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Cultural Heritage Interpretation through Extended Reality in Museums: A Systematic Thematic Review of Meaning-Making, Narrative, and Authenticity

Liu Jun[1], Maszura Abdul Ghafar[1]* and Adlina Ab Halim[2]

[1]Faculty of Design and Architecture, Universiti Putra Malaysia, Serdang, Selangor, Malaysia,

[2]Faculty of Human Ecology, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

Email: GS64132@student.upm.edu.my, adlina@upm.edu.my

* Corresponding Author Email: maszu@upm.edu.my

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Abstract

This systematic thematic review examines how extended reality (XR) mediates cultural-heritage interpretation in museums and comparable displays. It analyses English-language journal literature published in the seven complete calendar years 2019–2025, searched in Web of Science Core Collection and Scopus in October 2026. Following PRISMA 2020, 372 records were identified; 120 duplicates and 155 title-and-abstract exclusions left 97 reports sought. Four full texts were unavailable; 93 reports were assessed, 22 excluded, and 54 primary reports synthesised. Seventeen reviews or conceptual accounts informed context without entering theme counts. Four themes describe reconstruction and contextualisation, narrative mediation, embodied and social participation, and authenticity and interpretive responsibility. The reports document design approaches, engagement and perceived learning, but comparable evidence for sustained cultural understanding and causal effects remains limited. The synthesis identifies questions for museum learning and curatorial decisions, including provenance, narrative perspective and accessibility. Because the evidence window ends on 31 December 2025, the conclusions do not assess studies published in 2026.

Keywords: Extended Reality, Museums, Cultural Heritage Interpretation, Immersive Storytelling, Authenticity

Introduction

Museums increasingly use extended reality (XR) to interpret cultural heritage that cannot be fully experienced through conventional displays. This may include heritage that is geographically dispersed, physically fragile, inaccessible to visitors, reconstructed from incomplete evidence, or connected to living and contested traditions. Virtual reality (VR), augmented reality (AR), mixed reality (MR), projection mapping, virtual humans and social

virtual environments allow museums to place objects within reconstructed settings, connect artefacts with historical narratives and invite visitors to explore cultural content through movement and interaction (Bekele et al., 2018; Sylaiou et al., 2009; Li et al., 2023; Song & Evans, 2024). These applications support the interpretation of both tangible heritage, such as buildings, archaeological objects and museum collections, and intangible heritage, including oral traditions, craft practices, ritual knowledge and community memory (Bonacini, 2018; Hodgson et al., 2024). However, the educational and cultural value of XR depends on how these technologies are integrated into museum interpretation and visitor learning.

The interpretive value of XR cannot be explained by immersion or technological novelty alone (Shehade & Stylianou-Lambert, 2020; Song & Evans, 2024). From a social-science perspective, XR also shapes how museums support learning, how visitors construct cultural meaning, and how institutions decide which knowledge and perspectives are represented (Ch'ng et al., 2020; Shehade & Stylianou-Lambert, 2020). Museum interpretation involves selecting objects, places, voices and historical claims, and presenting them in ways that help visitors develop meaning (Sylaiou et al., 2009; Sylaiou et al., 2024). XR should therefore be understood as an interpretive and institutional medium that connects learning design, visitor participation, curatorial responsibility and cultural governance (Hodgson et al., 2024; Song & Evans, 2024).

Museums use XR to reconstruct heritage from incomplete evidence, foreground particular perspectives through narrative, and guide visitor attention through interaction. These choices can shape cultural understanding and perceived authenticity, making XR interpretation a curatorial as well as a technical issue. Existing reviews map immersive technologies, virtual exhibitions, and museum user experience (Li et al., 2023; Yang and Zhu, 2024; Cui and Wu, 2025; Illsley et al., 2025), while others address specific design dimensions (Xu et al., 2025; Lin et al., 2025; Pietroni, 2025; Privitera et al., 2025). However, evidence about interpretive functions, visitor understanding, and responsible representation remains fragmented across XR modalities and outcome measures. This fragmentation makes it difficult to determine how reconstruction, narrative, and participation relate to cultural meaning-making, whether engagement reflects measured understanding, and how uncertainty and contested perspectives are handled. This is the central problem motivating the present systematic thematic review.

To address this problem, the review identifies the interpretive functions attributed to XR; synthesises how reconstruction, narrative and embodied interaction relate to cultural meaning; distinguishes measured cultural understanding from perceived learning, expert opinion and design intentions; and examines authenticity, cultural representation and interpretive responsibility. The resulting framework is intended to inform museum education, visitor learning, cultural management and public cultural policy.

The review is guided by three research questions:

What interpretive functions of XR are reported in museum-based cultural-heritage interpretation?

How is XR reported to mediate cultural meaning through reconstruction, narrative and embodied interaction?

What issues concerning authenticity, cultural representation and interpretive responsibility are reported?

The remainder of this article is organised as follows. The Methods section describes the database searches, eligibility criteria, screening procedure, quality appraisal and thematic synthesis. The Results section presents the study selection, characteristics of the included studies and four thematic findings. The Discussion section interprets the findings in relation to XR-mediated cultural meaning-making, authenticity and interpretive responsibility, and outlines implications for museum practice and future research. The article then presents its limitations and concludes with the main contribution of the review.

Methods

Reporting standard and review design

This review adopted a systematic thematic design to synthesise research on XR-mediated cultural-heritage interpretation in museums. The review process was planned and reported in accordance with the PRISMA 2020 statement (Page et al., 2021), which guided the documentation of the search, screening, eligibility and inclusion stages. A thematic synthesis was selected because the evidence base covered different heritage forms, museum contexts, XR modalities, study designs, participant groups and outcome measures. Given this heterogeneity, statistical aggregation was not appropriate. The analysis therefore focused on identifying recurring interpretive functions and examining how reconstruction, narrative, interaction and interpretive responsibility were connected across the literature.

Search strategy and scope

Web of Science Core Collection and Scopus were searched on 16 October 2026. The publication window comprised the seven complete calendar years from 1 January 2019 through 31 December 2025. Using complete years provides a consistent temporal boundary; it does not imply that relevant research stopped in 2025. The geographic scope was global, and searches were limited to English-language records. The primary synthesis focused on peer-reviewed journal articles; non-journal formats were removed during screening. Selected review and conceptual papers informed context without entering primary-report theme counts.

The review considered museums, virtual museums, museum exhibitions and comparable museum-type cultural-heritage displays. Comparable settings included museum-linked landscape interpretation, in-situ heritage displays and implemented prototypes explicitly intended for museum interpretation. Eligible technologies included XR, VR, AR, MR and closely related immersive systems when cultural-heritage interpretation was central. Conventional 3D documentation, ordinary video and proposed future XR were insufficient on their own. Broad or mixed cases were identified as boundary cases and interpreted with their settings and designs in view. The review did not restrict studies by country, heritage category or hardware platform.

The databases were searched using combinations of terms related to extended reality, museums, cultural heritage and interpretation. In Web of Science, the Topic field was searched using:

TS=(("extended reality" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "immersive technolog*") AND museum* AND ("cultural heritage" OR "heritage interpretation") AND (interpret* OR storytelling OR narrative* OR contextual* OR "meaning-making" OR "cultural representation" OR authentic*))

In Scopus, the Article Title, Abstract and Keywords fields were searched using:

("extended reality" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "immersive technology" OR "immersive technologies") AND (museum OR museums OR "virtual museum" OR "virtual museums") AND ("cultural heritage" OR "heritage interpretation") AND (interpret* OR storytelling OR narrative* OR contextual* OR "meaning-making" OR "cultural representation" OR authentic*)

The Web of Science search returned 156 records and the Scopus search returned 216 records. Scopus did not accept the wildcard within the quoted phrase “immersive technolog*”; the two exact phrases “immersive technology” and “immersive technologies” were therefore used.

Eligibility criteria

Table 1 summarises the content eligibility criteria used in screening and the rule applied when a complete readable full text could not be obtained.

Table 1

The Inclusion-Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal articles published between 2019 and 2025	Conference papers, book chapters, theses, dissertations, editorials, letters, short abstracts and other non-eligible formats
Articles written in English	Articles published in languages other than English
Studies addressing a museum, virtual museum, museum exhibition or comparable museum-type cultural-heritage display	Studies in which the museum or heritage setting was mentioned only as background
XR, VR, AR, MR or a closely related immersive technology was central to the study or analysis	Purely technical or algorithmic studies without a cultural-heritage interpretation focus
Studies addressing cultural-heritage interpretation or communication	Studies focused primarily on physical conservation, material restoration or collection management
Studies addressing at least one interpretive issue, including reconstruction, contextualisation, storytelling, narrative mediation, heritage communication, meaning-making, cultural representation or authenticity	Studies focused only on satisfaction, presence, usability, technology acceptance or intention to use without substantive cultural-interpretation content
Retrieval status recorded separately: a complete readable full text is needed for assessment	Reports without a complete readable full text were excluded at the full-text screening stage for non-retrieval; their content was not assessed

The content criteria in Table 1 identified primary reports for thematic synthesis. Relevant reviews and conceptual papers were retained separately as contextual evidence. A complete readable text was required for content assessment; reports without one were recorded as not retrieved, with no content-based exclusion reason assigned.

Borderline studies were retained when their interpretive setting and research question were directly comparable to museum-based cultural-heritage interpretation. These included selected open-air museum representations, in-situ heritage visits, virtual heritage environments with explicit museum applications and design prototypes intended for museum interpretation or accessibility. Their setting and implementation boundaries were described when interpreting the evidence.

Study Selection Process

Initial Identification of Records

A comprehensive search was conducted in Web of Science Core Collection and Scopus. The searches were limited to English-language records published between 2019 and 2025. Document type was retained at the retrieval stage so that conference papers, book chapters and other non-eligible formats could be identified and excluded transparently during screening. A total of 372 records were identified, including 156 records from Web of Science Core Collection and 216 records from Scopus.

Removal of Duplicates

The records were exported from both databases with available bibliographic information, including title, abstract, keywords, authors, publication year, source, DOI and document type. Duplicate records were removed through DOI matching and normalised title, author and year checks. A total of 120 duplicate records were removed, leaving 252 unique records for title-and-abstract screening.

Title and Abstract Screening

The titles and abstracts of the 252 unique records were screened against the predefined eligibility criteria. Records were excluded when they clearly did not address a museum or comparable cultural-heritage setting, when XR or a related immersive technology was not central, when the publication format was not eligible, or when the study did not address cultural-heritage interpretation. Records were retained for full-text assessment when the abstract did not provide sufficient information for a reliable decision. A total of 155 records were excluded at this stage, and 97 reports were sought for full-text retrieval.

Full-Text Screening

Complete full texts were sought for 97 reports through DOI and publisher links, institutional and author repositories, public full-text services, article webpages and locally held files. Titles, authors and publication identifiers were matched to each record. Complete texts were assessed for 93 reports. Four reports could not be matched to a complete readable text and were recorded as not retrieved; their titles and abstracts were checked, but their full-text content was not assessed.

The 93 available reports were assessed against the content and language criteria. Twenty-two were excluded, with one principal reason recorded for each:

- wrong language (E2), n = 2;
- wrong setting, including non-museum or non-comparable heritage settings (E4), n = 5;
- XR not central to the implemented intervention or analysis (E5), n = 10;
- no substantive cultural-heritage interpretation focus (E6), n = 3; and
- visitor, marketing or technology-acceptance outcomes without substantive interpretation content (E8), n = 2.

The selection yielded 54 primary reports for thematic synthesis and 17 reviews or conceptual papers for contextual use. AI assistance supported record organization and synthesis; webpage-based full-text decisions were made by the author. Independent duplicate assessment was not documented, and no inter-rater reliability statistic was calculated. Figure 1 presents the selection flow.

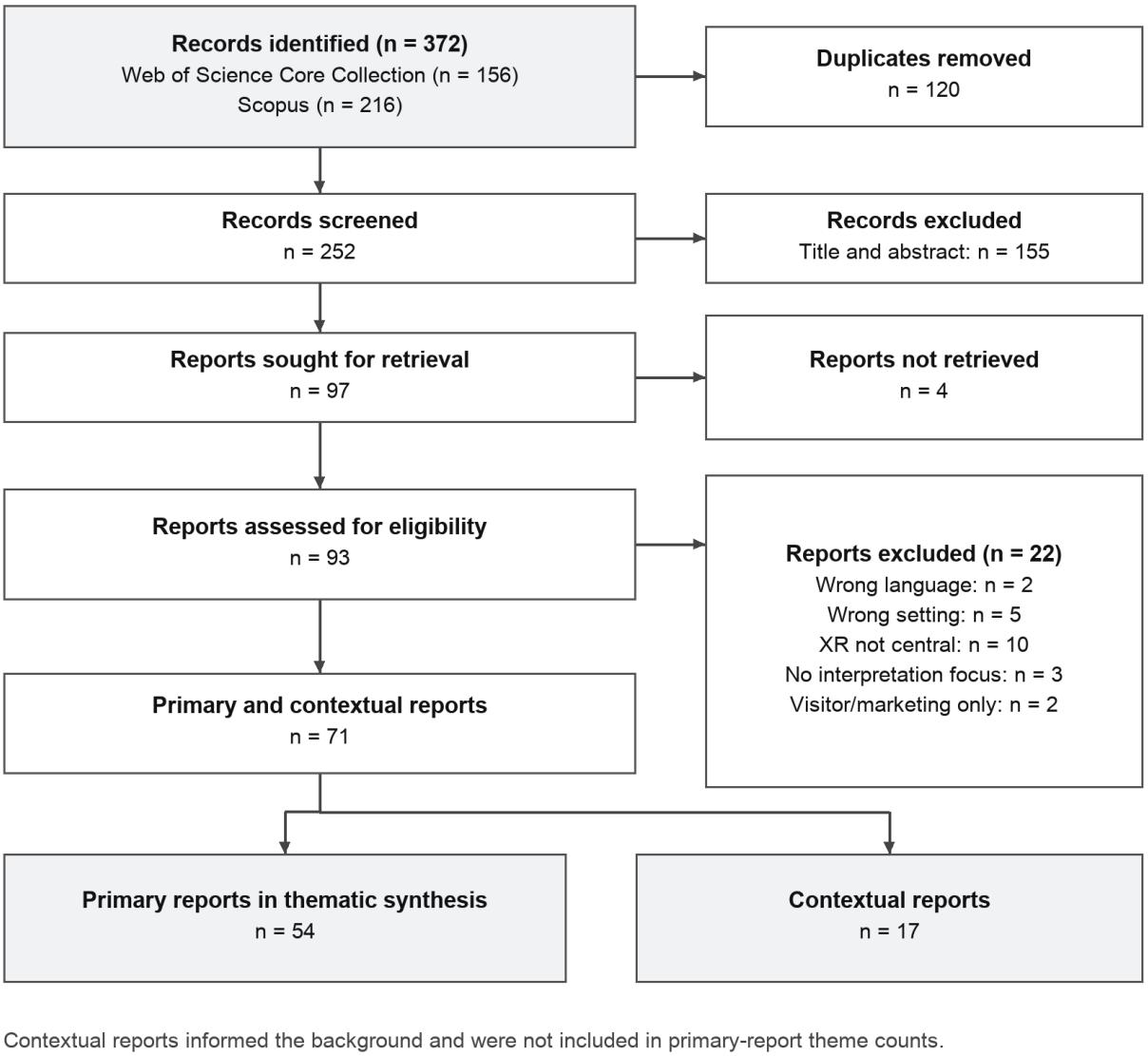


Figure 1 PRISMA 2020 flow of records and reports

Data Extraction and Management

Study-level information was organized around publication year, museum or heritage setting, heritage object, XR modality, research design, data source, interpretive purpose, reported findings and limitations. Table 2 presents a compact overview, while the thematic narrative distinguishes observed visitor responses from expert judgments, design analysis and proposed benefits.

The 17 reviews or conceptual papers were tracked separately as contextual evidence and excluded from primary-report theme counts. Record identifiers and screening reasons were retained to support selection traceability.

Extraction distinguished visitor observations and measured responses from expert feedback, design analysis and intended benefits. Technology acceptance, presence or usability was not treated as evidence of cultural learning. Mixed interventions and pooled samples were described explicitly: for example, a survey spanning XR and non-XR venues cannot isolate an XR effect.

Evidence appraisal

Evidence was appraised descriptively at the claim level using five considerations: clarity of the research question and design; adequacy of participants or other data sources; transparency of collection and measurement; traceability of analysis; and the fit between findings, interpretation and stated limitations. Table 3 explains how these considerations constrained the claims made in this review. No cross-design numerical quality score was assigned to the corpus.

Practice-led reports were used as evidence of implemented design and interpretation when documented, without implying tested visitor outcomes. Expert interviews were distinguished from visitor responses, and presence, usability or satisfaction were not treated as direct evidence of cultural learning.

Thematic synthesis

The 54 primary reports were analysed through concept-led thematic synthesis. Descriptive coding captured reconstruction and contextualisation, narrative mediation, embodied and social interaction, authenticity, representation and responsibility. Each report was assigned a principal interpretive theme; related contributions were considered in the narrative without treating theme frequency as a measure of effectiveness. The synthesis draws on analytic coherence and researcher judgment in thematic analysis (Braun & Clarke, 2006, 2019, 2021, 2022).

The four principal themes were: (1) reconstruction and contextualisation of heritage worlds; (2) narrative mediation and immersive storytelling; (3) embodied, social and participatory meaning-making; and (4) authenticity, cultural representation and interpretive responsibility. Primary-theme assignment considered the central XR intervention, interpretive object and reported findings. One primary theme per report was used for mutually exclusive descriptive counting.

Theme counts refer to reports, not independent interventions, effects or participant populations. Known or possible project overlaps were noted: Pietroni (2021) and Pietroni et al. (2021) cover CEMEC-related work, while Okanovic et al. (2022) and Rizvić et al. (2021) may share project material. These links do not establish duplicate participant samples. Comparable outdoor settings, museum-oriented prototypes and mixed interventions were described explicitly because their relevance depends on the review's setting boundary.

Results

The searches identified 372 records: 156 from Web of Science Core Collection and 216 from Scopus. Removing 120 duplicates left 252 records for title-and-abstract screening, of which 155 were excluded. Full texts were sought for 97 reports; four could not be retrieved. The remaining 93 reports were assessed for eligibility, and 22 were excluded after full-text assessment. The 71 retained reports comprised 54 primary reports for thematic synthesis and 17 contextual reports. Figure 1 shows the selection flow.

Characteristics of the included studies

The 54 primary reports have citation years from 2019 to 2025: 2019 (n = 1), 2020 (n = 6), 2021 (n = 12), 2022 (n = 7), 2023 (n = 6), 2024 (n = 8) and 2025 (n = 14). These descriptive counts generally follow bibliographic issue or citation years; online-first dates resolve eligibility where needed. Settings span Europe, Asia, North America, South America and Australia, as well as internationally sampled expert studies.

The evidence base was methodologically heterogeneous. It included visitor surveys and quantitative evaluations, mixed-methods prototype studies, qualitative interviews with museum professionals or visitors, participatory and practice-led design studies, comparative interaction studies, and virtual-museum or metaverse case studies. Because of this heterogeneity, a statistical meta-analysis was not appropriate; the synthesis therefore focused on recurring interpretive functions and patterns of meaning-making.

Table 2 summarises the 54 primary reports by setting, XR modality, study design and primary theme. Table 3 states the evidence-appraisal considerations applied when interpreting claims. Study designs range from visitor assessments and qualitative interviews to prototypes and expert accounts; these sources support different kinds of conclusions.

Table 2
Characteristics of the 54 included primary reports

Study	Region and setting	XR modality	Study design	Primary theme
Banfi & Oreni (2025)	Italy; Ospedale Maggiore virtual museum	VR/WebVR	Practice-led case study	T1
Banfi et al. (2023)	Italy; Appia Antica archaeological park	VR/AR; HBIM storytelling	Practice-led workflow; no participant test	T1

Study	Region and setting	XR modality	Study design	Primary theme
Barbara et al. (2023)	Malta; Sacra Infermeria heritage venue	Mobile AR	11 narrative specialists plus instructor; focus group	T4
Bekele (2019)	Museum/heritage-site prototype; setting not specified	HoloLens MR map	Practice-led interaction prototype	T3
Bekele (2021)	Australia; virtual heritage museum prototype	Collaborative MR/HoloLens	Practice-led prototype design	T3
Besoain et al. (2021)	Chile; virtual museum	VR virtual museum	Practice-led development	T3
Chen et al. (2025)	Portugal; Gulbenkian prototype, laboratory	Mobile AR	24 AR volunteers; separate 17-scientist desktop test	T1
Chernbumroong et al. (2024)	Thailand; HimmapanVR virtual museum	VR virtual museum	Quantitative visitor evaluation	T4
Chrysanthakopoulou et al. (2021)	Greece; Antikythera prototype	Haptic and locomotion VR	Presence questionnaire; 20 volunteers	T3
Ch'ng et al. (2020)	China/United Kingdom; cultural-heritage learning environment	VR	Mixed-methods evaluation	T3
Diamantis et al. (2025)	Greece; Onassis Library map exhibit	AR; broader digital programme	100 broader-programme questionnaires; not AR-only	T2
Economou et al. (2025)	United Kingdom; Hunterian Museum/Antonine Wall	VR; 3D storytelling	Mixed-methods iterative evaluation	T2
Evagelou et al. (2025)	Greece; Neolithic lakeside open-air museum	Location-based AR/MR/VR	Design and educational evaluation	T1
Hammady et al. (2020)	United Kingdom; Manchester Museum	MR/HoloLens	Visitor study/prototype evaluation	T2
Hauser et al. (2022)	Germany/Greece/Switzerland; Haus der Seidenkultur	AR/MR; virtual humans; Web media	Practice-led multimodal case study	T1
Kleftodimos et al. (2023)	Greece; Dispilio open-air museum	Location-based AR/MR	Design and educational evaluation	T1

Study	Region and setting	XR modality	Study design	Primary theme
Leow & Ch'ng (2021)	China; Sanjiangkou virtual heritage visit	VR	61-participant narrative study	T2
Liu et al. (2025)	China; Palace, Suzhou and Hunan museums	AR interactive exhibitions	Mixed-methods multi-case study	T4
Malik et al. (2021)	International/Europe; 3D museum presentation	AR/VR; digital screens/3D print	Mixed-methods exploratory evaluation	T4
Merchán et al. (2021)	Spain; La Matilla Roman site	AR scenes	Practice-led prototype; no public evaluation	T1
Mercuri et al. (2024)	Italy; manuscript VR/MR museum environments	VR/MR; 4D model	Documentation and public-facing design	T1
Mezzino (2023)	Myanmar/Italy; Bagan VR; Turin multimedia	360° HMD VR in Bagan	Mixed-case design analysis; no participant test	T1
Mohammed-Amin et al. (2025)	Iraq; difficult-heritage VR exhibition	Immersive VR	Mixed-methods evaluation	T4
Muñoz et al. (2025)	Spain; medieval sculpture XR exhibition	Spatial XR; tangible/multisensory interfaces	Practice-led prototype evaluation	T3
Neamțu et al. (2024)	Romania; Dacian object museum exhibition	AR/VR	Comparative XR user study	T1
Nikolakopoulou et al. (2022)	Greece; Chios Mastic Museum	Spatial AR; projection mapping	Iterative design/evaluation	T2
O'Dwyer et al. (2021)	Ireland; Trinity College Dublin Long Room	AR; volumetric video	Quantitative user study	T2
Okanovic et al. (2022)	Montenegro; Nikšić Museum	Interactive VR	Visitor questionnaire; N unreported	T3
Olaz et al. (2022)	Spain; Roncesvalles heritage visit	Spatial AR; projection mapping; tangibles	Participatory/practice-led study	T3
Olmedo-Pagés et al. (2025)	Spain; museum-library virtual exhibits	Spatial VR; parallel 2D exhibit	Accessibility design; no user validation	T4
Partarakis et al. (2022)	Greece; Chios Mastic Museum	AR; virtual humans	Practice-led accessibility study	T2
Petrelli & Roberts (2023)	United Kingdom/Italy; Roman heritage collections	VR; tangible installation	Comparative qualitative study	T3

Study	Region and setting	XR modality	Study design	Primary theme
Pietroni (2021)	Italy; six museum/heritage installations	VR; immersive audio; holography	Practice-led sound-design analysis	T2
Pietroni et al. (2021)	Italy; Museum of Civilization	VR/MR; holographic/tangible media	Practice-led accessibility study	T3
Pisani et al. (2024)	United Kingdom; Perth Museum/Pictish heritage	VR; virtual tour; 3D tools	Practice-led case study	T1
Plecher et al. (2022)	Germany; Roman-wreck museum prototype	VR diving simulator	Feedback from one archaeologist; no visitor test	T3
Rafeiro et al. (2024)	Portugal; Madre de Deus/Tile Museum	Immersive web environment	Source-based reconstruction; no visitor test	T4
Ravichandran & Nam (2024)	South Korea; museum-based MR experience	MR/HoloLens 2	Practice-led prototype evaluation	T3
Ress & Cafaro (2021)	United States; Historic New Harmony open-air museum	AR/VR	Visitor survey	T1
Rizvić et al. (2021)	Bosnia and Herzegovina; Virtual Museum of Old Crafts	VR/AR/360° video	Practice-led multi-case study	T1
Sfodera et al. (2020)	Italy; three Rome venues, one non-XR	VR; AR/VR; non-XR	Pooled survey/SEM; 300 respondents	T4
Shehade & Stylianou-Lambert (2020)	International; 15 museums	VR	Qualitative interviews	T4
Shim et al. (2024)	South Korea; Peaceful Hill heritage metaverse	Heritage metaverse	Qualitative end-user experiment	T3
Shim et al. (2025)	South Korea; Misreuksaji heritage metaverse	Social VR	Quantitative social-VR study	T3
Song & Evans (2024)	International/United Kingdom; museum practice	XR/VR/AR/MR	Qualitative interviews	T4
Song, Liu, & Zhao (2025)	China; museum-led Dunhuang Mogao Caves project	VR	Thematic analysis of online user feedback	T4
Song, Whyke, et al. (2025)	International; XR museum storytelling	XR/transmedia	Interviews with 27 experts	T2
Stichelbaut et al. (2021)	Belgium; In Flanders Fields Museum outposts	Mobile AR	Practice case and app usage metrics	T3

Study	Region and setting	XR modality	Study design	Primary theme
Sylaiou et al. (2020)	Greece; virtual museum/sculpture	VR; avatars	Experimental user study	T2
Toumpouri et al. (2025)	Cyprus; Venetian Walls outdoor heritage site	Augmented audio	Outdoor heritage case study	T2
Trichopoulos et al. (2022)	Greece; National Gallery	AR; tangibles; binaural audio	Prototype evaluation; 42 users	T2
Trunfio et al. (2020)	Italy; Ara Pacis Museum	MR	Visitor-experience model and evaluation	T4
Tsita et al. (2023)	Greece; MOMus and virtual museum	HMD VR	Practice-led development/evaluation	T1
Zhang & Chen (2025)	China; Palace Museum	VR	21 visitor interviews after VR experience	T4

Note. T1 = reconstruction and context; T2 = narrative; T3 = embodied and social meaning-making; T4 = authenticity and responsibility. Counts refer to reports. Study-design labels distinguish visitor results from expert and practice-led accounts.

Table 2 distinguishes visitor assessments from expert and practice-led accounts. VR, AR and MR applications often combined reconstructed content, narrative mediation and visitor interaction.

Table 3 bounds each claim by the study design, participants, measures and analysis; design accounts or expert views alone do not establish visitor learning.

Table 3
Evidence-appraisal considerations

Consideration	Applied in synthesis	Claim limit
Research question and design	Whether the XR intervention or analysis matches the interpretive question	A design proposal does not establish a visitor effect.
Participants and sources	Visitor, expert, document and project sources kept distinct	Expert judgment is not a representative visitor outcome.
Collection and measures	What was observed or measured, and in which setting	Presence, usability and satisfaction do not by themselves show cultural learning.
Analytic traceability	Whether reported findings follow from the collected material	Weakly specified analysis limits confidence in specific findings.
Interpretation and limits	Whether conclusions acknowledge sampling, setting and design limits	Associations and design intentions are not causal evidence.

Thematic synthesis

Each report received one primary theme. Primary counts were 14 for reconstruction and contextualisation (T1), 12 for narrative mediation (T2), 15 for embodied, social and participatory meaning-making (T3), and 13 for authenticity and responsibility (T4). These mutually exclusive counts sum to 54. Table 4 summarises each theme with illustrative studies and the principal limits of the evidence.

Table 4
Four-theme synthesis

Theme	n	Illustrative studies	Interpretation and examples	Main limitation
T1 Reconstruction and contextualisation	14	Mercuri et al. (2024)	Spatial and temporal context; links among objects, places and practices. Ress & Cafaro (2021); Banfi et al. (2023).	Many workflows document designs; learning and transfer are not consistently tested.
T2 Narrative mediation and immersive storytelling	12	Leow & Ch'ng (2021); Song, Whyke, et al. (2025); Toumpouri et al. (2025)	Characters, sound and audiovisual narratives frame interpretation. Economou et al. (2025); Trichopoulos et al. (2022).	Narrative response depends on perspective and context; mixed-programme outcomes do not isolate XR.
T3 Embodied, social and participatory meaning-making	15	Bekele (2019)	Movement, handling, co-presence, agency and co-creation. Shim et al. (2025); Okanovic et al. (2022).	Presence, use or satisfaction alone does not demonstrate learning; prototypes are common.
T4 Authenticity, representation and responsibility	13	Trunfio et al. (2020); Zhang & Chen (2025); Song, Liu, & Zhao (2025)	Provenance, uncertainty, access and institutional responsibility. Song & Evans (2024); Rafeiro et al. (2024).	Design intentions and cross-sectional associations cannot establish causal trust or inclusion benefits.

Reconstruction and contextualisation of heritage worlds

The first theme concerns making missing, changed or inaccessible heritage interpretable through reconstructed environments and contextual links. Examples include Historic New Harmony (Ress & Cafaro, 2021), Bosnian heritage (Rizvić et al., 2021), a Dacian object (Neamțu et al., 2024) and a Neolithic settlement (Evagelou et al., 2025). The approaches range from 360-degree VR in Bagan (Mezzino, 2023) and AR scenes for a buried Roman site (Merchán et al., 2021) to an implemented 4D manuscript model connected to VR and MR environments

for museum audiences (Mercuri et al., 2024). The separate Turin multimedia case in Mezzino (2023) was not a VR intervention.

These examples document ways to connect objects and places with historical context, but several offer design evidence without a visitor learning test. Chen et al. (2025), for instance, linked paintings to scientific information through AR, yet the AR evaluation involved 24 laboratory volunteers viewing printed reproductions. Its separate 17-scientist desktop evaluation was not part of that AR sample. Usability and acceptance findings therefore support feasibility claims, while effects on cultural understanding and transfer remain unestablished.

Narrative mediation and immersive storytelling

The second theme concerns how stories, sound and digital characters frame heritage encounters. Examples include EMOTIVE/Antonine Wall (Economou et al., 2025), Long Room volumetric video (O'Dwyer et al., 2021), and accessible virtual narrators (Partarakis et al., 2022). Leow and Ch'ng (2021) examined audience narratives following a VR heritage visit; Song, Whyke, et al. (2025) drew on 27 expert interviews about XR transmedia museum storytelling. Toumpouri et al. (2025) studied audio augmentation at the Venetian Walls of Nicosia, extending the discussion to a comparable outdoor heritage setting. These designs provide different forms of evidence about narrative mediation rather than a common measure of learning.

Narrative evidence must be attributed to the part of an intervention that was actually evaluated. Diamantis et al. (2025) describe animated and narrated map symbols in an Onassis Library AR exhibit. Their 100-questionnaire evaluation concerned a broader educational programme and cannot be treated as an isolated test of that exhibit. Across the reports, voice, perspective, pacing and the connection between story and object are design considerations; evidence for emotional or interpretive responses varies by study and does not establish a universal storytelling effect.

Embodied, social and participatory meaning-making

The third theme had the largest primary count (n = 15). It covers movement, handling, social interaction, user agency and multisensory exploration. Examples include in-situ MR design (Olaz et al., 2022), social heritage metaverses (Shim et al., 2025), multisensory systems (Muñoz et al., 2025) and heritage learning environments (Ch'ng et al., 2020). Bekele (2019) proposed and implemented a walkable MR map interface for interacting with cultural content in museum and heritage-site settings; its prototype design should not be read as a measured learning effect. Stichelbaut et al. (2021) link museum interpretation to landscape exploration through AR and historical aerial photographs; app sessions are usage metrics, not unique participant counts.

Evidence for embodied learning also has limits. Chrysanthakopoulou et al. (2021) evaluated presence with 20 volunteers in a haptic and locomotion-based Antikythera VR experience; presence and fatigue measures do not demonstrate historical learning. Plecher et al. (2022) report feedback from one underwater archaeologist on a museum-oriented diving simulator, with visitor evaluation left for future work. These findings support exploration of interaction

design. Stronger claims about cultural understanding require evidence beyond usability, presence or expert impressions.

Authenticity, cultural representation and interpretive responsibility

The fourth theme concerns provenance, uncertainty, cultural representation and responsibility. Examples include difficult-heritage VR (Mohammed-Amin et al., 2025), museum-professional interviews (Shehade & Stylianou-Lambert, 2020; Song & Evans, 2024), and 3D reproductions (Malik et al., 2021). Trunfio et al. (2020) examined mixed-reality visitor experience at the Ara Pacis Museum, including the relationship between authenticity and innovation. Zhang and Chen (2025) interviewed 21 visitors following a Palace Museum VR experience about perceived authenticity. Song, Liu, and Zhao (2025) analysed online user feedback on a museum-led Dunhuang VR project through the lens of decolonial practice. These studies address different forms of authenticity and representation, not one interchangeable outcome.

Accessibility intentions and authenticity associations also require qualification. Olmedo-Pagés et al. (2025) describe accessible virtual exhibits, but planned auditory-inclusion features and design choices were not validated with a user study. Sfodera et al. (2020) report associations among perceived authenticity, reconstruction and cultural awareness in 300 post-visit questionnaires pooled across three sites, including a non-XR venue. Their cross-sectional findings cannot isolate a causal XR effect. Together, the reports support source disclosure, explicit uncertainty and evaluation with intended users as design recommendations, rather than established guarantees of trust or inclusion.

Scope and boundary cases

The review includes museums and comparable heritage displays. Some reports concern outdoor sites or museum-oriented prototypes rather than established indoor exhibitions: audio augmentation at the Venetian Walls (Toumpouri et al., 2025), a walkable MR heritage map (Bekele, 2019), and the Codex 4D public-facing VR/MR environments (Mercuri et al., 2024) illustrate this range. Such reports were retained when implemented immersive interpretation or an explicitly museum-oriented application was identifiable.

These scope decisions broaden the kinds of interpretation represented in the corpus, but they do not make outdoor visits, prototypes and established museum installations equivalent. Thematic frequencies are descriptive and depend on the setting boundary and the assignment of one principal theme per report. The conclusions below focus on recurring interpretive functions rather than a ranking of devices or themes.

Discussion

Main interpretive contribution

This review shows that museums and comparable heritage displays use XR for four related purposes. Across the 54 included primary reports, XR was used to reconstruct heritage settings, present stories about them, let visitors explore them through physical or social interaction, and shape how cultural perspectives were represented. These purposes are connected rather than separate. A reconstruction can provide the setting for a story, the story can guide what visitors notice, and the visitor experience can raise questions about authenticity, authority and cultural responsibility.

VR, AR and MR appeared in more than one theme, and the same interpretive purpose was achieved through different devices. These devices included head-mounted displays, mobile overlays, projection mapping, virtual humans, tangible interfaces and social-metaverse platforms. It is therefore more useful to examine what the museum is trying to explain, how the story is presented, what visitors do, and who is responsible for the interpretation than to classify the experience by device alone.

Answer to RQ1: what interpretive functions are reported?

The most consistently reported function was to make historical and cultural contexts easier to understand. Reconstructions, virtual museums, HBIM/WebVR models and location-based overlays connected objects with the places, periods and practices related to them (Rizvić et al., 2021; Banfi & Oreni, 2025; Pisani et al., 2024). This was especially useful when heritage was fragmented, inaccessible, damaged or geographically dispersed. The evidence suggests that XR can show the context around an object, but it does not show that visual realism alone produces better understanding.

The second function was to help museums tell stories. Character-based storytelling, volumetric video, projection mapping, avatars and sign-language narration guided visitors' attention and connected objects with human perspectives (Economou et al., 2025; O'Dwyer et al., 2021; Nikolakopoulou et al., 2022; Partarakis et al., 2022). These narrative elements made XR more than a navigable 3D model. However, every story highlights some voices and events while giving less attention to others.

The third function was to let visitors engage with heritage through movement, handling, shared exploration and participation. Visitors explored reconstructed environments, manipulated tangible representations, shared virtual spaces or contributed to the design of the experience (Petrelli & Roberts, 2023; Shim et al., 2025; Muñoz et al., 2025; Shim et al., 2024). These activities can help visitors build understanding through movement, different viewpoints, interaction and conversation. However, usefulness, ease of use and intention to use only show whether visitors accepted the technology. They do not by themselves show that visitors developed a more complex understanding of the culture.

Answer to RQ2: how does XR mediate meaning?

Across the studies, XR mediated interpretation through a similar four-step process. Museums first selected evidence and built a digital reconstruction. They then used stories, sounds or images to guide visitors' attention. Visitors explored or interacted with the reconstruction. What they understood depended on the digital representation, their prior knowledge and the way the museum explained it. This process appeared in narrative installations, virtual museums, social metaverses and multisensory systems.

However, XR did not produce the same effect in every case. A reconstruction could help visitors understand the location of an object but provide little historical understanding without explanation. A powerful story could increase emotional engagement but limit interpretation if it presented only one perspective. Physical interaction could help visitors notice details but become distracting when it was not connected to the heritage topic. XR therefore supports understanding when the spatial design, story and interaction work together and when visitors receive enough explanation.

The evidence is strongest for reported engagement, presence, perceived learning and exploratory meaning-making. It is weaker for long-term learning, transfer beyond the installation, and changes in historical understanding measured with comparable instruments. This distinction is important because much of the literature consists of prototype evaluations, practice-led case studies or small visitor samples. The findings demonstrate possibilities and recurring mechanisms more often than they demonstrate generalisable causal effects.

Answer to RQ3: authenticity, representation and responsibility

Authenticity depended on more than visual realism. Digital reproductions could support access and interpretation, yet realism could conceal missing context or uncertainty (Malik et al., 2021; Pisani et al., 2024). Source paradata and alternative hypotheses in Rafeiro et al. (2024) illustrate how a reconstruction can disclose its evidential basis. Explaining sources and limitations is therefore a defensible design recommendation; the reviewed evidence does not establish that disclosure itself causes greater visitor trust.

These issues were especially important when museums presented difficult heritage, intangible heritage or cultures unfamiliar to the visitors. Immersive experiences can create emotional involvement, but they can also make selective storytelling or inadequate cultural consultation more influential (Mohammed-Amin et al., 2025; Nikolakopoulou et al., 2022; Ravichandran & Nam, 2024). The museum's staff, curatorial decisions, training, resources and long-term maintenance also affect how XR narratives are produced and updated (Shehade & Stylianou-Lambert, 2020; Song & Evans, 2024).

Interpretive responsibility therefore means more than making the technology accurate. Museums should explain how reconstructions were made, involve relevant communities, provide access for visitors with different abilities, treat traumatic and disputed histories carefully, and continue to provide human guidance. These practices determine whether XR presents more than one cultural perspective or simply creates a convincing but simplified version of the past.

Implications for museum practice

The review has implications for museum education, cultural management and public cultural governance. Museums should design XR around explicit educational objectives and evaluate cultural understanding, reflection and recall alongside presence, usability and satisfaction (Ch'ng et al., 2020; Economou et al., 2025; Ress & Cafaro, 2021). Institutions should document the sources and assumptions behind digital reconstructions, provide accessible forms of interaction, involve relevant communities and support staff training and long-term maintenance (Hodgson et al., 2024; Partarakis et al., 2022; Shehade & Stylianou-Lambert, 2020; Song & Evans, 2024). At the policy level, these findings may inform guidance on accessibility, provenance disclosure, community participation, responsible digital heritage interpretation and long-term maintenance. These recommendations reflect recurring concerns in the literature and should not be interpreted as causal effects established by the reviewed studies.

Priorities for future research

Future studies should focus on four areas. First, comparative studies should use shared measures for usability, presence, emotional response, cultural understanding and long-term

learning. Second, researchers should follow visitors beyond one visit or a short prototype session. Third, communities should participate in designing and evaluating reconstructions of living traditions, colonial histories, traumatic events and disputed heritage. Fourth, studies should clearly report the sources of reconstructions, narrative decisions, accessibility choices and evaluation limits. These steps would help the field explain when, for whom and under what cultural conditions XR supports responsible interpretation.

Limitations

This review has several limitations. First, its evidence window comprises complete calendar years from 2019 through 2025, although the databases were searched in October 2026. The conclusions describe the literature within that window and do not assess subsequent studies. Restricting searches to Web of Science Core Collection and Scopus and to English-language journal articles may omit relevant research in other sources, languages or formats.

Second, complete readable texts could not be matched to four of the 97 reports sought (4.1%). They were recorded as not retrieved. Excluding these four reports may introduce availability bias, whose direction and magnitude cannot be determined from the retrieved corpus.

Third, the included evidence was highly heterogeneous. The studies differed in heritage type, XR modality, museum setting, participant group, outcome measure and level of evaluation. The review therefore used a systematic thematic synthesis. Theme frequencies describe the distribution of reports in this corpus; they are not effect sizes or estimates of the relative effectiveness of XR modalities.

Finally, the setting boundary includes some outdoor heritage interpretations, prototypes and mixed XR/non-XR cases. These broaden the corpus but limit direct comparison with established museum installations. The four-theme framework describes patterns across the selected reports and remains sensitive to how comparable museum interpretation is defined.

Conclusion

This review examined XR-mediated cultural-heritage interpretation across 54 primary reports published through 2025 in museums and comparable heritage displays. The reports document reconstruction and contextualisation, narrative mediation, embodied and social exploration, and questions of authenticity and responsibility. Many describe design possibilities or immediate responses; evidence within the 2019–2025 corpus for sustained cultural learning and generalisable causal effects remains limited.

In relation to the research questions, the reports describe XR functions that reconnect objects with settings, organise historical narratives and support exploration. Reported interpretation depends on the evidence selected, the narrative perspective, the activities offered and the institutional explanation surrounding the experience. Source transparency, accessibility, community participation and human guidance emerge as recurring responsibilities. These are design and governance recommendations grounded in the reviewed accounts, rather than universal effects demonstrated across all settings.

The review offers a four-theme framework linking reconstruction, narrative, embodied and social engagement, and authenticity and responsibility. Compared with related museum-display and narrative-AR reviews, it connects interpretive functions with institutional responsibilities across XR modalities while distinguishing measured outcomes from design claims. This conclusion is bounded by the 2019–2025 corpus; later studies require separate assessment. The framework can guide evaluation questions for museum practice, while future research needs comparable measures, follow-up beyond one visit and direct involvement of intended users and relevant communities.

Declarations

Ethical approval

Ethical approval was not required because this study used published literature and did not involve human participants or identifiable personal data.

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Conflict of interest

The authors declare no conflict of interest.

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