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Cultural Edutainment Within the Context of Mixed Reality Heritage Tourism: A Systematic Review

Mazarina Md Zain[1,*], Nurhaya Baniyamin[1], Illyani Ibrahim[1], Khalilah Zakaria[1], Md Mizanur Rashid[2], Yasir Mohd Mustafah[3]

[1] Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, Malaysia
[2] School of Architecture & Built Environment, Faculty of Science, Engineering & Built Environment, Deakin University, Geelong, Australia
[3] Kulliyyah of Engineering, International Islamic University Malaysia, Malaysia

ABSTRACT

Within the heritage industry, Extended Reality (XR) is gaining popularity, and one particularly advanced option that stands out is mixed reality (MxR). This cutting-edge technology has the potential to revolutionize how people engage with and communicate cultural heritage, offering immersive experiences. The main objective of this study is to address the various potentials associated with implementing sophisticated mixed reality (MxR) technology to enhance user engagement in cultural heritage discovery. The problem statement explores how cutting-edge technology can be harnessed to effectively disseminate tangible and intangible cultural heritage elements in heritage urban landscape tourism sites. This study employs a systematic review methodology utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) procedure. Extensive searches are conducted across prominent databases, including Scopus, IEEE Xplore, and Web of Science (WoS). After a rigorous filtering process, the resulting data set consists of 40 pertinent research articles analyzed using a synthesis methodology. The review explores three main themes: (1) MxR technology, (2) edutainment, and (3) cultural heritage. The study's conclusion provides a concise overview of the main findings and implications of incorporating MxR into heritage tourism. It emphasizes the potential of MxR technology in smart tourism environments to communicate cultural edutainment experiences effectively. The report concludes by recommending further research and development in this domain, acknowledging the significant influence of MxR on the future of historical tourism and cultural edutainment.

Keywords:
Cultural edutainment; heritage tourism; mixed reality; smart tourism

1. Introduction

This paper systematically reviews "Mixed Reality" (MR) in cultural edutainment, focusing on its application in heritage tourism. Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MxR) are all subsets of Extended Reality (XR) digital technology, with Mixed Reality (MxR) uniquely combines both elements of VR and AR to create immersive experiences. Cultural edutainment is the fusion of cultural education and entertainment, engaging users in cultural heritage sites through

* *Corresponding author.*
E-mail address: mazarinamdzain@gmail.com

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educational experiences. The definition of cultural heritage encompasses tangible and intangible elements in physical forms, including built heritage, products of human creativity, natural physical features, and non-physical aspects that reflect the environment and the sense of place in heritage urban landscape. The research explore the implementation, impact, and potential of MxR in enhancing cultural heritage experiences within immersive cultural education. By seamlessly integrating physical and virtual elements, MxR creates immersive encounters that enrich the cultural significance of heritage sites and narratives. In heritage tourism, MxR technology has emerged as a powerful tool to connect historical stories with the present, offering visitors with unique and captivating experiences at cultural sites. By superimposing historical events and artifacts onto real locations, MxR revitalizes ancient sites, providing an immersive learning experience. This research aims to bridge the gap by investigating how cultural experiences can enhance cultural education through immersive methods. By incorporating MxR technology into cultural edutainment, the heritage tourism sector can provide more profound and immersive encounters, fostering a deeper appreciation for our shared cultural heritage.

2. Literature Review

2.1 Enhancing Heritage Urban Landscape Dissemination Through Mixed Reality Representation

MxR has significantly advanced the dissemination of architectural heritage in cultural heritage through interactive virtual tours and 3D representations of historic buildings, providing immersive experiences for visitors [1]. By utilizing morphological-metric, diagnostic, and archaeological analyses, these projects bring historical models to life, fostering appreciation and understanding among visitors and researchers. Unmanned Aerial Vehicles (UAVs) play a crucial role in safely acquiring data from challenging locations, further contributing to architectural heritage dissemination [2]. Integrating cloud computing and MxR platforms has enhanced accessibility, offering interactive 3D displays for smart tourism attractions and transforming architectural heritage preservation and presentation [3]. Additionally, digitizing art and cultural heritage through high-resolution digital archives and virtual reconstructions has created immersive experiences [4]. MxR technology in architectural heritage has been valuable for performance assessment and risk management with 3D reality-based and computer-based models integrated into VR tours [5]. Digitalization has also led to rich online resources for archaeology, offering specialized databases and interactive content for scholars, students, and the public [6]. MxR applications in museum collections have facilitated the dissemination of historical iconography and enhanced understanding of ancient architecture, bridging the past and present through interactive web applications and digital replicas [7]. Digital tools like digital modelings and VR exhibition systems have transformed architectural heritage conservation and restoration, providing insights into ancient structures and construction processes [8]. Overall, MxR technologies enrich the exploration and appreciation of cultural heritage, benefiting researchers, institutions, and visitors with innovative and interactive experiences.

2.2 Mixed Reality Technology Advancement in Heritage Edutainment

MxR technologies, including 3D modeling and virtual reality (VR), have revolutionized heritage edutainment by preserving and enhancing the understanding of architectural heritage. Researchers have utilized 3D modeling and VR to recreate historical structures, offering visitors immersive and realistic experiences of unfinished architectural spaces [9]. Digital heritage methodologies and interactive systems have preserved the aura of buildings, facilitating knowledge-sharing and public engagement [10]. These technologies connect audiences with the past, making heritage preservation

and dissemination accessible and engageable [11]. Integrating 3D surveys, BIM, and extended reality enriches cultural heritage knowledge [12]. Immersive VR applications enables the exploration of ancient fortresses, promoting cultural heritage appreciation [13]. MxR, through 3D digitization and AR applications, fosters engagement, interactive learning, and cultural appreciation [14, 15]. MxR technologies offer captivating ways to engage with architectural heritage, ensuring its preservation and appreciation. Figure 1 shows the cone of experience.

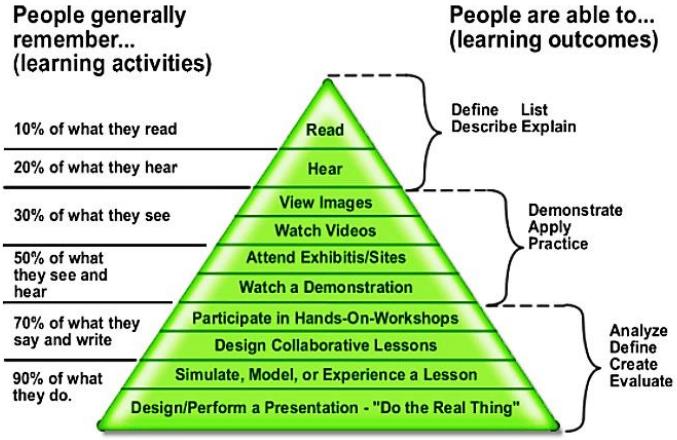

Fig. 1. Cone of experience (Source: Pagano *et al.,* [16])

2.3 Digitization and Virtual Representation of Heritage Urban Landscape Tourism Site

MxR has become a potent tool in disseminating heritage and urban landscape tourism sites, especially through digitization and virtual representation of archaeology and architectural heritage [17]. This technological advancement enables the connection of tangible and intangible cultural assets, supporting the conservation and documentation of cultural heritage. Virtual historical centers have further facilitated the archiving, storage, and dissemination of heritage knowledge, offering accessible and immersive experiences [18]. Figure 2 presents an example of the proposed method in digital reality development.

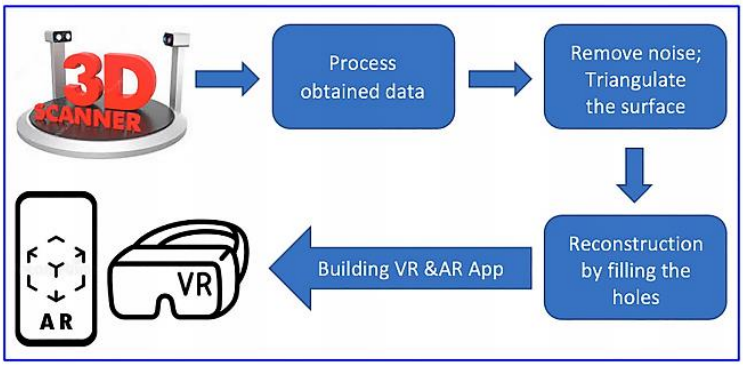

Fig. 2. Proposed method in digital reality development by Van Nguyen *et al.,* [18]

The Museum of Representation (Mu.Ra.) at the University of Catania adopts MxR to preserve and engage students, future designers, and potential visitors, fostering inclusive and interactive heritage tourism experiences [9]. MxR applications employing VR and AR technologies in architectural heritage recreate unfinished spaces and reanimate ancient cities, offering immersive and engaging

experiences [9]. The combination of BIM with VR and AR visualization makes architectural details accessible to the public [19]. Virtual architectural archaeology uses 4D capturing and component-based modeling to recreate lost heritage sites, promoting social cohesion and mutual understanding [20]. Virtual reality serves as a medium for knowledge transfer and cultural memory dissemination, conserving and displaying cultural evidence [21]. Digitization and virtual representation technologies revolutionize architectural heritage's recording, preservation, and communication, enhancing appreciation through interactive and immersive experiences in urban landscape tourism sites.

3. Methodology

Global studies have extensively explored systematic evaluations, but research explicitly focusing on extended reality technology, particularly MxR in cultural heritage contexts, is limited in Malaysia [22-24]. This section underscores the significance of conducting a systematic investigation into the global implementation of MxR in heritage sites. The subsequent section outlines the research methodology used to address the formulated research questions. The review is structured into two main areas: the potential of extended reality in tangible and intangible cultural heritage and the various types of extended facts used in cultural heritage presentations. Additionally, the study aims to examine the advantages of MxR in future cultural heritage edutainment, focusing on Malaysian heritage sites. The section comprehensively examines scholarly literature, identifying essential studies on MxR in cultural heritage contexts. Lastly, the paper addresses challenges and incorporates insights from relevant researchers. The systematic review follows the PRISMA approach, a recognized standard for systematic literature reviews.

3.1 Identification

The systematic review procedure involved three essential stages to select a substantial number of relevant papers for this investigation. In the first stage, keywords were carefully chosen, and related terms were identified using thesaurus, dictionaries, encyclopedias, and previous research. Once all relevant terms were determined, search strings for the databases Scopus, IEEE Xplore, and Web of Science (WOS) were created (see Table 1). During the initial step of the systematic review process, 559 papers were successfully retrieved from these three databases, marking the progress of the current research endeavor.

Table 1
The search strings

Scopus	TITLE-ABS-KEY (mixed OR mxr OR extended OR xr OR augmented OR ar OR virtual OR vr AND reality AND digital AND technology AND cultural AND edutainment OR education OR entertainment OR immersive AND heritage) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023))
IEEE	(mixed OR mxr OR extended OR xr OR augmented OR ar or virtual OR VR) AND reality AND digital AND technology AND Cultural AND (edutainment OR education OR entertainment OR immersive) AND heritage Filters Applied: IEEE, Journals, 2019 - 2023
WOS	(mixed OR mxr OR extended OR xr OR augmented OR ar or virtual OR VR) AND reality AND digital AND technology AND Cultural AND (edutainment OR education OR entertainment OR immersive) AND heritage Refined By: Open Access, Publication, Years: 2023 or 2022 or 2021 or 2020 or 2019, Document Types: Article, Languages: English

3.2 Screening

Throughout the initial screening process, duplicate, not accessible, and not comprehensible articles were disregarded. In the first round, 434 papers were excluded based on the researchers' specific inclusion and exclusion criteria. Subsequently, 99 items underwent a thorough examination in the next phase. Research articles were deemed essential for inclusion as they are the primary source of pertinent information. The study excluded systematic reviews, reviews, meta-analyses, meta-synthesis, book series, books, chapters, and conference proceedings. Moreover, the review was limited to studies published in English between 2019 and 2023 as shown in Table 2. The cumulative quality of 99 publications was assessed using the predetermined criteria.

Table 2
The search criteria are used for selection

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line / Years	2019 – 2023	< 2019
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

3.3 Eligibility

In the third level, referred to as an eligibility assessment, a total of 99 articles were considered. During this phase, thorough scrutiny of article titles and essential contents was conducted to ensure they were aligned with the inclusion criteria and complemented the objectives of the current study. As a result, 59 reports were excluded as their full texts were beyond the study's scope, lacking of significant relevance to the research, and their abstracts did not pertain to the study's focus. As of the present moment, 25 articles remain available for review (see Table 2).

3.4 Data Abstraction and Analysis

The study utilized an integrative analysis as a method of inquiry to examine and combine diverse research designs using qualitative methodologies (Figure 3). Proficient researchers aimed to identify suitable subjects and subcategories. The data-gathering phase involved meticulously examining 40 scholarly articles to extract pertinent assertions or facts for addressing the study's inquiries. The analysis yielded three primary themes: MxR, edutainment, and cultural heritage. The authors then elaborated on each subject, identifying interrelationships and correlations among themes, concepts, and ideas. The primary author collaborated with fellow authors to identify and develop thematic categories based on the research findings, maintaining a log to record analyses, opinions, perplexities, and other relevant thoughts. Disparities in theme creation were resolved through comparison and discussion. The established concepts underwent adjustments and refinements to maintain consistency. To verify the credibility of the inspection procedure, it underwent a thorough evaluation by two experts specializing in Architectural 3D Modelling Animation and Anthropology on the architectural built environment. The inclusion of the expert review phase served to enhance the comprehensibility, significance, and sufficiency of each sub-theme through domain validity, incorporating input and comments from experts, and making necessary revisions.

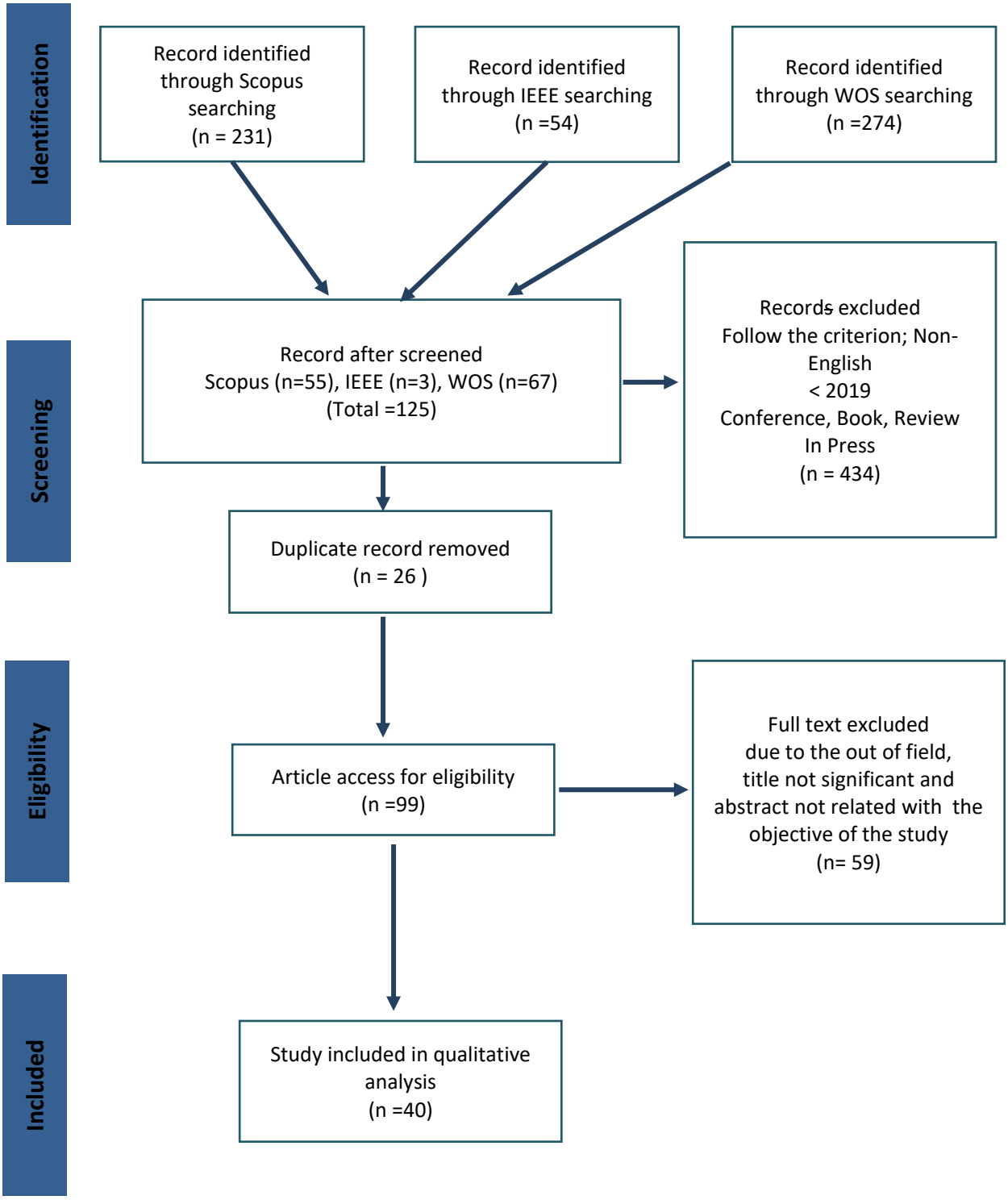

Fig. 3. Proposed research project flowchart

4. Results

The rapid growth and widespread adoption of smart digital technology in the cultural heritage industry have led to a significant shift towards a smart tourism approach. As this region embraces MxR technologies, the importance of public engagement has become increasingly prominent. Through a systematic review of 40 articles, two main themes emerged, focusing on the types of

heritage elements and the utilization of digital technologies. The heritage elements were categorized into tangible cultural heritage (21 articles) and intangible cultural heritage (19 articles). Regarding digital technology, the articles covered augmented reality (AR) (11 articles), virtual reality (VR) (16 articles), and MxR (1 article). Additionally, 11 articles utilized AR and VR technologies, while one explored extended reality (AR, VR, and MxR) in their study (Table 3).

Table 3
The research articles' findings are based on the proposed search criterion.

No	Author	Title	Sources			Heritage element		Digital technology			Research method	
			Scopus	IEEE	WOS	Tangible	Intangible	AR	VR	MxR	Case study	Empirical study
1	Zhong *et al.,* [25]	The Application of Virtual Reality Technology in the Digital Preservation of Cultural Heritage	/		/	/		/	/			/
2	Su *et al.,* [26]	Investigating the Relationship between Users' Behavioral Intentions and Learning Effects of VR System for Sustainable Tourism Development	/			/		/	/		/	
3	Bozorgi and Lischer-Katz [27]	Using 3D/VR for Research and Cultural Heritage Preservation: Project Update on the Virtual Ganjali Khan Project	/			/			/		/	
4	Bozzelli *et al.,* [28]	An Integrated VR/AR Framework for User-Centric Interactive Experience of Cultural Heritage: The ArkaeVision project	/			/			/			/
5	Tsepapadakis and Gavalas [29]	Are You Talking to Me? An Audio Augmented Reality Conversational Guide for Cultural Heritage	/			/		/				/
6	Hu *et al.,* [30]	Interactive Design and Implementation of a Digital Museum under the Background of AR and Blockchain Technology	/		/	/		/				/
7	Garro *et al.,* [31]	Impact of Location, Gender and Previous Experience on User Evaluation of Augmented Reality in Cultural Heritage: The Mjällby Crucifix Case Study	/			/		/				/
8	Rizvic *et al.,* [32]	Time Travel to the Past of Bosnia and Herzegovina Through Virtual and Augmented Reality	/		/	/			/			/
9	Damala *et al.,* [33]	The MUSETECH Model: A Comprehensive Evaluation Framework for Museum Technology	/		/	/		/	/		/	
10	Li *et al.,* [34]	Interactive Cultural Communication Effect in VR Space of Intelligent Mobile Communication Network	/		/	/			/		/	

Table 3. Continued

The research articles' findings are based on the proposed search criterion.

No	Author	Title	Sources			Heritage element		Digital technology			Research method	
			Scopus	IEEE	WOS	Tangible	Intangible	AR	VR	MxR	Case study	Empirical study
11	Presti and Carli [35]	Italian Catacombs and Their Digital Presence for Underground Heritage Sustainability	/		/		/	/	/		/	
12	Sun *et al.,* [36]	Restoring Dunhuang Murals: Crafting Cultural Heritage Preservation Knowledge into Immersive Virtual Reality Experience Design	/				/		/			/
13	Mavrin *et al.,* [37]	Immersive Cultural Tourism in the Context of COVID-19 Pandemic-Global Perspectives and Local Impacts	/			/			/			/
14	Kenderdine *et al.,* [38]	Radical Intangibles: Materializing the Ephemeral	/				/		/		/	
15	Arayaphan *et al.,* [39]	Digitalization of ancient fabric using virtual reality technology at the Wieng Yong House Museum: The FabricVR project	/				/		/			/
16	Manzollino *et al.,* [40]	Enhancement and Communication of Ancient Human Remains through VR: The Case Study of Sexual Dimorphism in the Human Skull	/		/		/		/			/
17	Hutson and Fulcher [41]	A Virtual Reality Educational Game for the Ethics of Cultural Heritage Repatriation	/		/		/		/			/
18	Van Nguyen *et al.,* [18]	Reconstruction of 3D Digital Heritage Objects for VR and AR Applications	/				/	/	/		/	
19	Sdravopoulou *et al.,* [42]	Naturalistic Approaches Applied to AR Technology: an Evaluation	/		/		/	/			/	
20	Taipina and Cardoso [43]	Spectare: Re-Designing a Stereoscope for a Cultural Heritage XR Experience	/		/		/		/			/
21	Gheorghiu and Ștefan [44]	Immersing into the Past: An augmented Reality Method to Link Tangible and Intangible Heritage	/				/	/			/	
22	Pagano *et al.,* [16]	ArkaeVision VR Game: User Experience Research Between Real and Virtual Paestum	/		/	/			/			/
23	Zhang *et al.,* [45]	A Virtual Experience System of Bamboo Weaving for Sustainable Research on Intangible Cultural Heritage Based on VR Technology	/		/		/		/			/

Table 3. Continued

The research articles' findings are based on the proposed search criterion.

No	Author	Title	Sources			Heritage element		Digital technology			Research method	
			Scopus	IEEE	WOS	Tangible	Intangible	AR	VR	MxR	Case study	Empirical study
24	Nishanbaev [46]	A Web Repository for Geo-Located 3D Digital Cultural Heritage Models	/			/			/		/	
25	Chen *et al.*, [47]	Design and Evaluation for Improving Lantern Culture Learning Experience with Augmented Reality	/				/	/				/
26	Bertrand *et al.,* [48]	From Readership to Usership: Communicating Heritage Digitally through Presence, Embodiment and Aesthetic Experience	/		/	/				/	/	
27	Okanovic *et al.,* [49]	Interaction in Extended Reality Applications for Cultural Heritage	/		/		/	/	/			/
28	Li *et al.,* [50]	Research on Relevant Dimensions of Tourism Experience of Intangible Cultural Heritage Lantern Festival: Integrating Generic Learning Outcomes With the Technology Acceptance Model	/		/		/	/				/
29	Echavarria *et al.,* [51]	Creative Experiences for Engaging Communities with Cultural Heritage through Place-based Narratives	/		/		/	/				/
30	Murphy *et al.,* [52]	A Human-Centred Systems Manifesto for Smart Digital Immersion in Industry 5.0: A Case Study of Cultural Heritage	/			/		/	/		/	
31	Ferretti *et al.,* [53]	A Comprehensive HBIM to XR Framework for Museum Management and User Experience in Ducal Palace at Urbino	/		/	/		/	/	/	/	
32	Kang and Su [54]	A Literature Analysis of Consumer Privacy Protection in Augmented Reality Applications in Creative and Cultural Industries: A Text Mining Study	/		/	/		/			/	
33	Shaharuddin *et al.,* [55]	A Review on the Malaysian and Indonesian Batik Production, Challenges, and Innovations in the 21st Century	/				/	/			/	
34	Martin *et al.,* [56]	A Digital Reconstruction of a Historical Building and Virtual Reintegration af Mural Paintings to Create an Interactive and	/		/		/		/		/	

Table 3. Continued
The research articles' findings are based on the proposed search criterion.

No	Author	Title	Sources			Heritage element		Digital technology			Research method	
			Scopus	IEEE	WOS	Tangible	Intangible	AR	VR	MxR	Case study	Empirical study
		Immersive Experience in Virtual Reality										
35	Puspasari *et al.,* [57]	Evaluation of Augmented Reality Application Development for Cultural Artefact Education	/			/		/				/
36	Man and Gao *et al.,* [58]	Digital Immersive Interactive Experience Design of Museum Cultural Heritage Based on Virtual Reality Technology	/			/		/	/			/
37	Čejka *et al.,* [59]	Evaluating the Potential of Augmented Reality Interfaces for Exploring Underwater Historical Sites		/			/	/			/	
38	Garro *et al.,* [31]	Impact of Location, Gender and Previous Experience on User Evaluation of Augmented Reality in Cultural Heritage: The Mjallby Crucifix Case Study			/	/		/	/			/
39	Su *et al.,* [26]	Investigating the Relationship between Users' Behavioral Intentions and Learning Effects of VR System for Sustainable Tourism Development			/		/	/	/		/	
40	Liritzis and Volonakis [60]	Cyber-Archaeometry: Novel Research and Learning Subject Overview			/	/			/		/	

4.1 Potential of Mixed Reality in Tangible Heritage Elements

Mixed Reality (MxR) technology offers great potential for safeguarding and showcasing tangible cultural heritage. Some studies have explored this domain, revealing MxR's capabilities. For instance, studies examined the use of digital edge technology in digitally conserving cultural treasures, playing a role in sustainable tourism and heritage edutainment, and transforming cultural exploration with the ArkaeVision project [28, 25, 26]. Tsepapadakis and Gavalas [29] unveiled Exhibot, a fusion of AR, chatbot, and IoT, aimed at enhancing cultural guidance. Other notable advancements encompassed the suggestion of AR and blockchain for digital museums, an examination of AR's influence on museum-goers, the MUSETECH model for appraising digital technology in museums, and the demonstration of VR's capabilities in cultural communications and musical presentations [30-34]. During pandemic, certain studies on advanced technology for cultural heritage dissemination were conducted. These included reshaping cultural encounters through immersive technology, creating a VR application for Italy's Paestum site, emphasizing narratives centred on users, utilizing AR Maps for community heritage connections, investigating immersive experiences, exploring the digitization of assets with HBIM and XR, and addressing privacy concerns related to AR [10, 37, 48, 51-54]. Certain studies improved learning using an AR app for artefacts, investigated VR's significance in museum

settings, examined the influence of AR on heritage, and introduced the concept of cyber-archaeometry as shown in Figures 4 to 7. Collectively, these studies showcased the diversity of MxR applications, contributing to the preservation and presentation of cultural heritage, enhancing education, and fostering a more profound cultural appreciation [31, 57-58, 60].

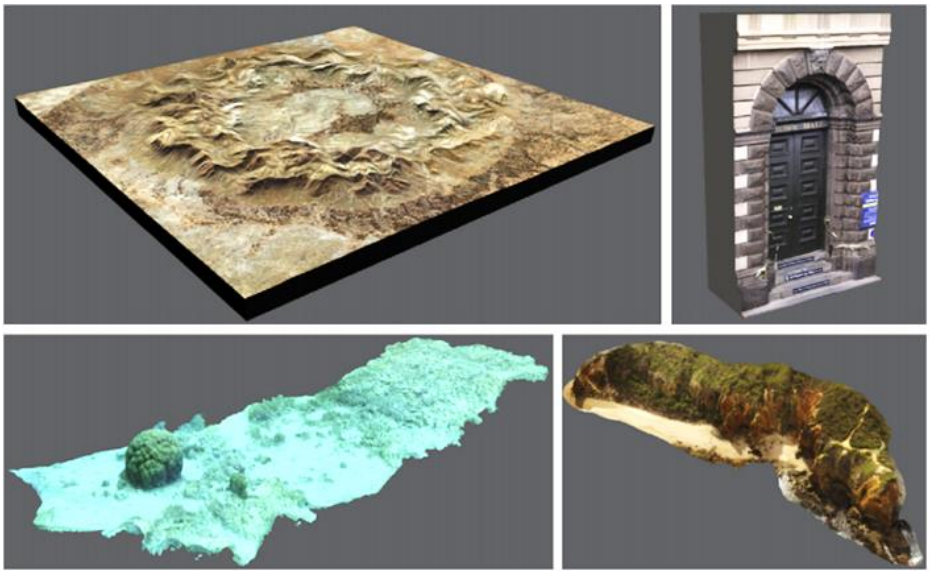

Fig. 4. Example of digitization cultural heritage model (Source: Nishanbaev [46])

Fig. 5. Example of interface in virtual reality exhibition (Source: Hutson and Fulcher [41])

Fig. 6. Example of AR Virtual Museum (Source: Bertrand *et al.,* [48])

Fig. 7. Visitors explore virtual heritage site (Temple of Hera) using HTC Vive (Source: Pagano *et al.,* [16])

4.2 Mixed Reality in Intangible Heritage Elements for Cultural Edutainment

Mixed Reality (MxR) technology offers significant potential for preserving and promoting intangible cultural heritage through engaging experiences. Research has explored various MxR applications, elevating cultural education and heritage conservation. For example, a study showcased the significance of MxR in Italian catacombs, employing augmented and virtual reality to restore Dunhuang murals via VR for heightened awareness. Other research delved into pandemic-induced cultural changes using immersive technology, endorsed naturalistic AR approaches, re-envisioned history with "Spectare," merged tangible and intangible heritage through Mobile Augmented Reality (MAR), and safeguarded the Dongyang bamboo weaving tradition via a virtual platform [35-37, 42-45]. Another illustration of advanced technology research for intangible heritage edutainment involves enhancing Lantern Culture education through AR and mobile tools, emphasizing the significance of digital storytelling, introducing the concept of "radical intangibles," utilizing VR to offer accessible heritage experiences, and employing VR for the study of ancient remains [38-40, 47, 49] Certain researchers have utilized VR to enrich cultural education, reconstruct historical artefacts through virtual means, and elevate Intangible Cultural Heritage (ICH) tourism experiences using Augmented Reality (AR) [18, 41, 15]. Additionally, research focused on involving youth in batik heritage, digitally revitalizing historical sites, enhancing underwater exploration through AR, and showcasing the beneficial effects of the 4DKanKan system on sustainable tourism education [26, 55, 56, 59]. These studies illustrate MxR's diverse applications in safeguarding cultural heritage, enriching education, and nurturing deeper cultural appreciation.

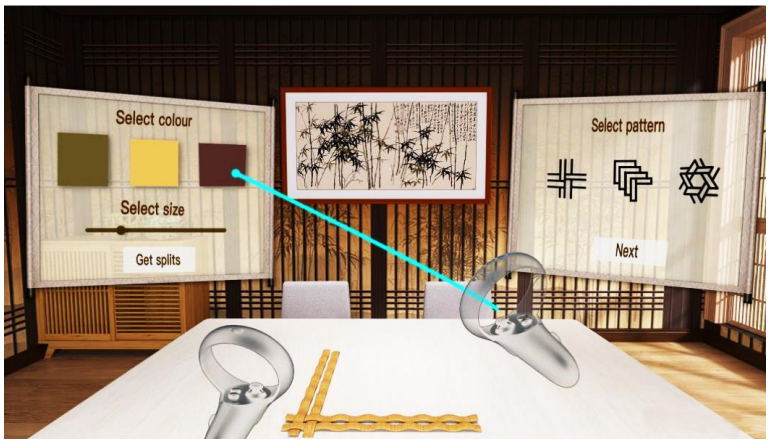

Fig. 8. Example of learning intangible cultural heritage (bamboo weaving patterns) in VR (Source: Zhang *et al.,* [45])

5. Discussion

This systematic review extensively examines the use of XR technologies in the cultural heritage sector, emphasizing the potential of MxR for cultural edutainment at heritage sites. MxR seamlessly integrates digital reconstructions of historic structures and artifacts into real-world environments, enriching the understanding of their historical context. Interactive MxR exhibitions enhance educational experiences and emotional connections with cultural elements. Moreover, MxR promotes accessibility, allowing individuals with physical impairments to engage virtually with historical monuments. Multilingual support broadens participation among diverse cultural backgrounds. However, the study acknowledges limitations, including the lack of MxR research in cultural edutainment compared to AR and VR and challenges like device costs and expertise shortages in this emerging field. Only two studies were identified, both emphasizing the significant role and impact of Mixed Reality (MxR) in heritage tourism [48, 53].

6. Conclusion

In conclusion, this systematic review of MxR in cultural heritage for edutainment highlights its transformative capabilities. MxR facilitates immersive storytellings, virtual performances, and interactive experiences and deepens the understanding and appreciation of cultural heritage. By preserving and promoting these aspects, MxR plays a vital role in safeguarding diversity and transmitting traditions to the future generations. Integrating MxR in cultural heritage environments enriches education, fostering stronger connections between visitors and cultural artefacts. The utilization of digital technology is an essential aspect of informal learning tools that can enhance users' understanding, knowledge, and visualization [61]. This study aims to explore cost-effective MxR solutions and draw insights from related XR subdomains like AR, VR, and MxR. The goal is to provide innovative and interactive experiences benefiting researchers, institutions, and visitors. Future research should focus on cost-effective MxR adoption, involving collaborative expertise to enhance content quality and user experiences.

References

[1] Bertocci, Stefano, Andrea Arrighetti, Andrea Lumini, and Federico Cioli. "Multidisciplinary study for the documentation of the Ramintoja Church in Vilnius. Development of 3D models for virtualization and historical reconstruction." *Disegnarecon* 14, no. 27 (2021): 13-1. https://doi.org/10.20365/disegnarecon.27.2021.13

[2] Germanese, Danila, Maria Antonietta Pascali, Andrea Berton, Giuseppe Riccardo Leone, Davide Moroni, Bushra Jalil, Marco Tampucci, and Antonio Benassi. "Architectural heritage: 3D documentation and structural monitoring using UAV." In *VIPERC@ IRCDL*, pp. 1-12. 2019.

[3] Lv, Hengxiu. "Construction of a virtual reality model of smart tourism scenic spot based on cloud computing." *Mathematical Problems in Engineering* 2022, no. 1 (2022): 5833861. https://doi.org/10.1155/2022/5833861

[4] Calisi, Daniele, and Stefano Botta. "Virtual reality and captured reality for cultural landscape communication." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 46 (2022): 113-120. https://doi.org/10.5194/isprs-archives-XLVI-2-W1-2022-113-2022

[5] De Fino, Mariella, Silvana Bruno, and Fabio Fatiguso. "Dissemination, assessment and management of historic buildings by thematic virtual tours and 3D models." *Virtual Archaeology Review* 13, no. 26 (2022): 88-102. https://doi.org/10.4995/var.2022.15426

[6] Alberti, Maria Emanuela, Cristian Faralli, and Anna Margherita Jasink. "A multivariate use of digital cultural heritage: Online resources for archaeology in the DBAS—MUSINT websites (University of Florence, Italy)." *Digital Cultural Heritage* (2020): 139-156. https://doi.org/10.1007/978-3-030-15200-0_10

[7] Turco, Massimiliano Lo, Paolo Piumatti, Michele Calvano, Elisabetta Caterina Giovannini, Noemi Mafrici, Andrea Tomalini, and Bruno Fanini. "Interactive digital environments for cultural heritage and museums. Building a digital

ecosystem to display hidden collections." *Disegnarecon* 12, no. 23 (2019): 7-1. https://doi.org/10.20365/disegnarecon.23.2019.7

[8] Wang, Huan, Jue Zhong, Wen Li, and Cameron Clarke. "Study on restoration-oriented digital visualization for architectural trim-work of Guanlan Hall in Yuanming Yuan." In *Cross-Cultural Design. Applications in Health, Learning, Communication, and Creativity: 12th International Conference, CCD 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II 22*, pp. 573-594. Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-49913-6_47

[9] Galizia, Mariateresa, Graziana D'Agostino, Raissa Garozzo, Federico Mario La Russa, Gaetano Seminara, and Cettina Santagati. "Novel cultural experiences for the communication of museum collections: the Francesco Fichera projects fund at Museo della Rappresentazione in Catania." *Disegnarecon* 12, no. 23 (2019): 8-1. https://doi.org/10.20365/disegnarecon.23.2019.8

[10] Rushton, Hannah, and Marc Aurel Schnabel. "Immersive architectural legacies: the construction of meaning in virtual realities." In *Visual Heritage: Digital Approaches in Heritage Science*, pp. 243-269. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-030-77028-0_13

[11] Nicastro, G., and P. Puma. "Virtual heritage for the dissemination of the Baratti in 3D project." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 42 (2019): 529-534. https://doi.org/10.5194/isprs-archives-XLII-2-W9-529-2019

[12] Banfi, Fabrizio, Raffaella Brumana, and Chiara Stanga. "Realidad extendida y modelos informativos en patrimonio arquitectónico: del proceso scan-to-BIM a la realidad virtual y aumentada." *Virtual Archaeology Review* 10, no. 21 (2019): 14-30. https://doi.org/10.4995/var.2019.11923

[13] Fiel, Mónica Val, and Alba Soler-Estrela. "Interactive Virtual Reality applications for the enhanced knowledge of Spanish Mediterranean Fortress-Castles." *DisegnareCon* 14, no. 27 (2021): 19-1. https://doi.org/10.20365/disegnarecon.27.2021.19

[14] Malik, Umair, Liselore NM Tissen, and Arnold POS Vermeeren. "3D reproductions of cultural heritage artifacts: evaluation of significance and experience." *Studies in digital heritage* 5, no. 1 (2021): 1-29. https://doi.org/10.14434/sdh.v5i1.32323

[15] Katika, Tina, Spyridon Nektarios Bolierakis, Emmanuel Vasilopoulos, Markos Antonopoulos, Georgios Tsimiklis, Ioannis Karaseitanidis, and Angelos Amditis. "Coupling AR with object detection neural networks for end-user engagement." In *International Conference on Virtual Reality and Mixed Reality*, pp. 135-145. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-031-16234-3_8

[16] Bozzelli, Guido, Antonio Raia, Stefano Ricciardi, Maurizio De Nino, Nicola Barile, Marco Perrella, Marco Tramontano, Alfonsina Pagano, and Augusto Palombini. "An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The ArkaeVision project." *Digital Applications in Archaeology and Cultural Heritage* 15 (2019): e00124. https://doi.org/10.1016/j.daach.2019.e00124

[17] Murphy, Maurice, Stephen Fai, Lara Chow, Eimear Meegan, Simona Scandurra, Sara Pavia, Anthony Corns, and John Cahil. "Virtual historic centers: Digital representation of archaeological heritage." In *Handbook of Cultural Heritage Analysis*, pp. 1497-1528. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-030-60016-7_51

[18] Van Nguyen, Sinh, Son Thanh Le, Minh Khai Tran, and Ha Manh Tran. "Reconstruction of 3D digital heritage objects for VR and AR applications." *Journal of Information and Telecommunication* 6, no. 3 (2022): 254-269. https://doi.org/10.1080/24751839.2021.2008133

[19] Carrión-Ruiz, Berta, Silvia Blanco-Pons, M. Duong, J. Chartrand, M. Li, Kristine Prochnau, Stephen Fai, and J. L. Lerma. "Augmented experience to disseminate cultural heritage: House of commons windows, parliament hill national historic site (canada)." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 42 (2019): 243-247. https://doi.org/10.5194/isprs-archives-XLII-2-W9-243-2019

[20] Rashid, Md Mizanur, and Kaja Antlej. "Geospatial platforms and immersive tools for social cohesion: the 4D narrative of architecture of Australia's Afghan cameleers." (2020). https://doi.org/10.4995/var.2020.12230

[21] Namiceva, Ekaterina, and Petar Namicev. "Virtual reality as a method of promoting architectural cultural heritage and cultural memory." *Palimpsest International Journal for Linguistic, Literary and Cultural Research* 4, no. 8 (2019): 113-122.

[22] Rosli, Hafizah, Norfadilah Kamaruddin, and Badrul Isa. "The integration of digital storytelling with information visualisation on exhibition design in museums: A primary inquiry." (2022). https://doi.org/10.6007/IJARBSS/v12-i10/15427

[23] Department of Meseums Malaysia Virtual Gallery. *Department of Museums Malaysia, Ministry of National Unity*, Kuala Lumpur, Malaysia

[24] Agency. "Department of Museums targets 1 million visitors to visit its 22 museums." The Star (2022)

[25] Zhong, Hong, Leilei Wang, and Heqing Zhang. "The application of virtual reality technology in the digital preservation of cultural heritage." *Computer Science and Information Systems* 18, no. 2 (2021): 535-551. https://doi.org/10.2298/CSIS200208009Z

[26] Su, Po-Yuan, Peng-Wei Hsiao, and Kuo-Kuang Fan. "Investigating the relationship between users' behavioral intentions and learning effects of VR system for sustainable tourism development." *Sustainability* 15, no. 9 (2023): 7277. https://doi.org/10.3390/su15097277

[27] Bozorgi, Khosrow, and Zack Lischer-Katz. "Using 3D/VR for research and cultural heritage preservation: project update on the virtual Ganjali Khan project." *Preservation, Digital Technology & Culture* 49, no. 2 (2020): 45-57. https://doi.org/10.1515/pdtc-2020-0017

[28] Bozzelli, Guido, Antonio Raia, Stefano Ricciardi, Maurizio De Nino, Nicola Barile, Marco Perrella, Marco Tramontano, Alfonsina Pagano, and Augusto Palombini. "An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The ArkaeVision project." *Digital Applications in Archaeology and Cultural Heritage* 15 (2019): e00124. https://doi.org/10.1016/j.daach.2019.e00124

[29] Tsepapadakis, Michalis, and Damianos Gavalas. "Are you talking to me? An audio augmented reality conversational guide for cultural heritage." *Pervasive and Mobile Computing* 92 (2023): 101797. https://doi.org/10.1016/j.pmcj.2023.101797

[30] Hu, Wangming, Hyunsuk Han, Gulong Wang, Tao Peng, and Zhiqiang Yang. "Interactive Design and Implementation of a Digital Museum under the Background of AR and Blockchain Technology." *Applied Sciences* 13, no. 8 (2023): 4714. https://doi.org/10.3390/app13084714

[31] Garro, Valeria, Veronica Sundstedt, and Christoffer Sandahl. "Impact of Location, Gender and Previous Experience on User Evaluation of Augmented Reality in Cultural Heritage: The Mjällby Crucifix Case Study." *Heritage* 5, no. 3 (2022): 1988-2006. https://doi.org/10.3390/heritage5030104

[32] Rizvić, Selma, Dušanka Bošković, Vensada Okanović, Ivona Ivković Kihić, Irfan Prazina, and Bojan Mijatović. "Time travel to the past of bosnia and herzegovina through virtual and augmented reality." *Applied Sciences* 11, no. 8 (2021): 3711. https://doi.org/10.3390/app11083711

[33] Damala, Areti, Ian Ruthven, and Eva Hornecker. "The MUSETECH model: A comprehensive evaluation framework for museum technology." *Journal on Computing and Cultural Heritage (JOCCH)* 12, no. 1 (2019): 1-22. https://doi.org/10.1145/3297717

[34] Li, Xiaoxia, Xi Deng, and Hongfei Xu. "Interactive cultural communication effect in VR space of intelligent mobile communication network." *Wireless Communications and Mobile Computing* 2022, no. 1 (2022): 9689272. https://doi.org/10.1155/2022/9689272

[35] Presti, Olga Lo, and Maria Rosaria Carli. "Italian catacombs and their digital presence for underground heritage sustainability." *Sustainability* 13, no. 21 (2021): 12010. https://doi.org/10.3390/su132112010

[36] Sun, Tongxin, Tongtong Jin, Yuru Huang, Meng Li, Yun Wang, Zhe Jia, and Xinyi Fu. "Restoring dunhuang murals: crafting cultural heritage preservation knowledge into immersive virtual reality experience design." *International Journal of Human–Computer Interaction* 40, no. 8 (2024): 2019-2040. https://doi.org/10.1080/10447318.2023.2232976

[37] Mavrin, Igor, Damir Šebo, and Jerko Glavaš. "Imerzivni kulturni turizam u kontekstu pandemije Covid-19–Globalne perspektive i lokalni utjecaji." *Ekonomski pregled* 73, no. 5 (2022): 739-767. https://doi.org/10.32910/ep.73.5.4

[38] Kenderdine, Sarah, Lily Hibberd, and Jeffrey Shaw. "Radical intangibles: materializing the ephemeral." *Museum & Society* 19, no. 2 (2021): 252-272. https://doi.org/10.29311/mas.v19i2.3638

[39] Arayaphan, Watsaporn, Kannikar Intawong, and Kitti Puritat. "Digitalization of ancient fabric using virtual reality technology at the Wieng Yong House Museum: The FabricVR project." *Digital Applications in Archaeology and Cultural Heritage* 26 (2022): e00233. https://doi.org/10.1016/j.daach.2022.e00233

[40] Manzollino, Roberta, Saverio Giulio Malatesta, Danilo Avola, Luigi Cinque, Antonietta Del Bove, Laura Leopardi, and Marco Raoul Marini. "Enhancement and Communication of Ancient Human Remains through VR: The Case Study of Sexual Dimorphism in the Human Skull." *Heritage* 6, no. 5 (2023): 4120-4133. https://doi.org/10.3390/heritage6050217

[41] Hutson, James, and Ben Fulcher. "A virtual reality educational game for the ethics of cultural heritage repatriation." *Games and Culture* 18, no. 6 (2023): 759-782. https://doi.org/10.1177/15554120221131724

[42] Sdravopoulou, Konstantina, Juan Jesús Gutiérrez Castillo, and Juan Manuel Muñoz González. "Naturalistic approaches applied to AR technology: an evaluation." *Education and Information Technologies* 26, no. 1 (2021): 683-697. https://doi.org/10.1007/s10639-020-10283-4

[43] Taipina, Daniel, and Jorge CS Cardoso. "Spectare: Re-designing a stereoscope for a cultural heritage xr experience." *Electronics* 11, no. 4 (2022): 620. https://doi.org/10.3390/electronics11040620

[44] Gheorghiu, Dragos, and Livia Ștefan. "Immersing into the past: an augmented reality method to link tangible and intangible heritage." *PLURAL. History, Culture, Society* 2 (2020): 91-102. https://doi.org/10.37710/plural.v8i2_9

[45] Zhang, Lufang, Yue Wang, Zhichuan Tang, Xia Liu, and Moran Zhang. "A virtual experience system of bamboo weaving for sustainable research on intangible cultural heritage based on VR technology." *Sustainability* 15, no. 4 (2023): 3134. https://doi.org/10.3390/su15043134
[46] Nishanbaev, Ikrom. "A web repository for geo-located 3D digital cultural heritage models." *Digital Applications in Archaeology and Cultural Heritage* 16 (2020): e00139. https://doi.org/10.1016/j.daach.2020.e00139
[47] Chen, Chun-Ching, Xin Kang, Xin-Zhu Li, and Jian Kang. "Design and evaluation for improving lantern culture learning experience with augmented reality." *International Journal of Human–Computer Interaction* 40, no. 6 (2024): 1465-1478. https://doi.org/10.1080/10447318.2023.2193513
[48] Bertrand, Stéphanie, Martha Vassiliadi, Paul Zikas, Efstratios Geronikolakis, and George Papagiannakis. "From readership to usership: communicating heritage digitally through presence, embodiment and aesthetic experience." *Frontiers in Communication* 6 (2021): 676446. https://doi.org/10.3389/fcomm.2021.676446
[49] Okanovic, Vensada, Ivona Ivkovic-Kihic, Dusanka Boskovic, Bojan Mijatovic, Irfan Prazina, Edo Skaljo, and Selma Rizvic. "Interaction in extended reality applications for cultural heritage." *Applied Sciences* 12, no. 3 (2022): 1241. https://doi.org/10.3390/app12031241
[50] Li, Xin-Zhu, Chun-Ching Chen, Xin Kang, and Jian Kang. "Research on relevant dimensions of tourism experience of intangible cultural heritage lantern festival: Integrating generic learning outcomes with the technology acceptance model." *Frontiers in Psychology* 13 (2022): 943277. https://doi.org/10.3389/fpsyg.2022.943277
[51] Echavarria, Karina Rodriguez, Myrsini Samaroudi, Laurie Dibble, Edward Silverton, and Sophie Dixon. "Creative experiences for engaging communities with cultural heritage through place-based narratives." *ACM Journal on Computing and Cultural Heritage (JOCCH)* 15, no. 2 (2022): 1-19. https://doi.org/10.1145/3479007
[52] Murphy, Cian, Peter J. Carew, and Larry Stapleton. "A human-centred systems manifesto for smart digital immersion in Industry 5.0: a case study of cultural heritage." *AI & SOCIETY* (2023): 1-16. https://doi.org/10.1007/s00146-023-01693-2
[53] Ferretti, Umberto, Ramona Quattrini, and Mirco D'Alessio. "A comprehensive HBIM to XR framework for museum management and user experience in Ducal palace at Urbino." *Heritage* 5, no. 3 (2022): 1551-1571. https://doi.org/10.3390/heritage5030081
[54] Kang, Yowei, and Yu-Sheng Su. "A Literature Analysis of Consumer Privacy Protection in Augmented Reality Applications in Creative and Cultural Industries: A Text Mining Study." *Frontiers in Psychology* 13 (2022): 869865. https://doi.org/10.3389/fpsyg.2022.869865
[55] Syed Shaharuddin, Sharifah Imihezri, Maryam Samirah Shamsuddin, Mohd Hafiz Drahman, Zaimah Hasan, Nurul Anissa Mohd Asri, Ahmad Amri Nordin, and Norhashimah Mohd Shaffiar. "A review on the Malaysian and Indonesian batik production, challenges, and innovations in the 21st century." *SAGE Open* 11, no. 3 (2021): 21582440211040128. https://doi.org/10.1177/21582440211040128
[56] Soto-Martin, Ovidia, Alba Fuentes-Porto, and Jorge Martin-Gutierrez. "A digital reconstruction of a historical building and virtual reintegration of mural paintings to create an interactive and immersive experience in virtual reality." *Applied Sciences* 10, no. 2 (2020): 597. https://doi.org/10.3390/app10020597
[57] Puspasari, Shinta, Nazori Suhandi, and Jaya Nur Iman. "Evaluation of augmented reality application development for cultural artefact education." *International Journal of Computing* 20, no. 2 (2021): 237-245.
[58] Man, Sihuang, and Ze Gao. "(Retracted) Digital immersive interactive experience design of museum cultural heritage based on virtual reality technology." *Journal of Electronic Imaging* 32, no. 1 (2023): 011208-011208. https://doi.org/10.1117/1.JEI.32.1.011208
[59] Čejka, Jan, Marino Mangeruga, Fabio Bruno, Dimitrios Skarlatos, and Fotis Liarokapis. "Evaluating the potential of augmented reality interfaces for exploring underwater historical sites." *IEEE Access* 9 (2021): 45017-45031. https://doi.org/10.1109/ACCESS.2021.3059978
[60] Liritzis, Ioannis, and Pantelis Volonakis. "Cyber-archaeometry: novel research and learning subject overview." *Education Sciences* 11, no. 2 (2021): 86. https://doi.org/10.3390/educsci11020086
[61] Jaafar, Nurulaini, Siti Rohani Mohd Nor, Siti Mariam Norrulashikin, Nur Arina Bazilah Kamisan, and Ahmad Qushairi Mohamad. "Increase students' understanding of mathematics learning using the technology-based learning." *International Journal of Advanced Research in Future Ready Learning and Education* 28, no. 1 (2022): 24-29.