[18]. Ramm, R., Heinze, M., Kühmstedt, P., Christoph, A., Heist, S., & Notni, G. (2022). Portable solution for high-resolution 3D and color texture on-site digitization of cultural heritage objects. *Journal of Cultural Heritage*, *53*, 165-175. Doi: 10.1016/j.culher.2021.11.006.