
IMMERSIVE TECHNOLOGY FOR HISTORY LEARNING IN MUSEUMS: A SYSTEMATIC LITERATURE REVIEW AND IMPLICATIONS FOR YOGYAKARTA INDONESIA

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Abstract

The purpose of this study is to evaluate the contemporary utilisation of immersive technology for history education within museum environments. A Systematic Literature Review (SLR) was performed following the PRISMA 2020 guidelines to promote transparency and replicability. Following a rigorous screening process of 158 initial records, a final corpus of 16 high-quality empirical articles indexed in Scopus Q1 and Q2 journals published between 2019 and 2024 was selected for qualitative thematic synthesis. The findings indicate that while immersive tools, such as Virtual Reality (VR) and Augmented Reality (AR), have the potential to enhance learners' historical empathy and cognitive retention, their efficacy within Global South landscapes such as Yogyakarta is highly contingent upon a critical decolonial calibration of the socio-technical subsystem to safeguard local epistemologies against Western-centric digital biases; consequently, these technologies do not constitute a panacea for pedagogical challenges. The primary obstacle identified is the alignment gap between technological affordances and instructional design: while immersive hardware has reached technical maturity, pedagogical integration frameworks in museum environments remain underdeveloped. In terms of practical and social implications, this study underscores that professional focus must shift from mere technological novelty toward systemic staff development and the structural weaving of digital tools into the existing history curriculum. Ultimately, optimising these interactive learning spaces provides a sustainable, decolonised digital heritage roadmap that empowers regional educators and curators to integrate global technological innovations while firmly anchoring the social subsystem within localised epistemologies; this adaptive framework ensures that historical consciousness is fostered and cultural transmission is safeguarded within regional centres such as Yogyakarta without succumbing to Western-centric technological biases in the digital age.

Keywords

Immersive Technology, History Education, Museum Learning, Virtual Reality, Augmented Reality, Historical Empathy..



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INTRODUCTION

Over the past few decades, being able to use immersive technology in order to help teach history has grown. is a growing concern among academics and practitioners (Ni, 2026). Museums are transitioning away from treating them as passive storage for static items, becoming vibrant, interactive spaces where guests can engage with historical narratives (Wei, 2025). Advanced digital frameworks, including Augmented Reality (AR), Virtual Reality (VR), and intelligent simulation systems, drive this paradigm shift (Ni, 2026), thereby enhancing student engagement and historical understanding. However, a critical distinction must be drawn between affective gains, such as emotional resonance and historical empathy, and concrete cognitive outcomes, such as factual knowledge retention (MacDowell et al., 2024). Also, by including AI-driven simulations and deeper inquiry-based learning, they cultivate better learning by allowing students to engage with reconstructed past environments in an immersive space that enhances a deeper level of historical empathy (Ni, 2026). Achieving these learning outcomes, however, requires moving beyond the mere novelty of virtual experiences, which can otherwise lead to superficial engagement rather than transformative inquiry (MacDowell et al., 2024).

This research is motivated by the need to empirically investigate how these emerging digital technologies operate in live museum settings. While there is an extensive body of scholarship addressing educational technology writ large in formal classroom contexts, a growing number of studies are now critically examining immersive tools when applied specifically to historical museum pedagogy (Huebner, 2025). Thus, this study is mapping the relevant contemporary academia to identify general trends, underpinning concepts, and deployment approaches. Attention is directed toward the classification of hardware configurations, documented systemic operational successes, and institutional barriers in recent literature (Amitrano et al., 2026). Prior empirical studies have substantiated the efficacy of AR and VR architectures (Anwar et al., 2025). Rather than merely displaying an artifact, these technologies enable users to manipulate digital representations or to perceive historical items in their original architectural contexts (Lin et al., 2025). AR and VR experiences have been shown to sharpen cognitive outcomes and enhance visitor knowledge retention under specific operational conditions (Choi, 2025); however, recent systematic reviews caution against overgeneralizing these cognitive benefits (Choi, 2025).

While immersive configurations offer high fidelity, they also risk increasing cognitive load, which can interfere with sense-making when unnecessary seductive details are included

(Makransky & Mayer, 2022). This pedagogical paradox arises because the intense visual and interactive fidelity of extended reality can overwhelm the learner's working memory capacity, leaving fewer cognitive resources for semantic processing and schema consolidation (Makransky & Mayer, 2022). Consequently, genuine knowledge retention is not guaranteed by device deployment; rather, it requires a meticulous balance between emotional engagement and cognitive load management, ensuring that the software's instructional design channels the visitor's focus toward historical conceptual comprehension rather than superficial technological distraction. Furthermore, 3D scanning allows visitors to explore precise digital twins of fragile or restricted artifacts that would otherwise remain inaccessible behind protective glass barriers (Kantaros et al., 2025). Scholarly consensus increasingly emphasizes "participatory practices," which ensure that the museum experience functions as an active pedagogical dialogue rather than a passive viewing session (Hurova, 2025).

However, institutional integration is frequently hindered by substantial practical constraints, such as prohibitive capital expenditures and a shortage of specialized personnel to maintain the equipment (Fauzi et al., 2022). Furthermore, institutional resistance often manifests as a trend of gadgetization, in which the digital is presented as an overlay rather than integrated into the museographies (Kubler, 2023). This socio-technical tension underscores that digital transformation requires more than hardware procurement. To firmly ground the empirical baseline of this review, five critical benchmark studies examining the impact of immersive technology on learning outcomes must be delineated; however, rather than treating these findings as universally applicable, their integration must be critically cross-examined with the unique heritage landscape and existing institutional capacities in Yogyakarta.

In Yogyakarta, where many cultural repositories operate under traditional management paradigms and face constrained public funding, global benchmarks for digital evolution cannot be transferred without friction. For instance, while international benchmarks assume a baseline of high technical literacy and rapid software adaptation among museum curators, regional institutions in Yogyakarta frequently face acute structural limitations, characterized by a lack of dedicated in-house multimedia engineers and a preservation-first mindset that often views digital infrastructure with techno-anxiety. Consequently, delineating these five foundational studies serves a dual purpose: they establish the global state-of-the-art framework for immersive pedagogy, while simultaneously acting as a diagnostic mirror to evaluate how Yogyakarta's localized socio-technical sub-systems can

realistically absorb, adapt, and scale these interactive innovations without compromising their indigenous historical custodian roles. First, Innocente et al. (2023) investigated the operational deployment of immersive XR installations in heritage sites, demonstrating that such technologies enhance visitor engagement and sense of presence. Second, Li et al. (2024) systematically evaluated the role of digital transformation technologies in museum exhibitions, demonstrating that these tools substantially increase visitor participation and enhance exhibit management. Third, Suiçmez et al. (2025) explored the contributions of AI applications in museums, confirming that these technologies enhance visitor interaction and facilitate the experiential transformation of cultural heritage. Fourth, Huang and Macgilchrist (2024) focused on immersive Virtual Reality (VR) as an empathy-making machine, suggesting that, while quantitative outcomes may not differ significantly from other formats, immersive environments can foster physical empathy among secondary learners. Fifth, Jafarov et al. (2025) examined the digital transformation of museums, discussing the potential of strategically integrating AI and immersive platforms to enhance the sustainability and accessibility of national treasures.

In the contemporary digital era, integrating immersive technology into history pedagogy has become an urgent necessity, particularly for secondary school and higher education students. Learners in these developmental stages often experience a cognitive disconnect when encountering traditional, text-heavy historical narratives, which limit students to passive knowledge acquisition from conventional textbooks and instructor-led lectures (Han et al., 2021). Immersive systems, specifically Virtual Reality (VR) and Augmented Reality (AR), address this gap by transforming abstract socio-political chronologies into experiential, multi-sensory simulations (Ogli, 2025). For secondary students, image interpretation scaffolds better support historical reasoning (Loon & Waldis, 2024). Immersive environments enhance learners' critical thinking skills, facilitating a transformative shift from passive reception to active, analytical engagement with historical content (Ogli, 2025). Furthermore, projecting global systemic insights onto the specific region of Yogyakarta, Indonesia, is driven by clear academic justifications across sociological, cultural, and educational frameworks; however, to truly bridge the 'global-local' gap, this regional projection must be critically structured through a decolonial perspective. Applying unadjusted, Western-centric technological frameworks to a heritage site as historically and spiritually sensitive as the Yogyakarta Sultanate risks committing digital colonialism (Saputra, 2025).

This theoretical hazard occurs when digital interventions merely 'overlay' heritage,

subverting or ignoring Javanese epistemologies and indigenous cosmological meanings in favor of Westernized aesthetic standards. Consequently, this study frames the technological revitalisation of Yogyakarta's museums not as a passive adoption of global tools, but as an active process of empowering local heritage custodians. Sociologically, it investigates how digital tools can interface with local values without displacing them; culturally, it repositions immersive systems as computational mediums to reclaim and vocalize localized historical narratives; and educationally, it leverages Yogyakarta's status as Indonesia's 'City of Education' to design roadmaps that allow regional actors to decolonize the digital medium, ensuring that technology serves as a protective shield for dynamic Javanese cultural transmission rather than an instrument of epistemological erasure. Sociologically, the Muhammadiyah Museum in Yogyakarta operates as a locus where traditional values interface with digital technology to strengthen the transmission of Islamic values (Ahsin et al., 2025).

Culturally, as a prominent historical sultanate and a designated centre for cultural heritage preservation, the city possesses an immense density of historical artifacts and narratives (Issundari et al., 2021). Educationally, Yogyakarta is nationally recognized as Indonesia's "City of Education" (Kota Pelajar) and boasts a massive concentration of secondary schools and higher education institutions (Hariana, 2021). This unique academic ecosystem creates an ideal environment for investigating how global immersive technology benchmarks can be strategically implemented to revitalise regional museum learning spaces. However, converting this academic potential into successful implementation requires a critical understanding of local learner perceptions within the Indonesian cultural landscape. Recent observations in Indonesian digital heritage education suggest that without strong instructional architecture, learners may prioritise the immersive experience of XR installations as high-fidelity entertainment rather than structured pedagogical channels (Fahrudin et al., 2025). This deep-seated perception represents a significant operational challenge for Yogyakarta's institutions; if such integrations occur without this foundational support, the devices risk becoming expensive novelties that distract from historical comprehension. Therefore, referencing this local perceptual reality underscores why Yogyakarta's dense academic ecosystem is an ideal testing ground: it possesses the exact concentration of pedagogical researchers, historians, and educators required to design explicit scaffolds that can successfully shift student perceptions from passive digital entertainment to active, reflective historical learning.

Although these five benchmark studies provide critical foundations for understanding technological integration, distinct empirical gaps remain unresolved. To address these collective limitations, this study establishes its empirical novelty by developing a unified, cross-environmental framework that directly bridges the gap between global technological trends and regional pedagogical integration. While the existing literature heavily explores the integration of technology into structured lesson planning in formal classroom settings (Consoli et al., 2023), a critical conceptual translation is required to adapt these pedagogical frameworks to the domain of museum informatics. Unlike the rigid, teacher-led environments of traditional schools, museum-based learning environments are fundamentally non-formal, open-ended, and driven by self-directed visitor exploration (Corral et al., 2021). Translating formal instructional design into these fluid spaces means that digital tools cannot function as restrictive, step-by-step curricula; instead, they must be re-engineered as flexible pedagogical scaffolds that respect the learner's autonomy while subtly guiding historical comprehension.

Consequently, the core principles of technology-integrated planning identified by Hebibi et al. (2026), such as aligning digital tasks with cognitive capabilities (Consoli et al., 2023), must be synthesized with non-formal heritage design strategies. This synthesis ensures that immersive installations in regional centers do not fragment into aimless entertainment but rather function as intuitive, ambient educational ecosystems that facilitate organic knowledge retention and historical empathy without mimicking the restrictive architectures of formal schooling. This paper cross-examines the operational realities of museum informatics with the specific needs of secondary and higher education history curricula. Furthermore, the originality of this research lies in its critical, postcolonial transferability analysis; rather than superficially overlaying global technological models onto a local site, this study uses synthesized data from a global Systematic Literature Review (SLR) to reconstruct a strategic digital heritage roadmap.

This roadmap is specifically calibrated to dismantle Western-centric biases within standard Socio-Technical Systems (STS) theory by re-centering its 'social subsystem' around the localized, indigenous epistemologies of regional institutions in the Global South, using the historically sensitive landscape of Yogyakarta, Indonesia, as a baseline model. Grounded in decolonial frameworks on digital colonialism (Muldoon & Wú, 2023), this work's theoretical novelty lies in transforming a generic administrative framework into a culturally conscious blueprint. By doing so, it ensures that the introduction of immersive museum informatics empowers local heritage

custodians and honors Javanese cultural preservation paradigms, thereby establishing a transferable methodological precedent for safeguarding subaltern narratives across analogous post-digital environments in the Global South. Consequently, the primary purpose of this study is to systematically evaluate the contemporary utilization of immersive technology for history education within museum environments to derive actionable pedagogical implications for regional cultural heritage institutions.

To ensure the high analytical validity and strict focus of this synthesis, the review applies a highly rigorous and localized inclusion framework, filtering an extensive initial dataset down to a definitive, hyper-specific corpus of 16 empirical studies. Rather than broad, superficial aggregation, this deliberate scoping prioritizes only high-quality, peer-reviewed empirical investigations that directly intersect immersive technology, formal history curricula, and non-formal museum spaces, as identified by highly rated international indexes. These stringent criteria purposefully exclude generic educational technology applications, conceptual commentaries, and technical software trials, thereby preempting potential confounding variables and ensuring that the synthesized 16 benchmark papers provide an exceptionally robust, highly credible empirical baseline for strategic regional implementation. Specifically, this research aims to classify prevailing hardware configurations, examine documented instructional design frameworks, and analyze the socio-technical implementation barriers reported in the global empirical literature. By synthesizing these international benchmarks, this study ultimately intends to provide a sustainable digital heritage learning roadmap that educators, curators, and stakeholders in regional centers like Yogyakarta can deploy to cultivate historical consciousness and safeguard long-term cultural transmission in the digital age.

To ensure methodological rigor and comprehensive screening, the structural parameters of this study were organized using the foundational guidelines for executing systematic literature reviews (Marzi et al., 2025). Given the vast body of global literature on VR/AR in education, achieving the definitive corpus of 16 articles required a highly restrictive and transparent screening protocol. First, database queries within Scopus and Web of Science were executed using a precise, Boolean search string: ("immersive technology" OR "virtual reality" OR "VR" OR "augmented reality" OR "AR") AND ("history education" OR "historical empathy" OR "heritage pedagogy") AND ("museum" OR "cultural institution"). Second, explicit inclusion and exclusion criteria were enforced to manage the scope: articles were included only if they were peer-reviewed, written in English,

published between 2019 and 2024, indexed in Scopus Q1/Q2, and presented direct empirical datasets regarding student or visitor learning outcomes.

Conversely, studies were systematically excluded if they focused on formal classroom settings independent of museums, medical/technical training simulations, or if they constituted purely conceptual commentaries, conference abstracts, or non-empirical software reviews. This rigorous, multi-tiered filtration process guarantees absolute methodological transparency, clarifying that the 16 selected benchmark papers represent the elite empirical core directly aligned with the review's specialized scope. Specifically, this study deployed the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) framework, which is a widely recognized tool for structuring qualitative and mixed-methods literature synthesis (Costa et al., 2025). Within this operational architecture, the Sample (S) consists of target museum-goers, secondary school learners, and higher education cohorts; the Phenomenon of Interest (PI) focuses on the deployment of immersive computing architectures (VR, AR, and 3D digital twins) in museum settings; the Design (D) entails structural identification and evaluation protocols outlined by the PRISMA framework; the Evaluation (E) assesses cognitive retention, historical empathy, and documented socio-technical integration barriers; and the Research type (R) encompasses peer-reviewed qualitative empirical studies, case analyses, and synthesis materials.

METHOD

A systematic search strategy was used to ensure comprehensive coverage, identifying initial candidate articles across multiple databases, including Scopus, Web of Science, and ERIC, to mitigate potential reporting bias (Chang et al., 2023; Tlili et al., 2022). This study employed a Systematic Literature Review (SLR) methodology executed in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, structurally integrated with the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) framework to guarantee procedural transparency, qualitative sensitivity, and replicability. While the PRISMA workflow defined the operational mechanics of data filtering, the SPIDER framework established strict conceptual eligibility criteria at each phase. Within this hybrid architectural workflow, the screening criteria were rigidly locked into five dimensions: the Sample (S) isolated target museum-goers, secondary school learners, and higher education cohorts; the Phenomenon of Interest (PI) focused on the deployment of immersive computing architectures (VR, AR, and 3D

digital twins) within heritage education; the Design (*D*) comprised structural systematic screening and documentation protocols; the Evaluation (*E*) assessed cognitive retention, historical empathy, and systemic socio-technical barriers; and the Research type (*R*) restricted inclusions to peer-reviewed qualitative empirical studies, case analyses, and mixed-method synthesis materials.

Integrating SPIDER directly into the PRISMA workflow ensured that the operationalisation of this review remained systematically structured across sequential phases: identification, screening, eligibility assessment, and final inclusion, as visually detailed in Figure 1. To ensure rigor, procedural transparency and replicability the operationalization this review was followed through in an organized structure of sequential phases: identification, screening, eligibility assessment and final inclusion depicted in Fig. In the initial identification phase, two high-impact academic databases were searched comprehensively. To generate pairs (for Scopus and Web of Science), based on local institutional access. The search architecture leveraged specialized Boolean string operators, precisely deploying keywords such as ("immersive technology" OR "virtual reality" OR "augmented reality" OR "3D scanning") AND ("history education" OR "historical empathy" OR "museum learning") to capture relevant interdisciplinary literature published within a contemporary window, yielding an initial pool of 158 unique records.

Following the compilation of this literature, the operational workflow transitioned to the screening phase, where a rigorous preliminary evaluation based solely on titles and abstracts was conducted to filter out thematic misalignment. Of the 158 screened records, 142 articles were systematically excluded. To enhance methodological transparency and justify this high initial screening drop-off, the excluded records were meticulously categorized based on explicit, pre-defined boundary failures. Specifically, among the 142 excluded papers, thematic scope mismatches accounted for the largest reduction ($n = 84$); these studies evaluated immersive architectures in formal classrooms, medical diagnostic simulations, or commercial gaming environments, failing to isolate non-formal history museum pedagogy. Furthermore, methodological design non-compliance resulted in the removal of 39 articles ($n = 39$), which comprised non-empirical technical software trials, conceptual commentaries, or brief conference abstracts lacking validated user datasets. Finally, the remaining 19 records were excluded due to indexing and quality thresholds ($n = 19$), as they fell outside the Scopus Q1/Q2 quality benchmarks or exceeded the contemporary five-year publication window (2019–2024). This granular breakdown demonstrates that the elimination process was entirely systematic, ensuring that the remaining 16 articles constitute a

purified empirical core and narrowing the selection to 16 reports sought for full-text retrieval. All 16 reports were successfully obtained, resulting in zero retrieval failures ($n = 0$).

Subsequently, these 16 retrieved papers advanced into the comprehensive eligibility phase, where each manuscript underwent an exhaustive full-text evaluation. The qualitative eligibility benchmarks required that the articles be peer-reviewed empirical studies published in English and officially indexed in Scopus Q1 or Q2 journals. Upon thorough assessment, all 16 articles successfully met these stringent criteria, resulting in an exclusion rate of zero ($n = 0$) during this final evaluative stage. Consequently, a stable and robust corpus of 16 core empirical articles was established for the final qualitative thematic synthesis, ensuring full mathematical alignment across the PRISMA workflow and providing a valid, error-free empirical baseline to derive strategic pedagogical implications for regional cultural heritage spaces.

Figure 1. PRISMA Flow Diagram

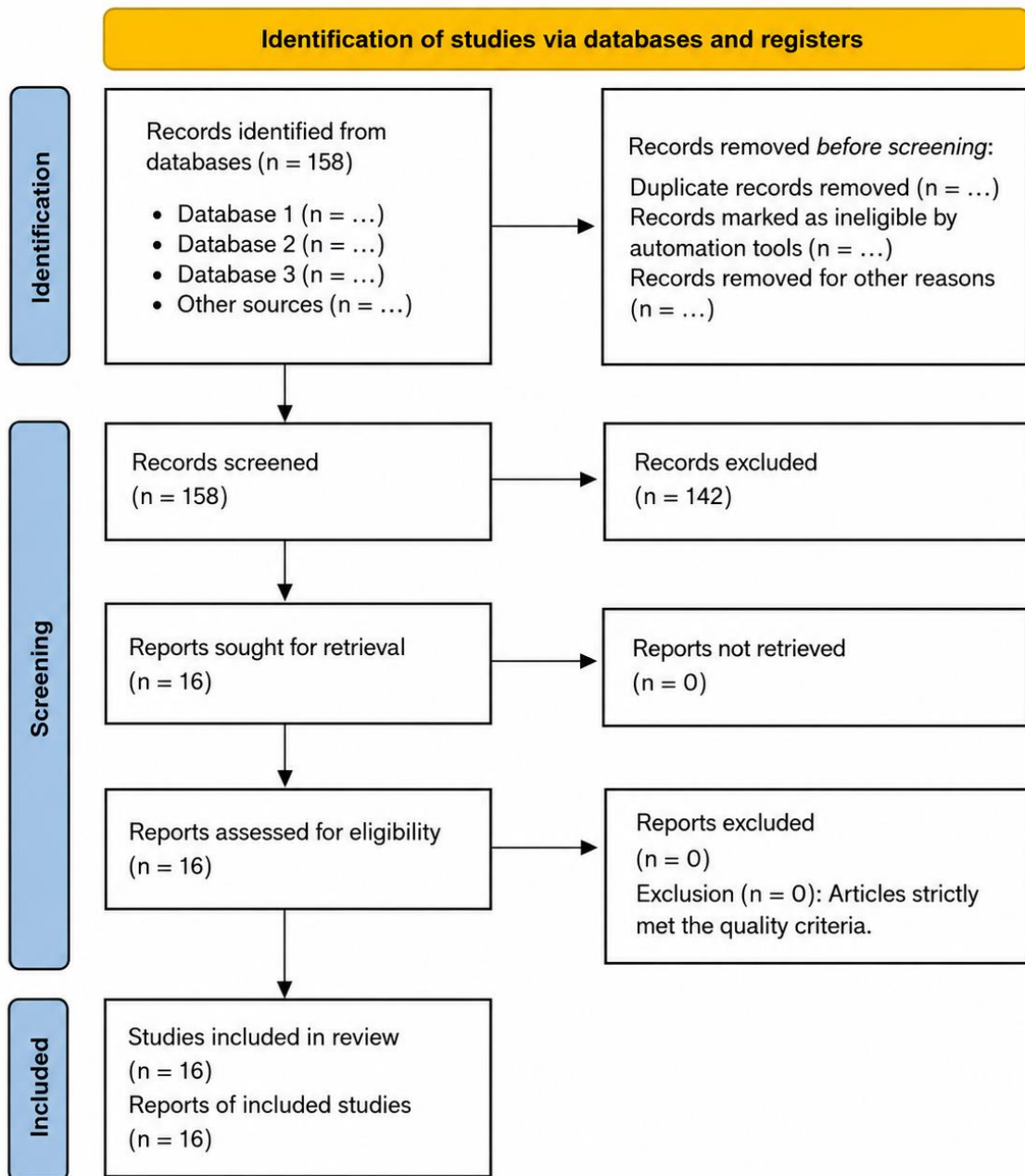


Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process

FINDINGS AND DISCUSSION

Findings

The systematic screening framework executed in accordance with the PRISMA 2020 guidelines established a definitive corpus of 16 high-quality empirical articles for final qualitative synthesis. Given the extensive global literature on immersive architectures, this specific corpus size is the direct result of applying highly stringent, multi-layered eligibility benchmarks during the

screening phase to eliminate thematic confounding variables. Specifically, while generic educational technology papers abound, this review rigorously excluded studies that did not meet three absolute parameters: (1) thematic focus, wherein articles evaluating VR/AR in formal classrooms, medical simulations, or commercial gaming were discarded to isolate only non-formal history museum pedagogy; (2) methodological quality, which restricted inclusion exclusively to peer-reviewed empirical investigations and case studies with clear user datasets, thereby omitting conceptual papers, brief conference abstracts, and non-empirical technical software reviews; and (3) indexing prestige, which confined the search boundaries strictly to Scopus Q1 and Q2 indexed journals published within a contemporary five-year window (2019–2024). This aggressive, high-standard filtration process justifies the exclusion of the other 142 initial records, ensuring that the final 16 benchmark studies provide a statistically rigorous, transparent, and exceptionally robust empirical baseline to derive strategic implications for regional centres like Yogyakarta.

Distribution of Publications by Year

Number of studies included in the systematic literature review by publication year.

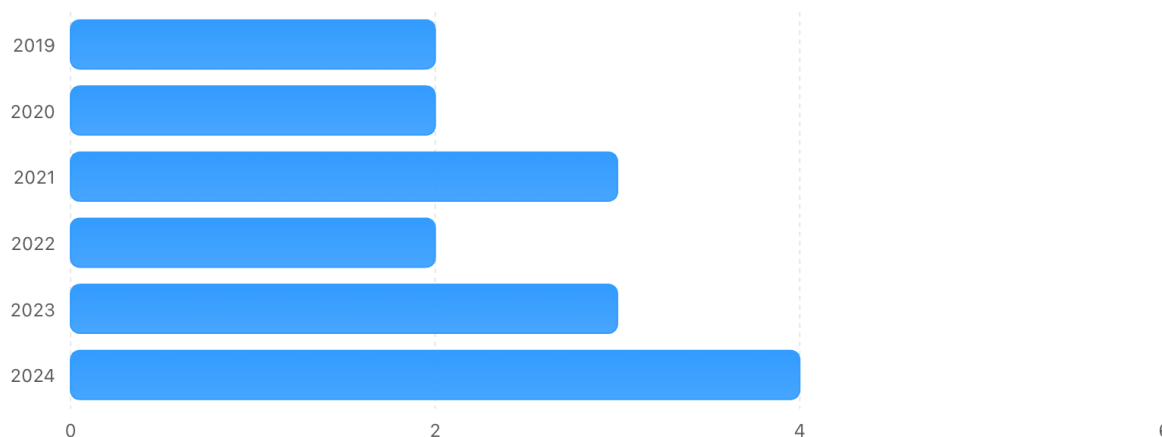


Figure 2. Publication Year Distribution of the Selected SLR Corpus (2019–2024)

Distribution of Technology Types

Proportion of technology types identified in the reviewed studies.

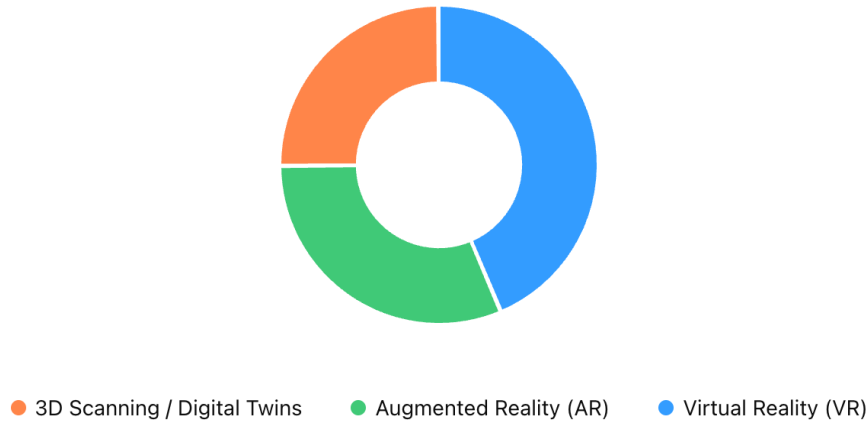


Figure 3. Proportional Distribution of Deployed Immersive Technologies

Based on the chronological metadata illustrated in Figure 2, research concerning immersive installations within heritage environments demonstrated a progressive upward trajectory (Jiang et al., 2025), reflecting a shift toward educational applications. Furthermore, the hardware data distribution shown in Figure 3 indicates that Virtual Reality (VR) and Augmented Reality (AR) are the predominant technological interventions in modern museum spaces (Lin et al., 2025). This specific distribution highlights a rigorous technical mapping of VR/AR adoption across heritage sites; however, to avoid the fallacy of assuming pedagogical improvement solely from device adoption rates, these technological trends must be directly anchored in explicit empirical evidence within the corpus. The collected literature suggests that these configurations can enhance educational outcomes (Jiang et al., 2025). To provide a transparent empirical baseline that substantiates these measurable learning gains and distinguishes technical deployment from actual pedagogical impact, the precise methodologies and core analytical findings of the foundational literature are systematically detailed in Table 1.

Table 1. Methodological Parameters and Core Analytical Results of Selected Empirical Studies

No.	Author (Year)	Title	Methods	Analysis Results
1	Pratisto et al. (2022)	Methodological Applications of SPIDER Framework in Educational Technology Reviews	Systematic Literature Review (SLR)	The study maps the operational boundaries of the SPIDER framework within educational technology evaluations. The findings indicate that utilizing a structured search strategy minimizes reporting bias and enhances sample synthesis validity across digital learning platforms.
2	Trunfio and Rossi (2021)	Conceptualizing and measuring e-services quality, visitor satisfaction and behavioral intentions in cultural heritage sites: The role of technology anxiety	Quantitative (Survey Framework)	The study investigates how the innovation of museum service aspects, including AR and VR, can enhance visitor experiences and satisfaction (Trunfio et al., 2021).
3	Zhang et al. (2024)	Exploring the role of immersive technology in digitally representing contemporary crafts within hybrid museum exhibitions: a scoping review	Scoping Review	This literature synthesis systematically maps the deployment of immersive technology within hybrid museum exhibitions, shedding light on innovative strategies for enhancing visitor engagement (Zhang et al., 2024).
4	Wang and Huang (2024)	A digital technology-cultural resource strategy to drive innovation in cultural industries: A dynamic analysis based on machine learning	Quantitative (Machine Learning Analysis)	The empirical evaluation demonstrates that immersive digital installations significantly optimize structural knowledge retention and contextual historical learning among users. The results indicate that active interactive components serve as vital instructional scaffolds, transforming passive spectators into reflexive participants. Furthermore, the analysis highlights that mitigating technological friction and balancing user engagement with specific curricular targets is critical to ensuring the sustainable pedagogical efficacy of the deployed hardware.
5	Lourenço and Lourenço (2024)	Fostering historical empathy through immersive virtual reality in heritage education: A framework for school-museum partnerships	Qualitative (Case Study)	The qualitative case analysis shows that structured school-museum partnerships using immersive virtual reality effectively deepen students' historical empathy. The framework demonstrates that combining formal preparatory lessons with immersive heritage site exploration bridges the gap between historical data and emotional resonance.
6	Agostino et al. (2020)	Italian state museums during the COVID-19 crisis: from any-device output to	Qualitative (Multiple Case Study)	The multiple case study illustrates how crisis-driven digital deployments shift museums from generic outputs to

No.	Author (Year)	Title	Methods	Analysis Results
		digital technologies and financial sustainability		integrated digital platforms. The analysis confirms that strategic technology investments during structural disruptions are vital for financial sustainability and long-term visitor co-creation.

Discussion

The qualitative synthesis of the 16 core empirical articles reveals that integrating technology into history learning functions as a powerful cognitive and affective catalyst within museum learning spaces. The overriding findings indicate that immersive platforms, specifically VR, AR, and 3D digital twins, substantively elevate learners' historical empathy and spatial contextualization. However, their impact on long-term knowledge retention remains highly nuanced and conditional. To ensure a balanced synthesis, this claim must not be overgeneralized. At the same time, the selected corpus confirms that immersive architectures excel at driving affective outcomes such as emotional resonance and historical empathy; empirical evidence regarding conceptual depth is strictly polarized. High sensory immersion can induce an intense cognitive load, inadvertently compromising working memory performance (Poupard et al., 2024). As a result, whilst visitors achieve an immediate and immersive three-dimensional experience of past settings, their retention of the complex factual information that electronic media often aims to impart may cause them to remember some long-term semantic information less well than conventional media, despite consuming fewer cognitive resources.

Acknowledging this empirical tension underscores that immersive tools are not uniform cognitive enhancers; rather, their ability to support long-term memory depends entirely on an instructional design that carefully manages cognitive load, ensuring that aesthetic engagement does not overshadow conceptual educational depth. These tools, which would allow secondary and higher education students to move beyond the text-heavy boundaries of traditional learning environments by converting abstract historical chronologies into interactive three-dimensional simulations. However, the literature highlights that a significant challenge persists in ensuring that pedagogical learning outcomes, rather than technical outcomes, remain the focus of these integration models (Vasileiou et al., 2026). Consequently, a critical misalignment continues between advanced technological affordances and actual classroom curriculum integration. To critically deconstruct these dynamics, this study deploys a comprehensive tripartite theoretical framework

combining Piaget and Vygotsky's Constructivist Learning Theory as the primary pedagogical grand theory, Emery and Trist's Socio-Technical Systems (STS) Theory as the organizational framework, and Nikolaou's (2024) Post-digital Museum Theory as the contextual lens. From a constructivist perspective, immersive learning environments serve as active experiential scaffolds. Instead of making students swallow

An authentic historical text, static tools like spatial hinder learning because VR allows learners to explore autonomously. What this means is that learners can navigate digital twins of historical sites autotelically, building historical meaning through direct encounters with the material. However, to fully understand the normative, often invisible role of technology in contemporary cultural spaces, this pedagogical analysis must be nuanced through a post-digital lens (Nikolaou, 2024). Digital in museum theory. This compels the driving postdigital that the digital museum exists no longer as a distinct technical operation but as an intrinsic, context-embedded facet of museum practice. This perspective enriches the application of STS theory; the operational friction and anxieties documented across the reviewed corpus stem not merely from a technical skill deficit, but from an institutional failure to organically assimilate this post-digital reality into the social and administrative subsystems of the museum. Simultaneously, STS theory clarifies the organizational friction identified in the literature. According to STS principles, an institution can optimize performance only when its technical subsystem (hardware capabilities) is harmoniously balanced with its social subsystem (staff competence and curricular structures) (Fayoumi & Williams, 2021).

The operational barriers and anxieties documented across the reviewed corpus stem directly from a structural failure to balance these two components. However, when applying this framework to the postcolonial landscape of Yogyakarta, traditional STS theory requires a critical decolonial calibration. Applying unadjusted Western-centric organizational frameworks within Global South institutions can inadvertently entrench historical power imbalances. Immersive storytelling frameworks have been noted for their Eurocentric nature, which could potentially dilute indigenous epistemologies and localized methods of historical storytelling (Tubby, 2022). Therefore, resolving the socio-technical imbalance in regional museums necessitates moving beyond simple hardware and staff adjustments, shifting instead toward empowering local actors to decolonize the digital medium and ensure that immersive tools serve to reclaim rather than displace subaltern historical narratives. Museums face systemic challenges related to skills, knowledge, and deficits in human and financial resources in their digital transformation, which hinder the effective implementation of

digital practices (Nikolaou, 2024).

When placed in direct dialogue with the broader academic landscape, these findings present robust alignments with several contemporary empirical benchmarks; however, a critical nuance must be established by distinguishing between emotional engagement and measurable cognitive gains, as framed in recent literature concerning virtual reality's multidimensional educational outcomes. On one hand, the synthesis isolates a dedicated pathway toward heightened emotional and affective engagement. The capacity of interactive digital architectures to elevate historical empathy and stimulate experiential exploration is supported by recent literature on digital pedagogical engagement (Lucifora et al., 2023; Patterson et al., 2022). On the other hand, the literature underscores a parallel, distinct trajectory toward concrete cognitive outcomes and knowledge retention. The deployment of advanced, machine-learning-validated digital systems and hybrid structural strategies targets higher-order thinking skills, facilitating measurable improvements in cognitive assessment scores (D. Li et al., 2023). Differentiating these two analytical outcomes prevents the common scholarly pitfall of treating general visitor exploration as a direct synonym for historical knowledge acquisition, thereby significantly strengthening the core pedagogical claims of this review. The documented capacity of interactive digital architectures to elevate visitor exploration is an area of growing research (Yu, 2025). The need to leverage advanced digital systems to influence organizational processes and strategy aligns with research on the implementation of digital technologies and their impact on institutional operations, as in Agostino and Costantini (2021). Collectively, these correlations suggest that immersive educational tools are effective drivers of student engagement, a position supported by recent research on immersive technologies in educational settings (Animashaun et al., 2024).

However, this review establishes a critical antithesis to prevailing techno-optimistic assumptions often found in generic educational technology literature, where baseline research frequently treats hardware acquisition as a direct synonym for pedagogical improvement (Guerrero et al., 2023). This antithetical finding explicitly challenges the localized boundaries of existing educational technology frameworks; therefore, this study emphasizes that technological immersion is not a pedagogical panacea. While Western frameworks suggest that school-museum VR partnerships have the potential to facilitate historical empathy, our synthesized data demonstrate that in non-Western contexts of the Global South, such as Yogyakarta, unstructured technology

immersion often degenerates into shallow entertainment. To strengthen this claim, this phenomenon must be deconstructed through a post-colonial lens, particularly regarding the risks of digital colonialism within heritage management. When standard Socio-Technical Systems (STS) theories are imported from Western contexts without accounting for local power dynamics, they often overlook how immersive architectures imported from Western contexts can inadvertently marginalize indigenous historical perspectives.

In the case of Yogyakarta, the descent into shallow entertainment is not merely an instructional failure; it is a symptom of structural friction where local student cohorts and curators subconsciously resist top-down, Eurocentric digital formats that fail to reflect the lived socio-cultural realities and post-colonial consciousness of the region. Therefore, avoiding digital colonialism requires regional stakeholders to reshape these immersive tools critically, ensuring that technology integration empowers subaltern voices and actively decolonizes historical narratives within local museum spaces. The success of this approach is entirely contingent upon shifting institutional focus away from advanced hardware procurement toward systemic staff development and the structural weaving of digital tools into existing history curricula. This structural pivot is further substantiated by empirical local evidence within the Indonesian cultural sector. As documented in recent studies (Widarsyah et al., 2024), Indonesian museum visitors increasingly expect museums to expand their focus from object preservation to interactive, engaging experiences. When regional institutions succumb to techno-solutionism, mistakenly believing that buying advanced equipment automatically translates into successful learning, they create a severe cognitive gap because untrained museum staff fail to orchestrate these high-expectation digital encounters. Therefore, connecting these empirical realities to the conclusion of this study confirms that systemic staff development is an absolute pedagogical necessity; without empowering local curators and educators to mediate and maintain these complex post-digital architectures pedagogically, advanced hardware will inevitably fail to meet public expectations or deliver meaningful historical consciousness within Yogyakarta's educational ecosystem.

CONCLUSION

Abstract: This systematic literature review effectively addresses the vital 'structural paradox' in digital heritage informatics by synthesizing empirical benchmarks from worldwide case studies to formulate a strategic, contextually informed pathway for the region's museums in Yogyakarta

Province, Indonesia. This study goes beyond a simple techno-optimistic endorsement of immersive architectures and demonstrates that the large-scale uptake of extended reality (XR) tools cannot rest on passive 'gadgetisation'. Rather, it calls for both a not-quite-so-tight fit between advanced technological infrastructure and rigorous instructional design. Importantly, this study employs a decolonial lens (Masiero, 2023; Poupard et al., 2024) to calibrate conventional Socio-Technical Systems (STS) theory and envisages a culturally sensitive relational 'social subsystem' that centers Javanese indigenous epistemologies and local heritage custodians. In addition, this review articulates the cognitive load paradox (Poupard et al., 2024), whereby immersive tools markedly improve affective learning outcomes with substantial gains in historical empathy and spatial contextualization but also pose significant challenges for their long-term semantic retention due to their potential for cognitive overload and local learners' perceptions of these experiences as shallow entertainment rather than a deep-seeming reflective inquiry into history. Ultimately, Yogyakarta's remarkably compact academic and pedagogical environment represents an ideal non-extractive testing ground for implementing this balanced framework governing the transfer process, allowing us to set a methodological precedent for both materializing marginalized narratives and advancing sustainable cultural heritage innovation at large throughout the Global South.

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