Spatial Narratives in Mixed Reality

Immersive gamified heritage experience at Yedikule Fortress

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A comparative study was conducted to assess the impact of simple game elements on user experience and awareness of the historical Yedikule Fortress. The objective of this study was to ascertain whether the incorporation of gamified virtual overlays, which were designed to remain historically authentic, contextually grounded, and aligned with the physical environment, had an impact on participants' recollection of the visited space. An iterative development process was employed, commencing with expert evaluations followed by an extensive user study. The developed interface and features of the HoloLens 2 device are detailed, and the results of the user study are presented. Our findings highlight that, in contrast with previous assertions in the literature, there is no statistically significant difference in the impact of game elements on users' experiences of spatial technologies.

Keywords: *Gamified Experience, Cultural Heritage, Mixed Reality, Augmented Reality, User Perception.*

INTRODUCTION

The field of cultural heritage studies has witnessed a significant shift in its adoption of technological advancements, particularly in spatial computing technologies such as Mixed Reality (MR), which have gained prominence over the past decade. Recent studies have indicated that entertainment and gaming can support the learning and cultural mission in exhibitions, museums and archaeology as informal learning spaces, and can increase people's cognitive efficiency and experience in the space (Portugal et al, 2025; Krzywinska et al, 2020). Digital interactive technologies enrich the presentation of cultural information and increase the sensory participation of the audience (Santoso, Wang and Windasari, 2022). There is a substantial body of literature demonstrating that fun and game elements can stimulate behavioral motivation and foster spontaneous learning and discovery, particularly by encouraging individuals to explore spatial experiences based on their personal interests (Gür and Türel, 2025; Wang et al, 2016). Parallel to these endeavors, our research looked at spatial technologies and whether simple game elements affect such interaction, as claimed in the literature. The research we will present below is part of a comprehensive project on immersive technologies and the effects of game elements. This paper focuses on game elements as the research variable and presents a design perspective on the development and evaluation of a MR experience at the Yedikule Fortress, primarily focusing on the evaluation of Microsoft

HoloLens 2. Unity and the Mixed Reality Toolkit 2 (MRTK2) were utilized for MR application development enabling gesture-based interactions seamlessly integrated with holographic elements on the site's historic architecture with minimal visual interference.

GAMIFIED HERITAGE EXPERIENCE

Gamification and serious games have gained significant interest in cultural heritage over the past decade (Foni, Papagiannakis and Magnenat-Thalmann, 2010), focusing on virtual (VR) and augmented reality (AR), game narratives (Dow et al, 2005; Kim et al, 2015; Volkmar, Wenig and Malaka, 2018), and historical awareness (Volkmar, Wenig and Malaka, 2018; Kim et al, 2015). Mortara et al. (2014) examined serious games in cultural contexts, highlighting factors like gender, technical solutions, and learning efficiency. These games aim to provide engaging learning experiences, fostering curiosity about heritage (Mariotti, 2021). Game-based learning is increasingly studied across disciplines (Vaz de Carvalho, Latorre Andrés and Serón Arbeloa, 2013), such as Skamantzari et al.'s (2017) serious game featuring the Stoa of Attalos in Ancient Athens. Their objectives include raising awareness (Affleck and Kvan, 2005), enhancing visitor engagement (Doulamis et al, 2012; Coenen, Mostmans and Naessens, 2013), and allowing interactive architectural exploration (Aydın and Schnabel, 2016; Fanini and Pagano, 2015). Our study integrates gaming elements to improve spatial cognition and strengthen users' connection to heritage narratives.

Beyond entertainment, our approach emphasizes heritage appreciation by linking game features to spatial cognition concepts such as landmarks, route planning, and mental mapping (Özer et al, 2025). According to the ICOMOS (2008), heritage interpretation enhances public awareness, fosters respect, and deepens connections with cultural sites. Interpretation efforts should inspire curiosity, promote education, and facilitate engagement (Australia ICOMOS, 2013).

Interpretation plays a crucial role in conservation, often through signage, exhibitions, guides, films, books, and interactive media. Several studies have explored AR and MR applications in heritage contexts. Varinlioglu and Halici (2019) analyzed AR-compatible games to enhance visitor engagement. Krzywinska et al. (2020) used MR glasses to recreate WWII telegraph training, while Chen, Guo and Lo (2021) employed HoloLens to present Chaozhou's history with 3D models. Banfi et al. (2021) recreated Milan's Cerchia dei Navigli through AR storytelling. The Augmented Museum project enables visitors to interact with digital artefacts via HoloLens (Giariskanis et al, 2022), demonstrating MR's role in both tangible and intangible heritage experiences.

SPATIAL NARRATIVE DESIGN IN MR

The integration of engaging storytelling elements within the physical route is essential for effective spatial narrative design in MR.

Route design

The first phase of our project was focused on designing the route based on the principles of heritage interpretation, including Provoke, Relate, Reveal, Address the Whole, and Message Unity, to create an engaging visitor experience that provides historical information (Gül et al, 2023). In this phase, we analyzed the historical site through visits with a historical expert, research on literature, observation of visitors' behaviors on the site, photogrammetric modelling (Sancak et al, 2023), workshops and investigation of approximately 300 Instagram images. This comprehensive approach ensured that the route provided precise historical facts while engaging visitors in an immersive and informative experience. As a result, the six focal points/areas in the Yedikule Fortress historical site that we called nodes are identified (Figure 1).

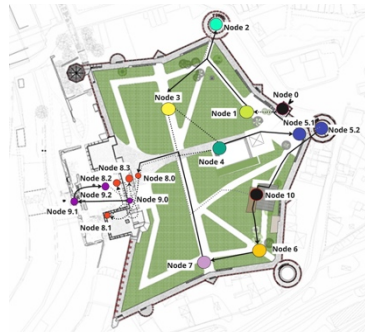


Figure 1
The nodes have narration, and links shows the direction from one point to another in the historical site of Yedikule Fortress

These nodes are connected through a designed path that we called links with visual and auditory signals to enable a spatial narrative throughout the site. Auditory signals include historical narratives vocalized using an AI voice generator (PlayAI, n.d.) as the guide. Visual elements consist of diegetic and interactive elements, such as objects, puzzles and collectible goods, incorporating a gamified aspect into the informative storytelling.

Spatial narrative and interface design for HoloLens 2

MR technology through Hololens 2 provides an immersive spatial narrative experience by overlaying virtual objects onto the real world without screen-based barriers. For the project, we created two MR experiences, one involving gamified components and the other not (Figure 2), to compare their effect on visitor's experience and awareness of the historical site. This process involved a continuous prototyping and evaluation process. We built the application on Unity using MRTK2 to support gesture-based interactions and spatial mapping, ensuring precise alignment of digital content with the Yedikule Fortress's physical context.

In the gamified experience, the visitor of the historical site is positioned as the main character. The AI guide Ahmet narrates historical context. According to the interpretive concepts established by Tilden (2008) and Ham (2013), at each node, various interactive game components such as mini puzzles, and collectible items are incorporated digitally in the HoloLens 2. The visitor progresses by completing the tasks in each node and in the end, discovers the secret of the historical site by connecting the collected clues. Selection of games and game mechanics focus on the importance of balancing challenge and skill to foster deep engagement (Cowley et., 2008; Csikszentmihalyi, 1990). Design goal is to sustain visitor attention without overwhelming or frustrating participants, many of whom had no prior experience with MR devices. The mechanics are chosen for their low learning curve, high intuitiveness, and immediate feedback, allowing visitors to remain within the interaction.

The gamified version is designed with interactive puzzles, quizzes, and collected objects including gold coins (sikke) and objects related to the historical storylines of the site. Collecting these objects, solving jigsaw puzzles and

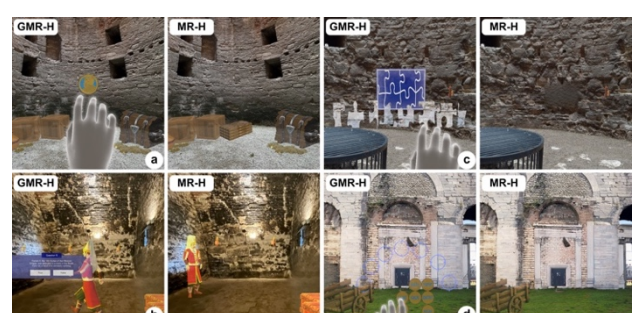


Figure 2
The comparison of gamified and non-gamified HoloLens experiences. The gamified version includes interactive elements such as coin collecting (a), quizzes (b), puzzles (c), and a final puzzle (d), while the non-gamified version presents the experience without these mechanics

completing the tasks on the route reveals a historical secret of the location, such as decoding the Latin inscriptions on the Golden Gate. As the interface of spatial interaction, a gesture-activated hand menu that has four buttons as Coins, Info, Objects, and Route (Figure 3a), is implemented. The interface is activated by a natural wrist motion, providing that digital content is easily accessible without interrupting the immersive experience. Some visual elements in screenshots appear distorted due to capturing holographic interactions and HoloLens 2 field-of-view limitations (Figure 3a, b).

The non-gamified experience offers visitors historical narrative, 3D visual reconstructions, and spatially anchored visual historical decorations while excluding interactive challenges and collectibles. For the non-gamified version, a gesture-activated hand menu as a main menu is implemented as well. The hand menu contains two main buttons: Info and Route (Figure 3b).

The audio feedback for button interactions is identical across both versions, in addition to other audio effects such as collecting coins or opening and closing info cards. This consistency is achieved by utilizing MRTK 2 toolkit interface elements that align with our gamified experience, thus providing a unified user experience framework across both versions. Prototyping is essential to enhance the interface and user experience design. Preliminary prototypes are created utilizing the Unity game engine and the MRTK2 library, with complex 3D models optimized in Blender and Rhino to ensure optimum performance for HoloLens 2. Design and performance evaluations are performed via on-site testing, expert feedback, surveys, sketch maps, and interviews to improve interactive components, interface layout, and narrative timing.

COMPARATIVE STUDY DESIGN

The broader research represents a comprehensive user-oriented study that examines the perception

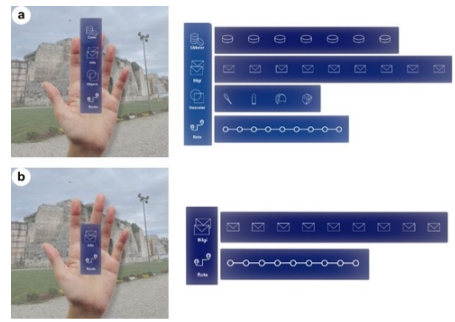


Figure 3
The hand menu with associated submenus on HoloLens 2 with game (a) and non-gamified (b) versions

of space and historical narrative in two environments related to technology involvement named One Reality and Mixed Reality (OR vs MR), as well as gamification involvement (GOR & GMR vs OR & MR) (Figure 4).

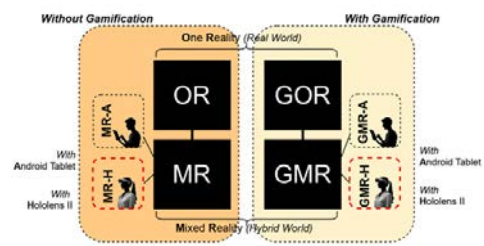


Figure 4
The comparative study design, this paper presents the development of the HoloLens experience with and without game elements (GMR-H vs MR-H) as highlighted red dashed line

This paper outlines the process of narrative development in MR, particularly focused on HoloLens 2 (H), and the user study results, which are developed through an experimental mixed method. This method includes a design, implementation, test (including pilot and expert studies), and refinement cycle (Creswell and Plano Clark, 2010; Ibrahim and Mohamed Ali, 2018).

The paper compares user perceptions of immersive heritage experiences with HoloLens for two versions: a gamified approach with interactive elements (GMR-H) and a non-gamified version (MR-H) with historical overlays and 3D reconstructions. Both versions shared the same route, audio narration, and visual cues, differing only in the presence or absence of game elements (Table 1).

Table 1
The application's features in gamified (GMR-H) and non-gamified version (MR-H)

Features	GMR-H	MR-H
Narration	AI voice guide	AI voice guide
Interface Design	Hand menu: Coins, Info, Objects, Route	Hand menu: Info, Route
Visual Content	Historical reconstructions and diegetic elements	Historical reconstructions and diegetic elements
Game elements	Puzzles, quizzes, collectibles	None
Interaction Type	Hand gestures, pointing, collecting	Hand gestures and pointing
Reward System	Reward-driven (Collecting, solving)	No rewards

This research utilized an open call approach, recruiting participants (N=40, 20 per group, GMR-H Female=10, MR-H Female=12, average age=30, SD=9) through public announcements and invitations, allowing for a diverse and voluntary sample to be gathered. It is conducted in accordance with the university's ethics committee regulations, with all necessary permissions obtained and informed consent forms signed by participants. Prior experience with MR devices was not necessary; as most participants had not used a HoloLens before, a tutorial scene was included in the application to guide them.

Materials and procedure

The study was conducted on the site with one participant at a time, by meeting the participant at the site entrance. At the beginning, each participant was requested to complete the consent form and the Santa Barbara Sense of Direction Scale (SBSoDS) (Hegarty et al, 2001) to baseline participants' spatial aptitudes. Then they were given a short HoloLens 2 tutorial scene, demonstrating basic hand gestures (e.g., air taps, pinching) and explaining how to interact with holograms.

In the gamified version, a tutorial also introduced jigsaw puzzle gestures (e.g., picking up virtual coins or aligning puzzle pieces) (Figure 5). Then, participants began the route and progressed through the predefined series of nodes connected by links. At each node, holographic overlays depict location-specific content such as architectural details, historical guide, and, when applicable, puzzle-based interactions.

In the gamified version, participants solved mini-puzzles or collected coins, triggering additional story elements. In the non-gamified version, participants viewed holographic reconstructions and listened to Ahmet without interactive challenges. Upon completion of the route, a detailed Post-Experience Survey (5-point Likert) was conducted. This survey encompassed multiple components:

- Route Experience Evaluation: questioning information adequacy, audio clarity, the effectiveness of spatial directions, the sense of exploration, and the overall engagement (e.g., "How would you evaluate the tour route?")
- Heritage Content Comprehension: evaluating their understanding and retention of historical and heritage-related information, naming specific historical identities and architectural features (e.g., "What do you remember most about the site?").
- Usability Assessment: gathering feedback on the comfort, ease of use, physical demands of interacting with the device, readability and visual clarity (e.g., "Rate the ease of interacting with holograms").

Additionally, semi-structured interviews were conducted immediately after the experiment that

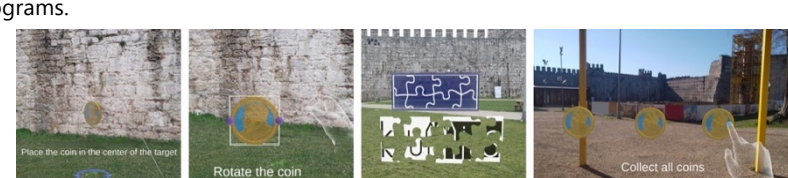


Figure 5
The scenes from the tutorial introducing users to HoloLens experience

aimed to elicit detailed descriptions from participants. Furthermore, they were asked to sketch their perceived route and indicate memorable architectural features, contributing valuable spatial recall data. These two data are not the topic of the present paper.

Each route lasted about 90 minutes in the non-gamified version and up to 120 minutes in the gamified version, depending on puzzle completion speed. The core challenges during the experiments were the bright sunlight, ergonomics, and battery life. Short breaks were scheduled between sessions to preserve device stability and to charge the battery. The hologram colors and placements are monitored and modified when necessary to provide the optimum conditions for participants.

ANALYSIS OF THE SURVEY

The average SBSoDS scores were high, indicating strong spatial confidence. This was evident in both the MR-H and GMR-H groups, with mean scores of 4.6 and 4.5. The data collected through the post survey were compared within each group (N=20 in GMR-H and N=20 in MR-H).

The analysis involved the visualization of survey results in histograms and conducting t-tests, followed by correlation analysis to identify significant relationships between results for a more detailed examination of meaningful findings. The resultant data were grouped based on question categories. The statistical significance of the association was determined by the p-value ($p > 0.05$). In this study, the strength and direction of the relationship between variables were assessed to better understand how one variable influences the other.

Route experience evaluation

Figure 6 compares the MR-H and GMR-H route experience scores (5-point Likert scale, with 5 denoting the highest score). The findings highlight differences in participant perceptions of the tour route, the information provided, and the efficiency of the device/application used during the experiment. The results indicate GMR-H scored higher in RE1, RE2, RE5, RE7, RE9; and RE3 and RE6 are almost equivalent in both groups.

It seems that in MR-H, the absence of game elements prompts participants to allocate greater attention to the audio narrative compared to GMR-H (RE4, RE8). Although the game components were expected influencing the route information and its content, RE3 (3.26 - 3.25) and RE6 (1.84 - 1.85) were equal for both groups. In contrast, the low scores for RE6 (1.84 - 1.85) and RE5 (2.11 - 2.45) indicated that most participants found the tour content sufficient.

Heritage content comprehension

Figure 7 compares MR-H and GMR-H in heritage content comprehension after visiting the site. This questionnaire comprises two open-ended questions: HR2 and HR3. HR2 inquired the names of two historical figures. The most memorized name was Osman II and then Mehmet the Conqueror. The reason may be the audio narrative telling the story of Osman II in one of the rooms in a tower. Most of the participants recalled two historical character names accurately

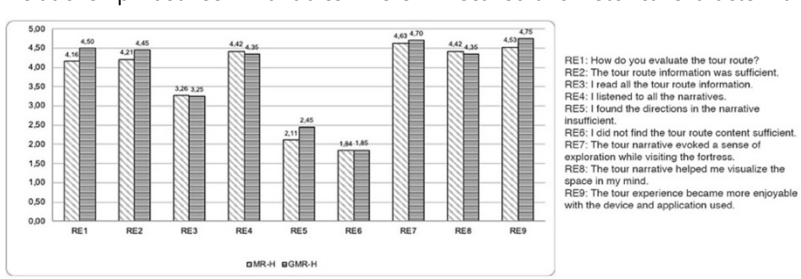
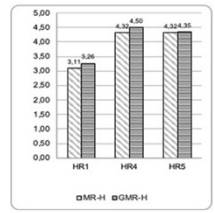


Figure 6
The average scores of route experience survey

(GMR-H: 70%; MR-H: 65%), while few participants recalled only one name (25% in both). 10% of MR-H did not name any.



HR1: How do you evaluate the preservation status of Yedikule Fortress?
HR4: This experience changed my perspective on the place.
HR5: Overall, this experience made me feel the need to research and learn more about the structure.

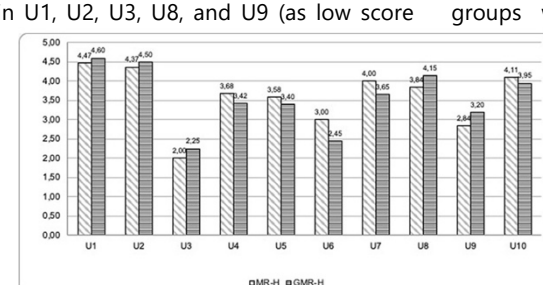
Figure 7
The average scores of heritage content comprehensive survey

HR3 asked the names of the two towers close to each other. Most of the answers included the Inscription and Treasury towers. 90% of GMR-H and 85% of MR-H demonstrated an accurate recollection of the tower names. The results show that the GMR-H scored slightly higher and the overall experience had a positive impact on perceiving the conservation status, changing their perception of the site in a valuable way and feeling slightly more inclined to learn more about the Inscription Tower.

Usability assessment

Figure 8 compares MR-H and GMR-H usability assessment responses. The findings suggest differences in comfort, ease of use, physical demands of interacting with the device, readability and clarity of visual content, and overall satisfaction with task performance during the site visit. The results indicate GMR-H scored higher in U1, U2, U3, U8, and U9 (as low score under 2.25). This finding suggests GMR-H exhibited a stronger consensus on the game features augmenting their sense of exploration, perceiving the tour as slightly more enjoyable than MR-H. Furthermore, GMR-H reported higher levels of confidence in the usage of gamified application and identified a stronger need for additional practice to achieve efficient use of the interface. Conversely, MR-H scored higher in U4, U5, U6, U7, and U10. GMR-H and MR-H exhibited similar performance in U4 and U5, with both groups achieving close scores (MR-H: 3.68, GMR-H: 3.42 and MR-H: 3.58, GMR-H: 3.40). This suggests MR-H participants perceived the device as being moderately more intuitive to use. This finding is consistent with our supposition that the collecting coins gesture (pointing and then pitching) in GMR-H, which was reported to be somewhat challenging, may have contributed to the observed outcomes.

In this study, statistical tests were selected based on the distribution of the data, as previously described by Mann and Whitney (1947). The Mann-Whitney U test was employed to analyze route experience, revealing a statistically significant difference in question 1 ($p < 0.0489$). Despite the p-value being very close to the 0.05 threshold, it still indicates a statistically significant difference. In the domain of historical recall, the graphical data failed to reveal any statistically significant differences. The results of the Mann-Whitney U test showed p-values > 0.05 for each question. Consequently, there is no statistically significant difference between the two groups with respect to "understanding the



U1: The headset/tablet and application provided to me supported the sense of exploration.
U2: The headset/tablet and application provided to me made the tour route more enjoyable.
U3: After using the headset/tablet and application for a certain period, I felt fatigue in my body.
U4: I think the headset/tablet and application provided to me were easy to use.
U5: I think controlling the headset/tablet and application provided to me was physically easy.
U6: I think the readability of the information on the application screen was low.
U7: I believe that many people can easily learn how to use the headset/tablet and application.
U8: I think I was able to use the application confidently.
U9: I think I need more experience to use the application effectively.
U10: To what extent did you successfully achieve the task completion goals, and how satisfied are you with your own performance?

Figure 8
The average scores of usability assessment

existing heritage content". While the test statistic values differ, these are not considered to be statistically significant. Regarding usability, no observable differences were identified in the graphical data. The results of the Mann-Whitney U test showed p-values > 0.05 for each question.

CONCLUDING REMARKS

The comparative study examining the gamified and non-gamified MR heritage experiences developed for HoloLens 2 revealed important insights into user experience, content comprehension, and usability within immersive cultural heritage contexts. Contrary to expectations suggested by existing literature, our findings indicate no significant difference in heritage content recall or route experience between GMR-H and MR-H users. This suggests that integrating the basic gaming mechanisms including coin collecting, puzzles, and quizzes into immersive heritage environments does not fundamentally improve historical understanding of the site.

However, the usability analysis shows slight differences. GMR-H required users to engage in a highly interactive environment, utilizing frequent hand gestures to interact. In contrast, MR-H involved minimal interaction, focusing on passive content through simple pointing gestures. This difference in interaction significantly influenced user engagement and cognitive processing. Participants in GMR-H reported heightened immersion and active involvement, aligning with existing studies that suggest gamification fosters hands-on exploration and task engagement. However, this immersed interactivity also appeared to increase cognitive load, as users had to manage game mechanics while simultaneously processing historical content. On the other hand, MR-H participants experienced a more passive yet concentrated interaction style, which may account for recalling spatial details and architectural features.

The main usability challenge in this study was device ergonomics. The GMR-H version was more demanding because the gestures required prolonged hand movements for grasping, aligning puzzle pieces and selecting virtual objects. Participants reported experiencing fatigue, especially during long sessions. By contrast, the MR-H version demanded fewer interaction requirements, leading to a more comfortable experience. This finding is related to usability studies highlighting the importance of minimizing repetitive gestures in MR applications.

GMR-H adopted a game-based learning approach. On the other hand, MR-H adopted a knowledge-based learning model. The study's findings indicate that game-based learning enhances engagement and motivation in users. The non-gamified knowledge-based learning model exhibited the potential to facilitate significant content recall and understanding by offering a more coherent and uninterrupted narrative. These findings underscore the necessity for a balanced approach, where gamified components do not overshadow the core content but rather serve to enhance learning without inducing cognitive overload.

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REFERENCES

Affleck, J. and Kvan, T. (2005) 'Reinterpreting virtual heritage', *Proceedings of the 10th International Conference on Computer Aided Architectural Design Research in Asia (CAADRIA 2005)*, 28–30 April 2005, New Delhi, India, vol. 1, pp. 169-178.

Australia ICOMOS (2013) *The Burra Charter: The Australia ICOMOS charter for places of cultural significance* [Original work published 1981].

Aydin, S. and Schnabel, M.A. (2016) 'The museum of gamers: unmediated cultural heritage through gaming', *Cultural Heritage In A Changing World*, pp. 125-141.

Banfi, F., Bolognesi, C. M., Bonini, J. A. and Mandelli, A. (2021) 'The virtual historical reconstruction of the Cerchia Dei Navigli of Milan: From historical archives, 3D survey and HBIM to the virtual visual storytelling', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVI-M-1-2021, pp. 39–46.

Chen, F., Guo, X. and Lo, T. (2021) 'MR Game for Historical Experience - A study on the interplay between tangible and intangible heritage in Chaozhou ancient town', *Proceedings of the 39th eCAADe Conference*, 8-10 September 2021, Novi Sad, Serbia, vol. 2, pp. 223–232.

Coenen, T., Mostmans, L. and Naessens, K. (2013) 'MuseUs: Case study of a pervasive cultural heritage serious game', *Journal on Computing and Cultural Heritage (JOCCH)*, 6(2), pp. 1-19.

Cowley, B., Charles, D. Black, M., and Hickey, R. (2008) 'Toward an understanding of flow in video games', *ACM Computers in Entertainment (CIE)*, 6(2), pp. 1-20.

Creswell, J.W and Plano Clark, V.L. (2010) *Designing and Conducting Mixed Methods Research*. 3rd edn. Thousand Oaks, CA: SAGE Publications.

Csikszentmihalyi, M. (1990) *Flow: The Psychology of Optimal Experience*. Harper and Row, New York.

Doulamis, A., Liarokapis, F., Petridis, P. and Miaoulis, G. (2012) 'Serious games for cultural applications', in: D. Plemenos and G. Miaoulis (eds.) *Intelligent Computer Graphics 2011*. Studies in Computational Intelligence, vol. 374. Berlin: Springer, pp. 97–115.

Dow, S., Lee, J., Oezbek, C., MacIntyre, B., Bolter, J. D. and Gandy, M. (2005) 'Exploring spatial narratives and mixed reality experiences in Oakland cemetery', *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology (ACE '05)*, 15-17 June 2005, Valencia, Spain, pp. 51-60.

Fanini, B. and Pagano, A. (2015) 'Interface design for serious game visual strategies the case study of "Imago Bononiae"', *Proceedings of the 2015 Digital Heritage International Congress (Digital Heritage)*, vol. 2, pp. 623–626.

Foni, A. E., Papagiannakis, G. and Magnenat-Thalmann, N. (2010) 'A taxonomy of visualization strategies for cultural heritage applications', *Journal on Computing and Cultural Heritage (JOCCH)*, 3(1), pp. 1-21.

Giariskanis, F., Kritikos, Y., Protopapadaki, E., Papanastasiou, A., Papadopoulou, E., and Mania, K. (2022) 'The augmented museum: A multimodal, game-based, augmented reality narrative for cultural heritage', *Proceedings of the 2022 ACM International Conference on Interactive Media Experiences (IMX '22)*, pp. 281–286.

Gül, F., Kilimci, E. S. Y., Özer, D.G., Moralioglu, B. and Coşkun, E. (2023) 'Fostering Cultural Heritage Awareness through Game Elements: Route Design for Mixed Reality Experience of the Yedikule Fortress', *Proceedings of the 11th International Conference of the Arab Society for Computation in Architecture, Art and Design (ASCAAD 2023)*, 7–9 November 2023, Amman, Jordan, pp. 652–666.

Gür, D. and Türel, Y.K. (2025) 'Beyond Play: Systematic Insights into Gamifying education across pedagogical, personal and gamification dimension', *Turkish Online Journal of distance Education*, 26(2), pp. 181-208.

Ham, S. H. (2013) *Interpretation: Making a Difference on Purpose*. Fulcrum Publishing, Colorado.

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K. and Subbiah, I. (2001) *The Santa Barbara Sense of Direction Scale (SBSOD)*. Unpublished manuscript, University of California, Santa Barbara.

Ibrahim, N. and Mohamad Ali, N. (2018) 'A Conceptual Framework for Designing Virtual Heritage Environment for Cultural Learning', *Journal on Computing and Cultural Heritage (JOCCH),* 11(2), pp. 1-27.

ICOMOS (2008) The ICOMOS charter for the interpretation and presentation of cultural heritage sites (The Ename Charter). Paris: ICOMOS.

Kim, H., An, S., Keum, S. and Woo, W. (2015) 'H-treasure hunt: A location and object-based serious game for

cultural heritage learning at a historic site', in: G. Meiselwitz (ed.) *Learning and Collaboration Technologies*. *Lecture Notes in Computer Science*, vol. 9192. Cham: Springer, pp. 561–572.

Krzywinska, T., Phillips, T., Parker, A. and Scott, M. J. (2020) 'From immersion's bleeding edge to the augmented telegrapher: A method for creating mixed reality games for museum and heritage contexts', *Journal on Computing and Cultural Heritage (JOCCH)*, 13(4), pp. 1-20.

Mann, H. B. and Whitney, D. R. (1947) 'On a test of whether one of two random variables is stochastically larger than the other', *The Annals of Mathematical Statistics*, 18(1), pp. 50-60.

Mariotti, S. (2021) 'The Use of Serious Games as an Educational and Dissemination Tool for Archaeological Heritage Potential and Challenges for the Future: Potential and Challenges for the Future ', *magazén: International Journal for Digital and Public Humanities*, **2**(1), pp. 119-138.

Mortara, M., Catalano, C.A., Bellotti, F., Fiucci, G. and Houry-Panchetti, M. (2014) 'Learning cultural heritage by serious games', *Journal of Cultural Heritage*, 15(3), pp. 318-325.

Özer, D.G., Gül, L.F., Coşkun, E., Yağmur-Kilimci, E.S. and Gül, M. (2025) 'Enhanced Knowledge Transfer in Historical Site Interpretation: A Gamified Approach for Yedikule Fortress/Türkiye', in Stellacci, S. and Aydin, S. (eds.) *Endangered Heritage Sites*. Springer Series of Cultural Computing. Cham: Springer.

PlayAI (n.d.) AI Voice Generator [Online]. Available at: https://play.ht/ (Accessed: 30 November 2022).

Portugal, C., Vaz, D., Dias, M.S., Trocado, P., Prata, A. and Abreu, F.B.e. (2025) 'Enhancing the Visitor Experience with Immersive Technologies and Gaming: The Monserrate Use Case', in: E. Kornyshova, R. Deneckère and S. Brinkkemper (eds.) *Smart life and smart life engineering: Current state and future vision,* Cham: Springer, pp. 273-291.

Sancak, N., Uzun, F., Turhan, K., Saraoglu Yumni, H. K. and Ozer, D. G. (2023) 'Photogrammetric model optimization in digitalization of architectural heritage: Yedikule Fortress', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-2-2023, pp. 1403–1410.

Santoso, H.B., Wang, J.C. and Windasari, N.A. (2022) 'Impact of multisensory extended reality on tourism experience journey', *Journal of Hospitality and Tourism Technology*, 13(3), pp. 356-385.

Skamantzari, M., Kontogianni, G., Georgopoulos, A. and Kazanis, S. (2017) 'Developing a virtual museum for the Stoa of Attalos', *9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*, pp. 260-263.

Tilden, F. (2008) *Interpreting our heritage*. 4th edn. The University of North Carolina Press.

Varinlioglu, G. and Halici, S. M. (2019) 'Gamification of heritage through augmented reality' *Proceedings of the 37th Education and Research in Computer Aided Architectural Design in Europe (eCAADe) and the 23rd Iberoamerican Society of Digital Graphics (SIGraDi)*, Joint Conference (Part 1), pp. 513–518.

Vaz de Carvalho, C., Latorre Andrés, P. M. and Serón Arbeloa, F. J. (2013) 'Serious games network', *Virtual Archaeology Review*, 4(9), pp. 174-180.

Volkmar, G., Wenig, N. and Malaka, R. (2018) 'Memorial quest-a location-based serious game for cultural heritage preservation', *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, 28-31 October, Melbourne, Australia, pp. 661-668.

Wang, Q., Chen, H., Li, J. and Zhu, D. (2016) 'A Methodology of Integrating Knowledge into Applied Game and Validation of Education and Entertainment Effects'. in: Z. Pan, A.D. Cheok, W. Müller and M. Zhang (eds.) *Transactions on edutainment XII*. *Lecture Notes in Computer Science*, vol. 9292. Berlin: Springer, pp. 21-37.

Welch, B. L. (1947) 'The generalization of "Student's" problem when several different population variances are involved', *Biometrika*, 34(1–2), pp. 28-35.