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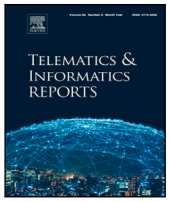

# Gamifying cultural heritage: Exploring the potential of immersive virtual exhibitions

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ABSTRACT

This paper reviews the potential of gamified cultural heritage in immersive virtual exhibitions. A systematic literature review following PRISMA guidelines identified 78 relevant papers from ACM and IEEE databases. Gamification and immersive technologies can provide interactive experiences to engage visitors and enhance their understanding of exhibits' historical and cultural significance. Theoretical frameworks, including gamification theory, heritage interpretation theory, participatory heritage, immersive experience theory, and pedagogy, guide designing compelling experiences. Case studies like "Rome Reborn", "Sutton House Stories", and "Assassin's Creed: Origins" demonstrate the efficacy of gamification in disseminating heritage. Key strategies include integrating augmented/virtual reality, multimodal data and 3D reconstruction, interactive narratives and gameplay, personalized experiences, advanced interfaces, balancing education and entertainment, and ensuring cultural sensitivity. Future work can explore AI-adaptive experiences, AR/VR integration, remote collaboration, educational game elements, and digital creativity models. Gamification and immersion provide innovative preservation and inheritance of cultural heritage. This review promotes digitalization and identifies literature gaps, supporting reflection on engagement's past, present, and future. It aims to enable a broader appreciation of cultural heritage through technology.

## 1. What is "Gamification"?

Gamification, as a concept, although deeply rooted in the historical lineage of games themselves, has emerged more recently as an academic term. The earliest mention of "Gamification" in the literature can be traced back to 2008, with systematic scientific research on gamification commencing around 2010 [1]. Regarding the definition of gamification, there is yet to be a consensus within the academic community. Scholars have proposed various interpretations based on their respective research perspectives.

Eser Çeker and Fezile Özdamlıoutlined the different perspectives in the research field of "Gamification" in their article published in 2017 [1]. Zichermann and Cunningham define gamification as a paradigm shift in thinking and applying game rules to enhance learner engagement and solve specific problems [2]. Yıldırım emphasizes from another perspective that gamification should not be perceived as omnipresent but rather as applying game design concepts to non-game contexts, a process inherently characterized by gamification elements [3]. Further, Deterding et al. view gamification as an emerging interdisciplinary methodology intended to augment learning motivation and stimulate enthusiasm through gamified means [4]. Bruder defines gamification as"non-gaming activities based on game principles", highlighting the need to blend various pedagogical and learning principles in completing complex tasks, utilizing gamification thinking and mechanisms to solve problems and enhance engagement [3].

Synthesizing these diverse viewpoints, this paper adopts and further develops the following definition of gamification in subsequent discussions: "Gamification refers to the purposeful application of game design elements and principles in non-game environments and activities, aimed at enhancing engagement, motivating users, and solving problems to improve user experience and achieve specific objectives".

## 2. Application of gamification framework in virtual exhibition

When discussing the application of gamification in virtual exhibitions, many theoretical frameworks provide a solid foundation for design (see Table 1). First, Fogg's behavioral model highlights three key factors of behavioral change: motivation, ability, and trigger, which

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**Table 1**
Important gamification frameworks and their applications.

| Frame | Core concept | Effects applied to virtual exhibitions |
|---|---|---|
| Fogg's Behavioral Model | Motivation, ability, trigger | Trigger design that promotes user behavior |
| Werbach's DMC Framework | Motive, means, triggers | Create an interactive environment that meets user needs |
| Zichermann's Motivational Framework | Intrinsic and extrinsic motivation | Balance rewards to suit different user motivations |
| Kapp's MDA Framework | Learning mechanism, motivation, aesthetics | Promote learning and engagement through gamification elements |

provides a direct guide to motivating user engagement [5]. This was followed by Werbach's DMC framework, which breaks down the gamification process into motivations, means, and triggers, providing a structured approach to creating engaging virtual experiences [6]. At the same time, Zichermann's intrinsic and extrinsic motivation framework emphasizes the different types of motivation that motivate user engagement, guiding designers to balance incentives to meet a wide range of user needs [2]. In addition, Kapp's learning Mechanism-Dynamic-Aesthetics (MDA) framework provides a multi-dimensional perspective for designing gamified learning experiences by focusing on learning dynamics and aesthetics [7].

The implementation of these frameworks guides how to integrate gamified elements, such as points, badges, leaderboards, etc., into virtual exhibitions to increase user engagement and learning efficiency. By introducing challenges, rewards, and social interactions, gamification design promotes emotional stimulation and social engagement, creating richer and more diverse user experiences.

However, relying on these frameworks alone does not fully address the design challenges of virtual exhibitions. Effective gamification design also needs to incorporate pedagogical principles, narrative techniques, and cultural sensitivity considerations, as well as the latest technological advances, such as VR, AR, and AI, to create more immersive and educational experiences. This integrated application will not only overcome the limitations of a single framework but also ensure that virtual exhibitions can better meet the needs of different users while promoting the understanding and appreciation of cultural heritage.

In conclusion, while gamification frameworks provide theoretical support and practical guidance for the design of virtual exhibitions, creating compelling and educational virtual exhibition experiences requires designers to consider multiple theories, user needs, and technological developments. Through this comprehensive approach, gamification can be a powerful bridge between users and cultural heritage, promoting a deeper understanding and wider dissemination of cultural heritage.

## 3. The human–computer interaction ecosystem of cultural heritage and digital technology

### *3.1. Literature collection and screening*

In this part of our study, we analyzed the human–computer interaction ecosystem between cultural heritage and digital technology. To this end, we employed comprehensive research methodologies such as data collection, spreadsheet organization, and meta-analysis. We followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematically collecting and organizing literature in related fields [8].

During the initial literature collection phase, we extensively utilized databases such as Google Scholar, ACM Digital Library, and IEEE Xplore to review academic papers on the gamification of cultural heritage and immersive virtual exhibitions. Following the preliminary screening, we identified "Cultural Heritage" AND "Gam*" AND ("Digital" OR "Immersi*" OR "Multimedia" OR "Interacti*" OR "Virtual*") as an efficient search keyword combination. On October 7, 2023, we searched the ACM Digital Library and IEEE Xplore databases using the keywords above, retrieving 167 documents, with 91 from the ACM and 76 from IEEE.

It is worth noting that the selection of ACM Digital Library and IEEE Xplore database for literature search in this study, rather than Web of Science and Scopus, was based on our study's specific needs and goals. Our work is a scoping review designed to explore the scope of existing research on gamification and immersive virtual exhibitions of cultural heritage rather than a comprehensive systematic review. Using a subject-specific database for keyword searches is sufficient and often more effective for scoping reviews. The ACM Digital Library and IEEE Xplore Database focus on computer science and engineering, making them ideal for exploring technical and interaction design literature relevant to our research topics. In addition, we conducted an extensive initial search through Google Scholar to ensure adequate coverage of the relevant literature. Therefore, our database selection is appropriate and can effectively support our research objectives.

In the first round of screening, we excluded 19 duplicate articles, reducing the total number of documents to 148. In the second round, we applied a minimum exclusion criterion to enhance the quality and representativeness of the selected literature. Specifically, we defined documents with less than four pages as short papers and excluded them, eliminating 53 short papers and leaving 95 remaining.

In the final round of screening, we established a detailed set of exclusion and inclusion criteria to ensure the academic rigor of the selection process. Through these criteria, we ensured that the selected literature strictly supported our research purpose and objectives. The specific criteria were as follows:

Exclusion Criteria (EC):

- EC1 Non-Main Conference Papers: Exclude articles published in supplementary conferences, poster presentations, extended abstracts, accompanying conference records, short papers, workshop proposals, position papers, demonstrations, or editorials.
- EC2 Missing Key Terms: Exclude articles not mentioning relevant vital terms (such as digital, immersive, multimedia, interactive, virtual, etc.). This reflects a potential irrelevance to the research theme.
- EC3 Misuse of Terminology: Exclude articles where the description or application of gamification does not align with the context of cultural heritage presentation. For example, articles that discuss "Gamification" merely as a classroom teaching method without addressing its application in cultural heritage presentation, such as enhancing the accessibility of cultural heritage materials, improving content interactivity, or enriching visitor experience, are considered a misuse of the term. This is because it needs to correctly reflect metadata's significant role and potential value in cultural heritage presentation. Similarly, articles that use technology for gamified learning or simple presentation of cultural heritage content without delving into its specific applications and impacts in cultural heritage presentation need to meet the research standards.
- EC4 Lack of Connection between Gamification and Cultural Heritage Presentation: Exclude articles that do not explicitly discuss the application of gamification in cultural heritage presentation. Articles that merely mention gamification without exploring its specific applications and impacts on cultural heritage presentation fail to meet the core focus of this research. For example, articles that focus on the design of game plots rather than their application in cultural heritage presentation or discussions of gamification methods that lack an apparent direct connection to presenting cultural heritage will be excluded.

- EC5 Marginal Mention of Gamification: Exclude articles where the mention of gamification is superficial, such as merely in the abstract or introduction, or where the application of gamification has a weak link to cultural heritage presentation and does not constitute the article's main content. This criterion ensures that the articles included focus on the practical application and in-depth analysis of gamification in cultural heritage presentation.
- EC6 Lack of Information: Exclude articles that need to provide sufficient detailed information to allow a complete application of coding standards.

Inclusion Criteria (IC):

- IC1 Application of Gamified Cultural Heritage: Include articles discussing the application of gamified cultural heritage in immersive virtual exhibitions, particularly those that provide visual and interactive experiences.
- IC2 Integrated Theoretical Frameworks: Include articles that analyze using frameworks of gamification theory, heritage interpretation theory, participatory cultural heritage, immersive experience theory, and educational theory.
- IC3 Case Studies: Include articles that conduct an in-depth analysis of specific cases, such as "Rome Reborn", "Sutton House Stories", "Assassin's Creed: Origins Discovery Tour", etc.
- IC4 Innovative Applications and Future Directions: Include articles exploring emerging directions such as AI-based adaptive experience design, augmented reality and virtual reality integration, remote visitation and collaboration, gamified educational applications, etc.
- IC5 Articles for Further Reading: If it needs to be clarified from an initial reading of the abstract whether an article meets the inclusion criteria, these articles will be included in a second screening phase.

Based on the criteria above, we conducted a detailed reading of the titles and abstracts of the 95 documents and a preliminary review of their entire content. As a result, 17 articles that did not meet the standards were excluded, yielding 78 documents as research samples for further comprehensive evaluation (see Fig. 1).

Our in-depth analysis of these 78 documents noted that their publication span extends from 2006 to 2023. Regarding the publication platforms, 31 of these documents were published in the ACM Digital Library, 40 in IEEE Xplore, four by Taylor and Francis, and three on other platforms. Concerning the distribution across journals or conferences, we observed that three documents were published in the VAST (Visual Analytics Science and Technology) conference, 1 in the CHI (Conference on Human Factors in Computing) conference, 5 in the IJHCI (International Journal of Human–Computer Interaction) journal, and 16 in the JOCCH (Journal on Computing and Cultural Heritage) journal (see Fig. 2).

### 3.2. Necessity and method of document classification

#### 3.2.1. Necessity of literature classification

The literature classification method adopted in this study is based on the following considerations: First, by classifying a large number of literature, the research status and trends in the field of cultural heritage gamification and virtual exhibition can be systematically understood. Second, classification helps to identify research gaps and challenges in the field, thus pointing the way for future research. Finally, through detailed categorical analysis, the application of specific topics or techniques in different cultural heritage gamification projects can be explored more deeply, thus revealing the interconnections and influences between different studies.

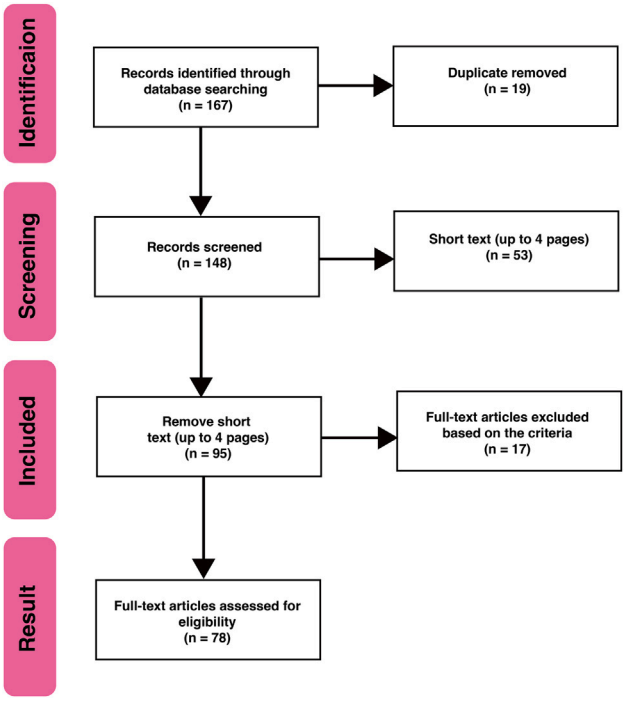


**Fig. 1.** Literature screening process.

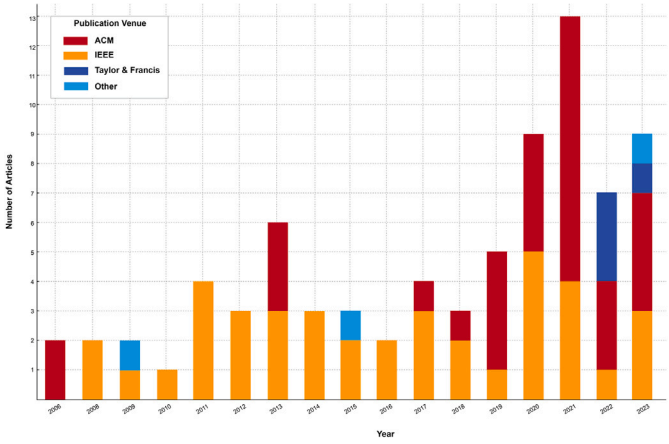


**Fig. 2.** Release date and publication platform of the final literature sample.

#### 3.2.2. Optimization of classification method

To effectively address the challenge of "many papers falling into more than one category" and to ensure the accuracy and comprehensiveness of classification, we have adopted a dominant idea and content-based classification approach:

We analyzed all the papers in depth to identify the main ideas or content of each paper, such as some papers may focus on a specific project. In contrast, others may focus on the application of cutting-edge technologies or experimental methods. This approach allows us to classify papers primarily based on their core contributions and focus. For those individual papers whose content covers more than one category, we allow them to belong to two or more categories simultaneously. Such a classification logic ensures a comprehensive and accurate understanding of the field while capturing the complex connections between the literature, making the classification more systematic.

By adopting a categorization approach based on dominant ideas and content, we not only address cross-category challenges but also

more accurately reflect the complexity and diversity of the field of gamification of cultural heritage and virtual exhibitions. This approach emphasizes the focus on the paper's main contributions and focus during the classification process, thus providing clear direction and insight for future research.

### 3.3. Literature categorization and analysis

#### 3.3.1. Papers centered on specific projects

In this study's literature categorization and analysis section, particularly in the in-depth literature review segment concerning the gamification of cultural heritage, we meticulously selected 45 papers focusing on specific projects as their core research subjects from the initial 78 research documents based on stringent criteria. The focal point of these papers predominantly revolves around exploring gamification strategies in disseminating and educating cultural heritage. The aim is to provide a comprehensive analytical framework for academic exploration and practical application in this field (see Table 2).

The primary characteristics and contributions of these studies include:

- Exploration of Gamification Application Strategies: These papers provide a detailed analysis of specific applications of gamification in the field of cultural heritage. This includes, but is not limited to, innovative use of game mechanics, methods of motivating participation, and the optimization of interactive experiences.
- Case Study Projects: The research samples encompass a range of representative case studies in the gamification of cultural heritage. These cases offer concrete examples of practical applications, bridging the gap between theoretical research and practical implementation.
- Integration of Interdisciplinary Perspectives: The collection of papers synthesizes research findings from multiple disciplinary fields, including game design, cultural heritage preservation, educational learning theories, and human–computer interaction technologies. This demonstrates the application prospects of gamification strategies in a diversified context.
- Evaluation of Gamification Effects: Some literature also includes assessments of the impact of gamification projects, such as participant engagement, learning outcomes, and user experience, through quantitative and qualitative analysis: *HieroQuest - A Serious Game for Learning Egyptian Hieroglyphs* [13]; *Location-Based Games for Cultural Heritage: Applying the Design Thinking Process* [16]; *Listening Space: An Exploratory Case Study on a Persuasive Game Designed to Enrich the Experience of Classical Music Concerts* [20]; *Enriching Malaysian Cultural and Folklore through Mobile Game Learning Development: Wau & Toyol* [25];*Natural interaction in VR environments for Cultural Heritage and its impact inside museums: The Etruscanning project* [39]; *I-BASA: Preserving Heritage Culture with IoT and Edge Cloud* [44]; *Development of a Virtual Reality Game for Cultural Heritage Education: The Voyage of "Gotheborg"* [52].

These 45 papers present a rich and diverse array of research findings and practical cases within gamified cultural heritage. Spanning multiple dimensions, such as aesthetic perception of artworks, virtual reality animation technology, and 3D online learning games, they collectively explore the potential and effectiveness of gamification strategies in enhancing the experience and education of cultural heritage. Specifically, the research encompasses practical applications of game design in enhancing the education of intangible cultural heritage, enriching interactive experiences with historical buildings and archaeological sites, improving linguistic learning efficiency, and augmenting participation in museums and exhibitions.

Employing various methodologies like empirical research, case studies, design prototypes, and framework construction, these papers demonstrate that gamification can be an effective educational tool to facilitate user learning and understanding of cultural heritage content while stimulating user engagement and interest. Case studies such as "ThIATRO" [11], "HieroQuest" [13], and location-based game [16] design highlight the potential of gamification in education and dissemination and reveal its value in preserving and transmitting cultural heritage.

Additionally, these papers unveil common challenges, including balancing educational objectives with the entertainment aspects of game design, ensuring cultural sensitivity and accuracy, and evaluating the real-world effectiveness of gamified learning. Overall, these studies provide a theoretical foundation and practical guidance for understanding and advancing the application of gamification in cultural heritage, offering significant reference value for future academic research and practical development.

These projects indicate that technologies like virtual reality, data mining, serious games, and 3D modeling are increasingly crucial in cultural heritage. By creating interactive, immersive experiences, these technologies offer new learning platforms and promote the preservation and dissemination of cultural heritage. Especially for the younger generation, these approaches provide engaging ways to explore and appreciate their cultural history.

In conclusion, these 45 papers not only deepen the theoretical understanding of gamification in cultural heritage but also provide significant practical reference value, playing a crucial role in advancing the preservation and transmission of cultural heritage in the digital era.

#### 3.3.2. Papers centered on cutting-edge technologies and research methods

In this overview's technology and methods section, after meticulous selection, we identified 19 papers focusing on cutting-edge technologies and research methodologies as their central research subjects. These papers are dedicated to exploring advanced technologies and research approaches that can be employed in the gamification of cultural heritage. They provide multidimensional perspectives and technical solutions for applying gamification methods and virtual technologies to preserve and disseminate cultural heritage (see Table 3).

The main features and contributions of these studies include:

- Application of Technological Innovations: The papers delve into the application of various emerging technologies in gamification, such as Augmented Reality (AR), Virtual Reality (VR), 3D modeling, and data visualization. These technologies provide new possibilities for the digital rendition of cultural heritage.
- Interaction Design Methods: A focused analysis of strategies and methods in interaction design within gamification projects, including User Experience Design (UX) and interface Design (UI), and their impact on user engagement and learning experiences.
- Integration of Multidisciplinary Methodologies: The papers demonstrate how knowledge and methods from multiple disciplinary fields such as computer science, game studies, anthropology, and history can be combined to facilitate effective dissemination and education of cultural heritage.
- Empirical Research and Case Analysis: These papers also contain empirical studies on the effects of specific technological applications, showcasing their efficacy and challenges in practical operations through case analyses.
- Sustainability and Adaptability of Technology Discussion: Discuss these technologies' sustainability, adaptability, and potential socio-cultural impacts in different cultural heritage contexts.

The studies above showcase how gamification and virtual technologies are crucial in enhancing engagement in cultural heritage education, enriching user experiences, facilitating knowledge dissemination, and protecting and documenting cultural assets in specific contexts such as the COVID-19 pandemic. They offer a range of innovative approaches for the digitalization and interactive display of cultural heritage, proving the practicality and expansiveness of gamified learning in the cultural domain.

**Table 2**
List of papers centered on specific projects.

| Project name | Short description | Link | Paper |
|---|---|---|---|
| PAGANS | Visitors' judgements of artwork similarity in a museum setting | https://doi.org/10.1145/3461663 | Sprugnoli et al. [9] |
| Dunhuang fresco | VR animation techniques in intangible cultural heritage games. | https://doi.org/10.1145/3488838.3488869 | Zou et al. [10] |
| ThIATRO | Learning art history online through 3D | https://doi.org/10.1145/2460376.2460378 | Froschauer et al. [11] |
| Egnatia Park | Four game design dimensions of experiences at archaeological sites | https://doi.org/10.1145/3382771 | Torsi et al. [12] |
| Hiero Quest | Learning Egyptian hieroglyphics through immersive virtual environments | https://doi.org/10.1145/3418038 | Plecher et al. [13] |
| Nerva Forum | Real-time navigation and interactive displays with AR and Blender | https://doi.org/10.1109/DigitalHeritage.2015.7419576 | Empler [14] |
| Nantong Blue Calico | Assess the impact of serious games on learning outcomes | https://doi.org/10.1145/3578837.3578849 | Zhou et al. [15] |
| Industrial Oil | To promote learning about industrial petroleum cultural heritage | https://doi.org/10.1145/3489410.3489419 | Koutsabasis et al. [16] |
| Groups | Cultural institutions promote human-social interaction | https://doi.org/10.1145/3290607.3312855 | Vayanou et al. [17] |
| FRACH | Immersive collaborative serious games in cultural heritage | https://doi.org/10.1145/3064644 | Andreoli et al. [18] |
| Jewels of Lublin | Board game enhances preservation of Lublin's cultural heritage | https://doi.org/10.1145/3446978 | Montusiewicz and Milosz [19] |
| Listening Space | Games enrich the classical concert experience | https://doi.org/10.1145/3458677 | Erdbrink et al. [20] |
| Praya Lane | Gamification enhances study in the cultural heritage of the community | https://doi.org/10.1080/10447318.2022.2144121 | Tan and Ng [21] |
| Cantonese Opera | Gamification for stimulating interest in learning Cantonese Opera | https://doi.org/10.1080/10447318.2022.2112567 | Pang et al. [22] |
| Portugal | Gamification strategies in ICH | https://doi.org/10.23919/CISTI52073.2021.9476328 | Cordeiro et al. [23] |
| Atacama | Gamification can increase children's motivation in learning | https://doi.org/10.1109/SCCC51225.2020.9281193 | Araya et al. [24] |
| Malaysian | Enriching learning experiences in Folklore in Malaysia | https://doi.org/10.1109/GAME50158.2020.9315081 | Ali et al. [25] |
| H2020 i-MARECULTURE | Enhance public awareness of Europe's underwater cultural heritage | https://doi.org/10.1109/OCEANSE.2017.8084984 | Bruno et al. [26] |
| Wheelbarrow | Enhancing its cultural value through immersive games | https://doi.org/10.1109/ICVR57957.2023.10169813 | Guojun et al. [27] |
| Malay Proverbs | Enhancing the learning of Malay proverbs | https://doi.org/10.1109/ICIT58056.2023.10226102 | Mazlan et al. [28] |
| Location-based APP | APP strengthening cultural heritage and collective memory | https://doi.org/10.2312/VAST/VAST09/001-008 | Koutsabasis et al. [16] |
| Shawbak Castle | Geographic information systems for the cultural heritage preservation | VAST. 2006: 67-74. | Drap et al. [29] |
| Australia | Audio experience to promote understanding of cultural heritage | VAST. 2006: 237-242. | Gibbons et al. [30] |
| Medieval towns | Digitalization as a means of tourism promotion | https://doi.org/10.1109/INNOVATIONS.2011.5893850 | Paolis et al. [31] |
| Cañari | The importance of educational games in cultural transmission | https://doi.org/10.1109/ARGENCON.2018.8646260 | Yaroslava Robles-Bykbaev et al. [32] |
| Jing-Hang Grand Canal | The potential of digital heritage for cultural preservation | https://doi.org/10.1109/MCG.2010.49 | Chen et al. [33] |
| Malaysian Folklore | Stimulating students' interest in Malaysian folklore | https://doi.org/10.1109/ITSIM.2008.4631538 | Chong et al. [34] |
| MediaEvo | Reconstructing a digital model of town to protect cultural heritage | https://doi.org/10.1109/ICCSN.2011.6013802 | Paolis et al. [35] |
| Pietrabuona Castle | Multidimensional characterization of cultural heritage | https://doi.org/10.1109/VSMM.2012.6365993 | Merlo et al. [36] |
| Schifffahrtsmuseum | Examples of game-based learning applied to cultural heritage | https://doi.org/10.1109/ICORIS52787.2021.9649584 | Pramono et al. [37] |

(*continued on next page*)

**Table 2** (*continued*).

| | | | |
|---|---|---|---|
| MediaEvo | Reconstructing Medieval Towns | https://doi.org/10.1109/ICCRD.2011.5763914 | Paolis et al. [38] |
| Etruscanning | Explored the use of interfaces based on body movement | https://doi.org/10.1109/VSMM.2012.6365943 | Pietroni et al. [39] |
| Musical Instruments | VR system for learning traditional Chinese musical instruments | https://doi.org/10.1109/VRW55335.2022.00080 | Zhang and Bryan-Kinns [40] |
| Post-independence architecture in Malaysia | Different approaches and technical challenges to 3D printing cultural heritage | https://doi.org/10.1109/VSMM.2014.713667 | Esmaeili et al. [41] |
| Locative Game | Combining immersion with real-world presence | – | Haahr [42] |
| Protestant reformation | MR technology is being used to tell historical narratives | https://doi.org/10.1109/VSMM.2016.7863203 | Viinikkala et al. [43] |
| I-BASA | Preserving heritage culture with IoT and edge cloud | https://doi.org/10.1145/3524458.3547122 | Susanto et al. [44] |
| Sports | Children's sports heritage | – | O'Connor et al. [45] |
| Borys Grinchenko | Gamification elements to promote cultural heritage | https://doi.org/10.1145/3526242.3526246 | Opryshko and Nazarovets [46] |
| DianTea | An immersive experience of the Chinese tea ordering ceremony | https://doi.org/10.1145/3565066.3608707 | Li et al. [47] |
| Decoding Kashgar | Using user data to discover the significance of cultural heritage | https://doi.org/10.1145/3084289.3084291 | Aydin [48] |
| Unreal Engine | Developing virtual environments with Unreal Engine | https://doi.org/10.1145/3480433.3480449 | Ren et al. [49] |
| HeGO | Users upload photos of cultural sites to enable accurate 3D reconstruction | https://doi.org/10.1145/3431926 | Fontanella et al. [50] |
| Educational AR books | An educational AR book for children aged 10–12 | https://doi.org/10.1109/IISA.2013.6623724 | Eleftheria et al. [51] |
| Gotheborg | A virtual reality game named The Voyage of "Gotheborg" | https://doi.org/10.1109/ICVR57957.2023.10169671 | Chen et al. [52] |

In the comprehensive literature exploration of gamified cultural heritage, researchers have enhanced the education and engagement of cultural heritage through various innovative technologies and methods. These technologies include Augmented Reality (AR), Virtual Reality (VR), 3D modeling and reconstruction, brain–computer interface technology, and mobile and location-aware technologies, which improve user interactivity and increase the accessibility of cultural heritage to varying degrees. The depth of the research reveals the importance of interactive digital narration, gamified learning, and multimodal presentation methods for the education and transmission of cultural heritage. These studies extend beyond the technology itself, encompassing in-depth considerations of User Experience (UX), emphasizing the need to balance intuitiveness and educational value in the design of tools and experiences. Future research is expected to optimize the design of these interactive systems further, enabling broader cultural dissemination and providing more diversified and personalized learning experiences, thereby playing a pivotal role in maintaining and promoting global cultural heritage.

In summary, these studies provide profound insights into the application of technology in the field of gamified cultural heritage and offer significant theoretical and practical guidance for the digital transformation of cultural heritage.

### *3.3.3. Papers emphasizing experiments or tests as primary research methods*

In this review's experiments and tests section, a meticulous selection process identified eight academic papers. These papers employ experiments or tests as their primary research methodology, aiming to assess and evaluate the advanced technologies applied in the gamification of cultural heritage. The selected papers encompass in-depth analysis and discussions of solutions regarding the application of gamification technologies and their integration with virtual technologies to protect and disseminate cultural heritage. By integrating these studies, this paper aims to provide a comprehensive assessment of the technological methods employed in the gamification of cultural heritage, thereby offering scientific references and guidance for research and practice in this field (see Table 4).

The main features and contributions of these studies include:

- Application of Experimental Methods: These papers explore the application of experimental design, user testing, and evaluation methods in gamification projects to validate the effectiveness of the proposed technologies.
- User Experience and Interaction Testing: Focused on assessing the impact of gamification elements on enhancing engagement and educational outcomes through user participation and interaction tests.
- Technological Validation and Performance Evaluation: Analyzed the actual performance of various technologies used in the gamification of cultural heritage, such as Augmented Reality (AR) and Virtual Reality (VR), including their stability, reliability, and user adaptability.
- Case Studies and Empirical Analysis: Provided detailed analyses of the practical application of these technologies through specific case studies, including successful implementations and challenges encountered.
- Suggestions for Improvement of Technology and Methods: Based on the testing of gamification projects, proposed recommendations for improving existing technologies and methods to enhance their application in disseminating cultural heritage.

The studies above indicate that integrating gamification and immersive technologies into cultural heritage education and presentation significantly enhances participant experience quality and knowledge acquisition efficiency. Through personalized virtual experiences, these technologies augment user engagement, sense of place, and understanding of cultural heritage content. Various research methodologies, including qualitative interviews, eye-tracking, narrative game evaluations, and mixed-methods studies, collectively validate the impact of

**Table 3**
List of papers centered on cutting-edge technologies and research methods.

| Technology or research method | Short description | Link | Paper |
|---|---|---|---|
| Innovative Cultural Experience (ICE) | A platform with interactive transparent screens and AR | https://doi.org/10.1145/3575879.3576001 | Kazanidis et al. [53] |
| IDN | UX Principles for Interactive Narrative Authoring Tools | https://doi.org/10.1145/3458769 | Green et al. [54] |
| HeGO | Users upload photos of cultural sites to enable accurate 3D reconstruction | https://doi.org/10.1145/3431926 | Fontanella et al. [50] |
| Dialogue management system | a Language interaction and easy-to-use authoring tools | https://doi.org/10.1145/2460376.2460381 | Mori et al. [55] |
| Four approaches | Exploring cultural dimensions in the context of digital game culture | https://doi.org/10.1145/2499931.2499933 | Suominen and Sivula [56] |
| Unity 3D | Multimodal data such as image-based 3D reconstruction | https://doi.org/10.1109/DigitalHeritage.2013.6744759 | Lercari et al. [57] |
| IVR | Incorporating multimodal interaction | https://doi.org/10.1080/10447318.2023.2232976 | Sun et al. [58] |
| 3D modeling | Using elements such as game narratives to build understanding of cultural heritage | https://doi.org/10.1109/ICISE-IE53922.2021.00269 | Zhang et al. [59] |
| Outdoor mobile AR system | An AR system integrating location-based navigation and puzzle-solving gameplay | https://doi.org/10.1109/ICVRV51359.2020.00027 | Ping et al. [60] |
| Prototype | A prototype using brain–computer interface technology is presented | https://doi.org/10.1109/VSMM.2012.6365937 | Vourvopoulos et al. [61] |
| Low-maintenance platform | Automated generation of questions about exhibits | https://doi.org/10.1109/IE49459.2020.9154911 | López-Martínez et al. [62] |
| Semantic Web technologies | Automated generation of interactive questions | https://doi.org/10.1109/VS-GAMES.2017.8056610 | Rizvic et al. [63] |
| MOOC | Aggregating lifelong learning data through gamification systems | https://doi.org/10.1109/Culture.and.Computing.2015.45 | Markovic and Sofronijevic [64] |
| GAINE | Provides high-level structure and simplified scripting language across operating systems | https://doi.org/10.4108/icst.intetain.2015.259627 | Bottino et al. [65] |
| Multimodal Interactive Game Framework | For virtualisation and modeling of cultural heritage | https://doi.org/10.1109/AICCSA47632.2019.9035357 | Belkhouche et al. [66] |
| TaggingCreaditor | A tool to create and share content | https://doi.org/10.1109/IMCTL.2014.7011148 | Sintoris et al. [67] |
| 3D Digitalization | Case Studies by the Use of a Multi-wavelengths Technique | https://doi.org/10.1109/ICIVC50857.2020.9177443 | Guarneri et al. [68] |
| costume-avatar | Simulated costumes combined with dance movement data | https://doi.org/10.1145/3537972.3537980 | Stergiou and Vosinakis [69] |
| 360° photography | A methodology for creating gamified learning experiences in 360° virtual environments | https://doi.org/10.1145/3594806.3594858 | Xhako et al. [70] |

game design elements and augmented reality interfaces on educational effectiveness. These findings underscore the critical role of technology in providing personalized learning paths and enhancing the interactivity of cultural heritage, suggesting a more central role for gamification and virtual reality technologies in the future of education and cultural dissemination. As technological advancements and research deepen, we can anticipate these tools becoming more finely tuned to meet the needs of diverse user groups, thereby ushering in a new era of cultural heritage conservation and education.

In summary, this body of research provides valuable experimental data and in-depth analyses for understanding and enhancing the application of gamification technologies in cultural heritage, laying a solid foundation for future research and practice.

### *3.3.4. Synoptic analysis of cultural heritage gamification*

The following nine articles collectively focus on utilizing modern technologies and methodologies to enhance cultural heritage's educational and presentational aspects. In particular, they emphasize enhancing user experience and learning outcomes through digital media, virtual reality, serious games, and interactive narrative methods. These studies encompass technological development, theoretical exploration, and methodological innovation, emphasizing the integration of user interface design and knowledge dissemination. These articles can be classified as synoptic research, comprehensively reviewing and analyzing current research and practices within their respective domains. Sometimes, they propose new research directions or application methods (see Table 5).

The main features and contributions of these studies are as follows:

- Integration of Technology and Methodology: These articles explore how advanced digital technologies can be integrated with traditional cultural heritage education and presentation methods to disseminate knowledge effectively.
- Theoretical Frameworks and Methodological Innovation: The research extends beyond mere technological development, encompassing in-depth explorations of related theories and innovations in methodology. This provides new theoretical perspectives for the digital study of cultural heritage.
- User Experience and Interface Design: There is a particular emphasis on the importance of user interface design and how design optimization can make knowledge dissemination more efficient and engaging for users.

**Table 4**
Papers that use experimentation or testing as the primary research methodology.

| Experimental method | Short description | Link | Paper |
|---|---|---|---|
| Qualitative experiment | Evaluation participants experience through head-mounted displays | https://doi.org/10.1109/VSMM.2016.7863169 | Ghani et al. [71] |
| Eye tracking | Cognitive traits promote adaptive mechanisms | https://doi.org/10.1145/3292057 | Raptis et al. [72] |
| Two interventions | The feasibility of narrative-based games in delivering cultural content | https://doi.org/10.1145/3414833 | Malegiannaki et al. [73] |
| Field and control experiments | Cultural heritage games in promoting users' influence on the city's history | https://doi.org/10.1145/3297716 | Jones et al. [74] |
| Mixed-Methods Study | The serious games is more effective than traditional teaching methods | https://doi.org/10.1080/10447318.2022.2125627 | Kara [75] |
| CubeMuseum AR | Effectiveness in users' motivation in learning about cultural heritage | https://doi.org/10.1080/10447318.2023.2171350 | Xu et al. [76] |
| Educational AR books | Technology for science learning | https://doi.org/10.1109/IISA.2013.6623724 | Eleftheria et al. [51] |
| Experimental visit test | Engagement in gamified tourism experiences, etc. | https://doi.org/10.1145/3341215.3354643 | Cesário et al. [77] |

**Table 5**
An overview analysis of the gamification of cultural heritage.

| Research area | Short description | Link | Paper |
|---|---|---|---|
| Modeling cultural heritage and education | The potential and effectiveness of games in education | https://doi.org/10.1145/3414831 | Champion [78] |
| Cultural presence | Innovative technologies in enhancing the cultural heritage experience | https://doi.org/10.1109/ISMSIT52890.2021.9604569 | Ekmekci [79] |
| Gotheborg | Potential impact of interdisciplinary research in the field of cultural heritage | https://doi.org/10.1109/ICVR57957.2023.10169671 | Chen et al. [52] |
| Augmented Visualization | Designing experience for an interpretative cultural heritage | https://doi.org/10.1109/IV.2008.103 | Flynn [80] |
| Digital Storytelling | Forms of interactive digital narrative guides for cultural heritage | https://doi.org/10.1109/VS-GAMES.2017.8056610 | Rizvic et al. [63] |
| User Interfaces | Exploring the feasibility of diegetic user interfaces within the cultural heritage | https://doi.org/10.1109/SITIS.2018.00101 | Caggianese et al. [81] |
| Museum Education | Mobile devices in education | https://doi.org/10.1109/DigitalHeritage.2013.6744831 | Gicquel et al. [82] |
| CTU Prague | Developed a systematic approach to user interface design | https://doi.org/10.1109/VSMM.2009.38 | Mikovec et al. [83] |
| SSocial sciences | The potential of serious games in sociological research | https://doi.org/10.1145/3483529.3483660 | Andrade [84] |

- Interdisciplinary Fusion: These studies demonstrate significant interdisciplinary characteristics, combining knowledge from computer science, cultural heritage studies, and education, thereby presenting a diversified research perspective.
- Proposal of New Research Directions and Application Methods: Building on a comprehensive review and analysis of current research and practice, some studies also propose new research directions or application methods, offering potential pathways for future developments in the field.

Collectively, these publications reveal the significant potential of gamification technologies and digital media in preserving, disseminating, educating, and enhancing experiences related to cultural heritage. They focus on realizing cultural presence through video games and employing innovative technologies such as Virtual Reality, Augmented Reality, and mobile learning environments to facilitate education and experiences in cultural heritage. These studies demonstrate the application of interdisciplinary approaches in developing interactive digital narrative technologies and their use in cultural transmission, emphasizing the proactive role of users in knowledge creation. Furthermore, these papers highlight the importance of narrative-based user interface design in immersive exhibitions and explore the potential of severe games in promoting sociological research, education, and cultural knowledge transfer. The current research challenges shift towards designing user-centric interactive systems and combining collaborations between cultural institutions and social actors to optimize these interactive experiences, thereby constructing more inclusive, educational, and immersive pathways for cultural heritage dissemination in the future.

In summary, these articles provide a comprehensive synoptic analysis of the gamification of cultural heritage, not only summarizing current research achievements but also directing future explorations and developments in the field.

### 3.4. Supplementary case analysis

To ensure a comprehensive, detailed, systematic, and rigorous discussion of the overall development in the field of gamification of cultural heritage, this review incorporates three selected case studies: "Rome Reborn", "The Story of Sutton House", and "Assassin's Creed: Origins Discovery Tour".

The reason for selecting these three cases is to demonstrate the application of gamified cultural heritage and immersive virtual exhibitions in different fields, technologies, and cultural contexts, as well as their positive impact on increasing audience engagement, deepening cultural understanding, and expanding audience groups. First, "Rome Reborn" shows how technology enables us to explore and


**Fig. 3.** "Rome Reborn".


**Fig. 4.** "Sutton House".


**Fig. 5.** "Assassin's Creed: Origins Discovery Tour".

experience the cultural heritage of historic cities through detailed three-dimensional reconstruction. Second, The Story of Sutton House combines emotional storytelling with cultural heritage through AR technology, demonstrating the potential of technology to deliver an in-depth and personalized educational experience. Finally, Assassin's Creed: Origins Discovery Tour is an educational platform based on popular games, demonstrating how gamification can promote interest and understanding of complex historical content. These three cases were selected because they each demonstrate how gamification and virtual technologies can be effectively used in the dissemination and education of cultural heritage in different technical, cultural and historical contexts, while highlighting the innovative potential of these approaches in engaging and educating audiences. Through these examples, we aim to demonstrate the diversity of technology applications in cultural heritage and its importance in enhancing cultural inheritance and educational experience.

### *3.4.1. "Rome Reborn"*

The "Rome Reborn" series of applications and videos are available for computers and VR headsets (see Fig. 3). Built on information technology and the internet and founded on a collaborative team conducting holistic research, it aims to create scientifically accurate 3D digital models depicting the development of the city of Rome from its first settlement in the late Bronze Age (circa 900 BC) to the early Middle Ages (circa 552 AD) when the population sharply declined [85]. The 3D models serve as a form of visualization. The visual elements of "Rome Reborn" offer a powerful means to deepen viewers' understanding of ancient Roman culture. Viewers can roam the virtual environment of ancient Rome, witnessing ancient buildings, streets, temples, theatres, etc., rather than merely looking at images or reading text descriptions. This immersive experience helps viewers understand ancient Roman culture more deeply as they can witness the city's scale and grandeur firsthand. Meanwhile, the detailed virtual modeling showcases various aspects of ancient Roman culture, including architectural styles, decorations, sculptures, daily life, entertainment, and religious rituals. Viewers can closely examine these cultural details, better understanding the richness and diversity of ancient Roman society and culture [85].

### *3.4.2. "Sutton House"*

"Sutton House" in Hackney, London, a Tudor-period building, had a 4-minute AR experience project - "Sutton House Stories", developed in 2019 (see Fig. 4). Utilizing Augmented Reality (AR) for emotional narration in a cultural heritage context, the narrative was developed based on the curatorial requirements of the site, with much content based on the archives of the house. Guided by three voices representing key figures who lived in the house over four centuries, visitors walk through the Great Hall, conversing with these voices and interacting with corresponding visuals and sounds [86]. The immersive virtual exhibition demonstrates the potential for emotional experiences. Utilizing virtual reality to create an immersive experience allows visitors to experience the heritage site as a sensory and bodily event, transforming the entire relationship between museum visitors or heritage site audiences and the heritage site into an experiential engagement with the past [87].

### *3.4.3. "Assassin's Creed: Origins Discovery Tour"*

"Assassin's Creed: Origins Discovery Tour" is a virtual educational experience developed based on the game "Assassin's Creed: Origins" (see Fig. 5). It uses the game engine to recreate ancient Egyptian cities, buildings, artefacts, and landscapes in a detailed 3D environment. These recreations are based on historical research and archaeological data, providing an authentic cultural heritage environment. Visitors can freely explore the virtual environment, interact with virtual guides, choose topics of interest, and learn about ancient Egypt's history, culture, and daily life. They can walk around the virtual world, stop to observe artefacts, architecture, and geographical landscapes, and delve into ancient civilization. Detailed historical and cultural information, including textual explanations, audio commentaries, images, and simulations, are also provided. This helps viewers understand ancient Egyptian culture and history more deeply. The virtual experience includes multiple themes covering different aspects of ancient Egypt, such as religion, architecture, social life, science, and art. This allows viewers to choose content that interests them most, personalizing their cultural heritage education experience [78]. In summary, "Assassin's Creed: Origins Discovery Tour" combines game technology and virtual environments with cultural heritage education, offering an interactive and engaging way to explore ancient civilizations and deepen viewers' understanding of history and culture. This innovative approach helps bring cultural heritage education to a broader audience and fosters interest and learning in history [78].

In conclusion, these cases demonstrate the positive effects of gamified cultural heritage and immersive virtual exhibitions in enhancing

audience engagement, deepening cultural understanding, and expanding audience reach. The gamification and virtualization of cultural heritage meet the audience's demand for knowledge and culture, and the interactivity and visual elements evoke positive emotional experiences, enhancing their cultural understanding.

### 3.5. Relevant theoretical frameworks

This paper will rely on gamification theory, heritage interpretation theory, participatory cultural heritage, immersive experience theory and pedagogy as the theoretical framework for this study to further illustrate how to integrate the theory with the core of the study and, in particular, how to promote the use and effectiveness of gamification principles in cultural heritage exhibitions. This study discusses good examples and realizations of the combination of novel digital technologies and game elements. The discussion of theories will provide academic guidance for this study.

#### 3.5.1. Gamification theory

Firstly, there is the theory of gamification, which focuses on how game design elements, principles, and thinking can be applied to non-game environments, in contrast to related concepts such as Alternative Reality Gaming (ARG), Games with a Purpose (GWAP) and Gamification Design, which emphasize the use of gamification techniques to enhance user engagement, motivation and experience. In the context of cultural heritage, gamification adds play elements and stimulates audience curiosity, exploration and learning. Gamification helps promote more profound understanding and emotional engagement with exhibits by introducing tasks, challenges, interactive storytelling, and feedback mechanisms. It is worth noting that gamification theory is currently present in several fields, such as education, information studies, human–computer interaction and health. The current shortcomings of gamification theory are discussed by Seaborne et al. such as the lack of empirical studies of effectiveness and the fact that the theoretical foundations and application guidelines still need to be mature [88]. However, it is still a comprehensive approach that integrates user motivation, engagement, and interaction. The authors argue that gamification can be used appropriately and improve interactive systems to enhance user experience; however, to further explore the practice of gamification and the impact it has, more empirical research is needed, such as experiments and surveys on how gamification affects user engagement, learning outcomes and user experience. In summary, gamification theory provides ideas and methods for cultural heritage exhibitions, which can help to understand and design exciting and interactive exhibitions, thus increasing user viscosity and improving their engagement and immersion.

#### 3.5.2. Heritage interpretation theory

Second, is heritage interpretation theory, which centers on communicating and explaining the significance and value of cultural heritage to the public and emphasizes the importance of the narrative, audience participation and cultural sensitivity in heritage displays; most importantly, heritage interpretation theory can enhance visitors' sense of place and place identity. Combining this with virtual exhibitions allows visitors to experience and understand exhibits from multiple perspectives, thereby increasing the effectiveness and cultural identity of the exhibition. It is worth noting that Uzzell assessed whether museums promoted visitors' perceptions of the heritage of the place in question, and the results were promising [89]. However, simple architectural heritage displays appeared to need to be more satisfactory with this conclusion in mind, including heritage interpretation theory is critical as it can suggest normative roles and functions for museums and heritage places that are not limited to the display of history but also the interpretation and reproduction of history. Such an approach helps to avoid vulgarization and simplification of history while enhancing the public's understanding of history and culture more deeply. Of course, not all approaches are only beneficial. The theory of heritage interpretation has its duality: on the one hand, it promotes the development of urban, industrial and rural areas through regenerative tourism and conservation projects; on the other hand, it has also been criticized for simplifying the past and teaching the public a romanticized and superficial view of the past. Therefore, finding a balance between the above two is significant and is one of the difficulties we face in utilizing the heritage interpretation theory in this study. Applying the theory to actual exhibitions can enhance visitors' sense of place identity and improve their understanding and appreciation of cultural heritage.

#### 3.5.3. Cultural heritage theory

Participatory cultural heritage theory was also applied in this study, which Chern et al. argue is moving towards a post-custodial, participatory paradigm that emphasizes the audience's active role in creating, interpreting and preserving cultural heritage [90]. Because it follows the principles of collaboration, interaction and sharing, applying the theory allows for more immersive audience participation in the experience and learning of cultural heritage. Digital platforms play an essential role in realizing participatory cultural theory because digital platforms facilitate the collection, curation, and sharing of collective memory. Through digital technologies, participatory cultural heritage activities can engage the public more broadly and deeply. However, a range of studies have shown that the participation realized through digital platforms varies in nature, depth and scope, and it is helpful to adopt a spectral approach to conceptualize and envisage the different levels of participation in participatory cultural heritage. Collective analyses have shown that more profound levels of engagement and sustained participation can be evidenced when projects focus on human-centered computing and are community-based.

In conclusion, in the context of cultural heritage exhibitions, participatory cultural heritage theory provides theoretical guidance for this study to design more inclusive and participatory exhibition experiences. By utilizing digital platforms and the principles of human-centered computing, public engagement and connectivity with cultural heritage can be enhanced whilst also contributing to the presentation of broader and diverse cultural perspectives. This participatory approach can provide a more comprehensive and authentic reflection of a community's history and culture while promoting the preservation and transmission of cultural heritage.

#### 3.5.4. Immersive experience theory

In addition, immersive experience theory has been increasingly applied in cultural heritage exhibitions, mainly discussing creating more immersive exhibition effects through technical means, such as AR, VR, 3D reconstruction, and other technologies. Currently, the definition and discussion of immersive experience are from two perspectives: system perspective immersion usually focuses on the design of technology and environment; Immersion from the user perspective is more about the depth of the experience [91]. The aim is to allow the audience to experience a more interactive and immersive exhibition, thus breaking through the single and tedious nature of traditional exhibitions. Researchers and curators are committed to immersive experiences because they can significantly enhance the depth of user interaction with content and enhance their perceptual and cognitive coherence. The measurement of exhibition immersion mainly relies on four methods: psychometric questionnaire, continuous subjective measurement, primary or secondary task performance, and neuropsychophysiological methods. This study will evaluate the exhibition immersion experience based on these measurement methods and improve the evaluation results. Undeniably, the theory of immersive experience gives new power to cultural heritage exhibitions, allowing them to play to the extreme and allowing the audience to experience the charm of exhibitions deeply. The measurement method mentioned above also provides an effective way to detect and evaluate the design and improvement of exhibitions. In short, the theory of immersive experience plays a huge role in further enhancing the audience's sense of experience immersion and cognition of cultural heritage.

#### 3.5.5. Pedagogical theory

Finally, the study will incorporate pedagogical theory, which provides a methodology for designing compelling learning experiences and emphasizes the importance of knowledge construction, learning skills and attitudes. Combining this with cultural exhibitions helps guide how to design exhibitions that combine knowledge acquisition, critical thinking and cultural understanding. This study focuses on both empirical and critical education. One of the common goals of these two pedagogies is to make education aim to develop a more just society, yet there still needs to be a match between theory and practice. This paper addresses this dilemma by focusing on how these quinoids can be utilized for more intentional classroom practice to achieve a shared vision of a more just world.

Regarding gamification's role in education, Garamkhand Surendeleg et al. points out that gamification aims to enhance user experience and engagement with the system and that education is a high-potential application of this concept [92]. Currently, research on 'Gamification in education' is still in its infancy, with the core objective of using game elements to improve the effectiveness of educational activities. In the context of cultural heritage exhibitions, applying pedagogical theories to exhibition design can help create more engaging, participatory and educational exhibition experiences. By further combining the goals of experiential and critical pedagogy and the techniques of gamification, more diverse and interactive learning environments can be provided, thus increasing audience motivation and cultural understanding.

In conclusion, pedagogical theories are crucial in designing and implementing cultural heritage exhibitions. By applying these theories in practice, we can create more meaningful and impactful educational experiences that contribute to transferring knowledge and constructing a more just and understanding society. Future research could further explore applying these theories in different exhibitions and educational settings and how innovation and change in education can be realized on a broader scale.

In conjunction with the above theoretical frameworks, this section explores how theoretical knowledge can be innovatively combined with gamification design and immersive technologies to enhance cultural heritage exhibitions' educational value and engagement. Through a multi-dimensional theoretical perspective, we can more fully understand and optimize the design and implementation of gamified cultural heritage exhibitions.

### 3.6. Gamification in cultural heritage: Advantages, limitations and strategies

#### 3.6.1. Advantages of the gamification approach to cultural heritage

The application of gamification methods in cultural heritage has dramatically improved the audience's participation and learning experience. By incorporating interactive game mechanics such as quests, achievement systems, and storytelling, gamification strategies inspire curiosity and engagement in audiences, and empirical studies and case studies further demonstrate how effective these strategies are in increasing engagement and satisfaction. In addition, gamified design, including role-playing and simulation experiences, promotes active learning and deepens the audience's understanding of the exhibition's content, helping them to absorb better and retain information. Gamification has also succeeded in broadening its audience, attracting a diverse audience including young people, gaming enthusiasts, and non-traditional museum visitors, highlighting the role of gamification in cultural communication by showing the participation stories of audiences from different backgrounds. Technological convergence, such as AR, VR and 3D reconstruction, combined with gamification elements, creates immersive experiences that enable cultural heritage to be activated innovatively, demonstrating how technology and creativity work together to present cultural heritage.

#### 3.6.2. Limitations of gamification approaches to cultural heritage

Although gamification approaches have significant advantages in the field of cultural heritage, their implementation also faces several limitations. The financial, technical and human resources required to develop and maintain high-quality gamified exhibitions are often significant, creating challenges for institutions with limited budgets. Technical barriers, especially requirements for specific technology or equipment, may limit participation by specific groups, especially audiences in technologically underdeveloped regions. In addition, gamification design must ensure cultural sensitivity and accuracy, requiring in-depth cultural research, collaboration with cultural experts, and supervised community engagement practices and continuous feedback. At the same time, the design process must balance educational goals with entertainment values to ensure that the gamified content is both educational and engaging. This requires careful strategic planning and practice, as well as the study of successful cases to achieve an effective integration of education and entertainment.

#### 3.6.3. How to use gamification principles effectively in cultural heritage exhibitions

In exploring the potential of immersive virtual exhibitions, applying gamification principles to cultural heritage exhibitions represents an innovative and productive approach. Grounded in a comprehensive analysis of existing literature, the ensuing delineates key strategies for realizing this objective. The following are specific implementation steps for this key strategy:

- Step 1: Multimodal Data Integration and 3D Reconstruction
  Integrate different forms of data (such as text, images, sound, etc.) and apply 3D reconstruction techniques. This requires collecting and processing multiple data types on the relevant cultural heritage, using 3D modeling and visualization techniques to recreate and present the cultural heritage. This step emphasizes the accuracy and diversity of the data to ensure the authenticity and comprehensiveness of the 3D reconstruction and provide a realistic learning experience.
- Step 2: Technology integration and immersive experience creation:
  Augmented reality (AR) and virtual reality (VR) technologies are used to create an immersive and interactive exhibition experience. This step includes the selection of technologies, the development of software and the creation of content, to increase the participation and quality of the experience of the participants and enhance their understanding and awareness of the cultural heritage content. Consider cost-effectiveness in technology selection to ensure project feasibility. The design process focuses on the educational value and engagement of the content, using storytelling and interactive tasks to enhance the appeal of the experience.
- Step 3: Consider the application of advanced technology
  Explore integrating cutting-edge technologies such as brain-computer interfaces and mobile AR systems to provide a more intuitive and immersive experience. Evaluate the practical application value and user acceptance of these technologies to ensure their introduction enhances the experience rather than adding unnecessary complexity.
- Step 4: Interactive narrative and gamified learning
  Combine game elements with narrative techniques to enhance participants' interest and improve the effectiveness of cultural education. This includes designing storylines, characters and interactive missions that present learning about cultural heritage through games to promote engagement and learning. This requires a balance between educational goals and fun, ensuring the game design is educational and engaging.

- Step 5: Personalized Experience and User Engagement
  Provide personalized virtual experiences that allow users to explore cultural heritage at their interest and pace. This requires the development of systems that can automatically adapt content to user preferences and behavior, enhancing user engagement and motivation to learn.
- Step 6: Balancing educational objectives with entertainment value
  Gamification content and mechanics are carefully designed to effectively balance educational goals and entertainment value. Adjust the content through user testing and feedback to ensure the game is fun and educational.
- Step 7: Cultural sensitivity and accuracy
  Ensure that the content of gamified exhibitions is culturally sensitive and accurate, respecting and accurately communicating the value and significance of cultural heritage. This includes in-depth research and examination of cultural heritage, as well as collaboration with cultural experts.
- Step 8: Evaluation and Feedback Mechanisms
  Establish practical evaluation and feedback mechanisms to monitor and enhance the quality and impact of gamified learning experiences. This requires developing systems that can collect user feedback and learning outcomes and adapt and iteratively optimize based on this data.

By following these steps, the gamified design of cultural heritage exhibitions can be effectively realized, creating more participatory, educational and immersive cultural heritage exhibitions that become essential platforms for knowledge dissemination and cultural experience.

## 4. Limitations of the research

While comprehensive in its exploration of gamification and immersive technologies in cultural heritage, this survey is subject to several limitations that merit acknowledgment. Firstly, the scope of literature reviewed was restricted to papers available within the ACM and IEEE databases, potentially omitting relevant studies published in other journals or platforms that could offer additional insights into the application and impact of gamification in cultural heritage. This database limitation may lead to a skewed understanding of the field, overlooking interdisciplinary contributions that might reside outside the typical purview of these databases.

Secondly, while rigorous, the methodological focus on systematic literature review following PRISMA guidelines limits the exploration of existing documented studies and their findings. The inherent nature of literature reviews means that emerging technologies and innovative gamification strategies in the nascent stages of development or application might not be adequately represented. Consequently, the survey may not fully capture the most cutting-edge or experimental approaches explored in the intersection of gamification and cultural heritage.

Furthermore, the reliance on published literature inherently limits the survey to the perspectives and biases present in existing research. It does not account for unpublished projects, failed experiments, or ongoing work that has yet to be documented, which could provide valuable lessons and insights into the challenges and opportunities of gamifying cultural heritage.

The analysis also predominantly focuses on the positive aspects and potential of gamification and immersive technologies, with less emphasis on critically examining their limitations or the complexity of their implementation in diverse cultural contexts. While efforts were made to discuss the limitations of gamification approaches, a deeper critical analysis of these limitations and practical implementation challenges would enhance the understanding of gamification's role in cultural heritage.

Lastly, the dynamic and rapidly evolving nature of digital technologies and gamification means that the findings and observations of this survey may quickly become outdated. The pace at which new technologies emerge and the context of their application in cultural heritage is subject to change, suggesting that continuous review and updating of literature are necessary to maintain relevance and accuracy.

In conclusion, while this survey provides valuable insights into the application of gamification and immersive technologies in cultural heritage, it is important for future research to address these limitations by expanding the scope of the literature review, incorporating a broader range of sources, and providing a more nuanced analysis of the challenges and practicalities of implementing gamification strategies in diverse cultural contexts.

## 5. Conclusion and future works

This research has conducted a comprehensive review exploring the potential of gamified cultural heritage in immersive virtual exhibitions. Through a systematic literature analysis following PRISMA guidelines, 78 relevant papers were identified from the ACM and IEEE databases. The research demonstrates that integrating immersive technologies like Augmented Reality, Virtual Reality, 3D reconstruction, and interactive narratives significantly enhances visitor engagement, cultural understanding, and the appeal of heritage exhibitions.

Case studies analyzed, including ''Rome Reborn'', ''Sutton House Stories'', and ''Assassin's Creed: Origins'', validate gamification's efficacy in disseminating cultural heritage. They improve audience participation, deepen cultural insights, and expand audience reach. The success of these cases highlights future development directions, including adaptive experiences with AI, AR/VR integration, remote collaboration, educational game elements, and digital creativity models.

Vital strategies were proposed for applying gamification principles in cultural heritage exhibitions. These include immersive technologies, multimodal data integration, balanced education and entertainment, cultural sensitivity, personalized experiences, advanced interfaces and assessment mechanisms. Such approaches can establish exhibitions as engaging platforms for knowledge dissemination and cultural experiences.

This paper has provided theoretical foundations and practical guidance regarding gamification and digitalization in cultural heritage. It promotes innovative preservation and inheritance of our past while exploring future visions. The research identifies literature gaps and supports reflecting on engagement's evolution, aiming to enable broader cultural appreciation through technology.

While this review paper has substantially advanced the understanding of gamified cultural heritage, ample opportunities remain for further exploration through future research. Quantitative empirical studies assessing the impact of gamification on metrics like visitor engagement, learning outcomes and user experience would provide valuable evidential insights. From an interdisciplinary perspective, additional research could investigate optimized frameworks and guidelines for balancing educational and entertainment objectives in gamified heritage exhibitions. The emerging extended reality, AI, and haptics technologies present promising avenues for creating personalized and adaptive exhibition experiences catering to diverse audiences. Scholars could also examine innovative gamification applications such as conversational interfaces, social interactivity, miniature worlds, and alternate reality games in the context of cultural heritage exhibitions. At the broader level, future research can explore novel business models, policy frameworks and digital ethics principles to promote the sustainable development of gamified cultural heritage across different societal and organizational contexts. Comparative analyses between diverse cultural settings and exhibition types would reveal best practices for implementing gamification in this domain. Building upon the theoretical and practical foundations established in this review paper, future research works can further unravel the immense potential of gamification and immersive technologies in transforming and enriching humanity's engagement with our shared cultural heritage.

## CRediT authorship contribution statement

**Hanbing Wang:** Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ze Gao:** Supervision, Project administration. **Xiaolin Zhang:** Writing – review & editing, Conceptualization. **Junyan Du:** Writing – review & editing, Data curation, Methodology. **Yidan Xu:** Investigation. **Ziqi Wang:** Methodology.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.teler.2024.100150.

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