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Assessing Digital Tools in Education Process for Cultural Heritage: A Literature Review / Jiang, Y., Liang, X., Coscia, C.. - In: INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES. - ISSN 2194-9034. - ELETTRONICO. - XLVIII-M-9-2025:(2025), pp. 645-652. [10.5194/isprs-archives-XLVIII-M-9-2025-645-2025]

*Availability:*
This version is available at: 11583/3003655 since: 2025-10-06T08:11:31Z

*Publisher:*
Copernicus Publisher

*Published*
DOI:10.5194/isprs-archives-XLVIII-M-9-2025-645-2025

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07 November 2026

# Assessing Digital Tools in Education Process for Cultural Heritage: A Literature Review

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**Keywords:** Digital Tools, Cultural Heritage, Participatory Leaning, Education, Assessment.

**Abstract**
Participatory learning plays a key role in people-centered heritage conservation by engaging communities and diverse audiences in knowledge co-creation and transmission. Emerging digital tools further expand access and enrich heritage education. While numerous case studies have explored these tools, existing research often isolates technological features from educational outcomes, lacking a comprehensive understanding of how tool types support participatory learning goals.
This study analyzes 140 relevant publications retrieved from the Scopus database, using a four-dimensional framework encompassing Cultural Heritage, Education, Digital Tools, and Participation. Following data purification, a quantitative analysis is performed to systematically examine keyword evolution and the development of research focus over time, utilizing the visualization tool CiteSpace. The findings reveal the research interests within the digital tools in participatory learning in education process of cultural heritage sector over the past decade have been evolving along time, encompassing areas such as immersive technologies (VR/AR), gamified learning (serious games), applications in higher education, and socio-cultural engagement, while increasingly expanding towards AI-driven personalized learning, multimodal interaction, and big data analytics.
Furthermore, by establishing an assessment framework, this study elucidates the distinct advantages and disadvantages of each digital tool in the educational process. The insights derived aim to provide practical guidance for researchers, policymakers, and educators on how to effectively integrate emerging technologies into participatory learning initiatives for cultural heritage conservation.

## 1. Introduction

The digital transformation of education has profoundly influenced how cultural heritage is communicated, preserved, and experienced. These technologies enhance immersion, interactivity, and accessibility, thus enabling broader participation in heritage experiences.

However, these opportunities are accompanied by challenges. Many digital platforms simplify content to cater to short attention spans, leading to a reduction in the depth and authenticity of cultural narratives. There is also a tendency to treat users consumers rather than active participants, diminishing the potential for community engagement and collective memory construction. Furthermore, the digital divide continues to marginalize older adults and under-resourced communities (Bowden et al., 2025).

While digital tools have transformed heritage education, their effectiveness hinges on inclusivity, participation, and pedagogical relevance. This study addresses a key gap by critically examining how digital technologies support participatory learning, guided by the following research questions:

1. What types of digital tools are currently being used in the education process for cultural heritage?
2. How do these tools support participatory learning?
3. In what educational contexts are these tools applied, and what impacts do they produce?

This study follows a multi-step approach to develop a user-centered evaluation framework for participatory digital learning in the heritage sector. It begins with a comprehensive literature review to establish an evaluation framework grounded in five dimensions of participatory learning. Based on a well-defined search string, 140 relevant articles are then retrieved from Scopus. In this phase, CiteSpace is used to identify key research trends. Subsequently, a qualitative assessment of eight digital tools is conducted to examine their strengths, limitations, and impacts.

## 2. Research Background: Participatory Learning in Education Process for Cultural Heritage

### 2.1 The Role of Digital Technology in Supporting Participatory Learning

As digital tools are increasingly used in heritage education, they have helped democratize access, reduce dependence on physical infrastructure, and enhance user engagement through immersive and interactive experiences. However, their rapid integration also presents challenges. Digital media may sometimes shift the focus of cultural engagement toward entertainment, weakening the depth of heritage interpretation (Darda et al., 2025). Moreover, certain populations—such as older adults or users with disabilities—often encounter usability and accessibility barriers in virtual environments (Habarurema et al., 2025; Jangra et al., 2025).

Participatory learning offers a value-based response to these emerging risks by placing the learner at the center of the educational process. This approach emphasizes active meaning-making, collaborative engagement, and cultural contextualization. Two key concepts—co-creation and community engagement—underscore this learning model. In co-designed virtual environments, for example, users with intellectual disabilities have contributed meaningfully to the development of inclusive museum experiences, showing how participatory practices can promote both empowerment and innovation (Bianco et al., 2025). Community-driven projects, such as interactive augmented reality exhibits targeting younger audiences, illustrate how participatory design enhances relevance, motivation, and intergenerational learning (Khan et al., 2025). Participatory learning reframes digital heritage education not as a matter of delivering content, but of cultivating active, inclusive, and culturally resonant learning experiences. This approach becomes particularly urgent in an era of rapid technological innovation, where ensuring meaningful engagement is as critical as expanding access.

### 2.2 Evaluating the Impact of Digital Tools on Participatory Learning in Education Process of Cultural Heritage: A Five-Dimensional Value Framework

To understand how digital tools contribute to participatory learning in cultural heritage education, this study identifies five interrelated value dimensions: **engagement, collaboration, co-creation, personalization, and inclusiveness**. They reflect not only what tools can do, but what they should enable—active, meaningful, and inclusive learning across contexts.

**Engagement** is foundational to sustained learning. Immersive environments such as virtual museums and serious games have shown strong potential to evoke curiosity, emotional connection, and focused attention. For example, augmented reality apps tailored for younger generations have successfully increased motivation and interest in museum settings. Similarly, game-based museum experiences encourage curiosity-driven learning and deeper reflection (Chen et al., 2025).

Digital tools that promote social interaction help shift learners from passive consuming to active **collaboration**. The use of AI-powered chatbots can enhance user interaction in museums by supporting dialogue-based exploration and personalized responses. Multi-user VR environments and collaborative museum platforms also offer opportunities for synchronous and asynchronous peer exchange, reinforcing collective memory-building (Mestiri et al., 2025).

Participatory learning thrives on opportunities for users to contribute meaningfully to content development. In co-designed virtual museums, users have actively shaped exhibit narratives, demonstrating that **co-creation** fosters both inclusivity and personal expression (Bianco et al., 2025). Interactive AR platforms also allow learners to map their own stories or observations onto existing heritage content, blending formal and informal knowledge (Liang et al., 2025).

**Personalization** learning is particularly valuable in digital heritage contexts, where users may differ in background knowledge, interest, or technological fluency. Mobile and web-based applications with adaptive navigation, modular content, or self-guided routes enable learners to control their pace and path. Serious games and XR experiences with branching narratives also allow for differentiated engagement, encouraging reflective learning aligned with personal goals (Zhan et al., 2025).

**Inclusiveness** ensures that diverse users can participate equitably. AI telepresence robots have extended access to cultural spaces for users with mobility limitations, allowing them to remotely explore heritage sites (Iodice et al., 2025). Similarly, immersive VR environments designed with sensory and interface adaptations have enabled users with disabilities to engage meaningfully with museum content. These innovations demonstrate how digital tools can bridge—not widen—access gaps when developed with inclusive principles.

## 3. Methodology

This study follows a three-step methodology:
(1) collecting articles using a four-dimensional conceptual framework; (2) reviewing and classifying digital tools used in heritage education, and applying three CiteSpace functions—Keyword Co-occurrence, Cluster Analysis, and Timeline View; (3) analyzing case studies drawn from the literature sample identified in Section 3.1 to assess how these tools support engagement, collaboration, co-creation, personalization, and inclusion, and offering practical recommendations for tool selection (as detailed in Figure 1).

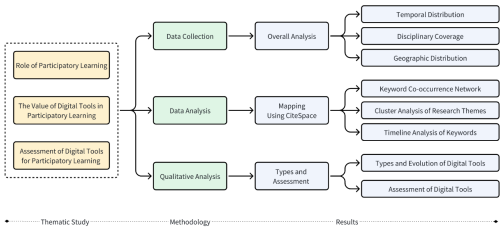


Figure 1. Research Framework. Source: Authors' elaboration.

### 3.1 Data Collection

A four-dimensional conceptual framework—covering Cultural Heritage, Education, Digital Tools, and Participation—guided the literature search to ensure thematic and interdisciplinary relevance. To improve precision, participation was defined using targeted terms such as “co-creation” and “student engagement.” Preliminary tests showed that broad adjectives like “participatory” or “engaging” often yielded irrelevant results, prompting the use of compound expressions (e.g., “participatory learning”, “collaborative education”) to capture the intended educational context more effectively.

The final query string used in the Scopus TITLE-ABS-KEY field was as follows:
*TITLE-ABS-KEY (("heritage") AND ("educat*" OR "teach*" OR "learn*" OR "train*") AND ("participat* learning" OR "collaborat* learning" OR "participat* education" OR "collaborat* education" OR "student* engag*" OR "engag* learning" OR "active learning" OR "experien* learning" OR "interact* learning" OR "co-creation") AND ("digital" OR "technolog*" OR "ICT" OR "e-learning" OR "interact*" OR "applicat*" OR "virtual reality" OR "augmented reality" OR "serious game*" OR "gamif*"))*

This search strategy initially retrieved 382 records from Scopus, which was selected as the primary source for data collection. The search covered publications from 2022 to 2025 and was completed as of June 10, 2025. Subsequently, a manual screening was conducted (as detailed in Table 1), resulting in a final set of 140 publications included for bibliometric and qualitative analysis.

| No. | Selection Criteria |
|---|---|
| 1 | Only peer-reviewed journal and conference papers. |
| 2 | Studies had to explicitly focus on educational contexts related to cultural heritage. |
| 3 | Articles focusing exclusively on intangible heritage (e.g., music) were excluded. |
| 4 | Records without full-text access were also removed. |

Table 1. Literature Selection Criteria. Source: Authors' elaboration.

### 3.2 Data Analysis and Visualization

Before conducting bibliometric visualization, a basic descriptive statistical analysis was performed on the selected articles. This step aimed to provide an overview of the dataset's temporal distribution, disciplinary scope, and geographic origins. These descriptive statistics serve as a contextual foundation for the subsequent CiteSpace-based knowledge structure analysis.

In order to analyze the knowledge structure, thematic patterns, and temporal evolution of participatory learning digital tools in cultural heritage education, this study used CiteSpace (version 6.3. R1) to conduct a series of visual and bibliometric analyses of literature published between 2015 and 2025. This study applied three CiteSpace functions: Keyword Co-occurrence to identify key themes and tool categories; Cluster Analysis to group related concepts; and Timeline View to trace the evolution of digital tools over time.

### 3.3 Assessment Framework

This section offers a qualitative evaluation of eight categories of digital tools identified through typological analysis. The assessment focuses not on technical performance but on five value-based dimensions—engagement, collaboration, co-creation, personalization, and accessibility—derived from the theoretical framework in Section 2.2. Each tool type was analyzed for its capacity to support participatory learning, revealing distinct strengths, limitations, and suitable application contexts.

## 4. Results

### 4.1 Overall Analysis

From 2002 to 2015, publication activity was limited, but it began to accelerate during and after the COVID-19 pandemic. By 2024, the number of publications peaked at 30 (Figure 2, Temporal). The field is highly interdisciplinary, dominated by Computer Science (65%), with notable contributions from Social Sciences, Engineering, and Humanities (Figure 2, Disciplinary). Geographically, research is concentrated in Europe and Asia, with Italy, China, and the UK leading in publication volume (Figure 2, Geographic Distribution).

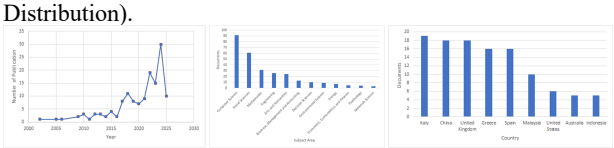

Figure 2. From left to right: Temporal, Disciplinary, and Geographic Distribution of Selected Publications (2002–2025). Source: Authors' elaboration.

### 4.2 Mapping Using CiteSpace

**4.2.1 Keyword Co-occurrence Network**: The 2015–2025 keyword network highlights a focus on immersive and interactive strategies. Core terms like "virtual reality," "augmented reality," and "serious games" highlight the roles of immersion and gamification, while peripheral terms such as "children" and "design" indicate growing focus on youth education. Overall, digital tools are reshaping both content delivery and participatory modes (Figure 3).

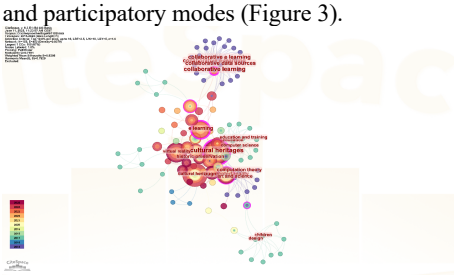

Figure 3. Keyword co-occurrence network (2015–2025). Source: Authors' elaboration.

**4.2.2 Cluster Analysis of Research Themes**: Cluster analysis based on keyword co-occurrence revealed six thematic groups. Cluster #0 ("learning and gamification", 2019) reflects the rise of serious games and storytelling. Cluster #1 ("semantic web", 2015) focuses on linked data and user modeling. Clusters #2 and #4 highlight interactive and immersive approaches, including and mixed reality. Cluster #6 centers on children's embodied learning, while Cluster #9 emphasizes experiential, real-world engagement. Together, these clusters illustrate the field's shift toward participatory, technology-enhanced education (Figure 4).

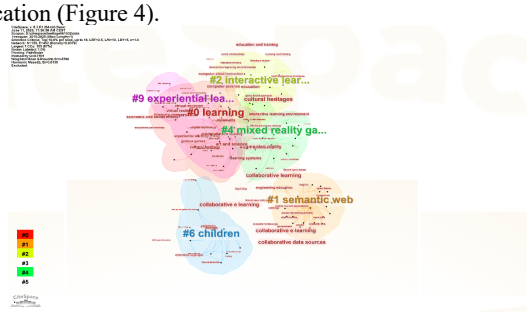


Figure 4. Clustered visualization of the keyword co-occurrence network (2015–2025). Source: Authors' elaboration.

**4.2.3 Timeline Analysis of Keywords**: Timeline visualization reveals three thematic phases in participatory heritage education. From 2015 to 2016, research focused on system infrastructure (e.g., semantic web and linked data). Between 2016 and 2018, attention shifted to experiential and learner-centered approaches, such as AR, serious games, and embodied learning. Since 2019, immersive and user-driven models—featuring co-creation, user experience, and gamification—have become dominant. This evolution reflects a transition from technical foundations to interactive, affective, and participatory learning strategies (Figure 5).

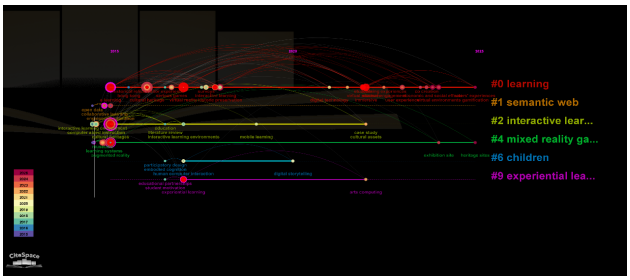


Figure 5. Timeline view of keyword clusters (2015–2025). Source: Authors' elaboration.

### 4.3 Types and Evolution of Digital Tools in Education Process for Cultural Heritage

Since 2009, digital tools in participatory heritage education have evolved through three phases: visualization, interactivity, and co-creation. From 2009 to 2015, early tools like Google Earth and photogrammetry focused on documentation and visual storytelling, offering limited interaction. Between 2015 and 2020, advances in consumer VR and 3D engines, along with supportive policies such as Horizon 2020, enabled more interactive, learner-centered applications like virtual tours and AR games. From 2020 onward, driven by the COVID-19 pandemic and emerging technologies such as XR, AI, and the Metaverse, digital heritage education has entered a co-creation phase—emphasizing collaboration, personalization, and shared authorship in cultural learning.

| Tool Type | Targeted Heritage | Targeted User | Objectives |
|---|---|---|---|
| Virtual Reality (VR) | Large-scale tangible heritage (e.g., archaeological sites) | Students, tourists, mobility-impaired users | To simulate immersive environments that enable emotional engagement with inaccessible or lost heritage sites. |
| Augmented Reality (AR) | Architectural remains, urban heritage, intangible practices | Tourists, families, students | To enhance physical exploration of real-world sites with contextual digital layers, promoting situated learning. |
| Serious Games | Intangible heritage, urban heritage planning, rituals | Youth learners, school groups | To gamify heritage learning and foster decision-making, critical thinking, and emotional connection through role play. |
| Web-based Learning Platforms | Documented heritage, archives, digital storytelling | Educators, students, heritage professionals | To enable scalable and flexible heritage learning through structured and collaborative digital environments. |
| Mobile Applications | Living heritage, local festivals, monuments | Tourists, local students, remote learners | To support self-directed learning with personalized and mobile access to heritage. |
| Multimedia Installations | Artifacts, performing arts, oral history | Tourists, families, older adults | To create multisensory, on-site learning experiences that encourage exploration and tactile engagement. |
| Semantic Web and AI-based Tools | Text-rich materials, digital databases, multi-source knowledge | Researchers, educators, advanced learners | To deliver personalized, semantic-rich heritage content and connect fragmented knowledge through intelligent systems. |
| Metaverse Platforms | Reconstructed cities, digital rituals, shared museums | Students, museum educators | To facilitate social co-creation, cross-cultural dialogue, and collective meaning-making in persistent virtual heritage spaces. |

Table 2. Summary of Digital Tools for Participatory Learning in Education Process of Cultural Heritage. Source: Authors' elaboration.

**4.3.1 Virtual Reality (VR):** Virtual Reality (VR) demonstrates strong potential in enhancing learner engagement through immersive 3D environments that simulate historical settings and foster emotional connection. Studies show that VR can significantly improve learners' motivation and interest in cultural heritage education (Zhong et al., 2025).

It enables embodied experiences that support active exploration and memory retention. However, in terms of interaction and collaboration, VR tools often focus on individual immersion, offering limited real-time communication or group-based learning activities (González Vargas et al., 2025). Regarding content co-creation, most VR applications present pre-designed scenarios, restricting users from contributing their own perspectives or annotations. In autonomy and personalization, while users can freely navigate virtual environments, task sequences are typically predefined, offering limited adaptability to individual needs. The most critical limitation lies in inclusiveness and accessibility. VR systems usually require expensive headsets and high digital literacy, creating barriers for elderly users, people with disabilities, and those in low-resource settings (Abukarki, 2025).

**4.3.2 Augmented Reality (AR):** Augmented Reality (AR) effectively enhances learner engagement by overlaying digital content onto physical heritage spaces, encouraging curiosity and situated learning. It allows learners to interact with cultural artifacts in real-world contexts, which strengthens spatial understanding and emotional connection (Anwar et al., 2025). In terms of interaction and collaboration, AR shows moderate performance. While it can support shared exploration, such as group visits enhanced by AR devices, collaborative features are often limited unless intentionally designed. As for content co-creation, most AR systems are developer-driven, with few offering tools for users to annotate or contribute content during the learning process. AR supports autonomy and personalization by enabling learners to access context-specific information based on location or object recognition. However, the depth of personalization is constrained when the user journey is overly structured. In terms of inclusiveness and accessibility, AR performs better than VR, as it typically runs on smartphones or tablets. Nonetheless, visual interface complexity and screen fatigue may still pose challenges, especially for older adults or visually impaired users.

**4.3.3 Serious Games**: Serious games offer strong performance in learner engagement, utilizing narrative-driven missions, rewards, and simulations to create immersive and emotionally resonant learning experiences. Studies show that game-based heritage learning improves motivation, especially among younger audiences, by transforming passive information intake into active problem-solving (Cheng et al., 2024). In terms of interaction and collaboration, serious games can be highly effective when designed for multiplayer modes or group-based challenges. However, many educational heritage games remain single-player, limiting their social learning potential (Aksay et al., 2024). Regarding autonomy and personalization, serious games can support adaptive difficulty and branching paths, giving learners partial control over their journey. Yet, the depth of personalization depends heavily on the game's underlying mechanics (Wang & Arif, 2024). In inclusiveness and accessibility, serious games outperform VR in hardware requirements but may still present challenges due to interface complexity or cultural specificity in game content.

**4.3.4 Web-based Learning Platforms**: Web-based learning platforms, including MOOCs, offer high flexibility and broad accessibility. Learners can engage with content at their own pace and access educational resources across geographic or socioeconomic barriers, including underserved or remote populations (Kamara et al., 2018).

These platforms also perform well in supporting learner engagement, especially when they include multimedia elements, discussion boards, or gamified modules. However, sustaining long-term engagement can be challenging without real-time interaction or feedback mechanisms (Enriquez et al., 2024). In terms of interaction and collaboration, MOOCs often include peer forums and collaborative assignments, yet the depth of

interaction may remain superficial due to limited instructor mediation and high learner-to-facilitator ratios (Truyen et al., 2021). Regarding content co-creation and expression, opportunities remain limited. Learners are typically passive consumers rather than active contributors, though some platforms are beginning to incorporate user-generated content and comment-based annotation features (Fermoso et al., 2015).

**4.3.5 Mobile Applications:** Mobile apps support participatory learning by enabling users to interact with heritage content in site or remotely. They foster autonomy exploration, and continuous engagement through notifications, self-paced modules, or community contributions. Some apps include features like user story uploads, quizzes, or feedback forms, encouraging active input and co-creation from learners. Mobile applications offer high accessibility and contextual relevance, making them particularly strong in the dimensions of autonomy and personalization and inclusiveness. Learners can engage with location-based heritage content during real-world visits or remotely via smartphones, benefiting from flexible timing and portable access (Kulkarni et al., 2024). In terms of learner engagement, mobile apps provide interactive experiences, enhancing attention and motivation, especially among digital-native audiences (Wang & Md Arif, 2024). However, their effectiveness in interaction and collaboration is limited unless social or multiplayer features are explicitly designed, which is still relatively uncommon in heritage apps. Regarding content co-creation and expression, some applications allow users to upload photos, leave reviews, or annotate locations, but these contributions are usually peripheral rather than integrated into the learning structure. Additionally, small screen sizes and interface limitations may reduce accessibility for older adults or people with disabilities, though overall hardware requirements are minimal compared to VR.

**4.3.6 Multimedia Installations:** Multimedia installations perform well in enhancing learner engagement, particularly in museum and exhibition settings where sensory-rich interfaces promote curiosity and experiential learning. Tangible interfaces, audio-visual feedback, and physical interaction contribute to memorable and embodied heritage education experiences (Dimitropoulos et al., 2018).

In terms of interaction and collaboration, these tools often support co-located learning through group exploration or shared touchscreen devices. However, the interaction is typically limited to physical proximity and does not support remote or asynchronous collaboration (Krishnasamy & Vistisen, 2024). As for content co-creation, most installations offer fixed pathways and predefined content, allowing only limited user input or annotation, though creative examples such as interactive weaving projects are emerging (Xiong et al., 2024). With regard to autonomy and personalization, some systems allow learners to select topics or adjust difficulty levels, but personalization is constrained by the physical setup and programming logic (Peng et al., 2024). In terms of inclusiveness and accessibility, kiosks offer advantages for users with limited digital literacy, yet they may pose challenges for visually impaired users or those requiring assistive devices if not properly designed.

**4.3.7 Semantic Web and AI-based Tools:** Semantic Web and AI-based tools offer potential in autonomy and personalization by enabling adaptive learning pathways, intelligent content recommendation, and context-aware guidance. These tools also show strength in content co-creation and expression. By linking open datasets and allowing user input, they enable collaborative knowledge-building and annotation of heritage resources (Williams et al., 2024). However, the implementation of such features remains complex and underutilized in most practical applications.
In terms of interaction and collaboration, semantic platforms may facilitate indirect collaboration through shared data layers or co-edited knowledge graphs, but lack intuitive real-time social interaction tools (Orphanidou et al., 2024). For learner engagement, AI can improve relevance and interactivity, though the abstract nature of semantic systems may reduce emotional resonance compared to visual or embodied tools (Ozdemir & Zonah, 2025). Inclusiveness and accessibility depend on system design: while AI can adapt to diverse needs, opaque algorithms and high literacy demands may exclude certain user groups if not properly mitigated (Merchan et al., 2025).

**4.3.8 Metaverse Platforms:** Metaverse platforms combine real-time interaction, immersive environments, and social presence, making them highly effective in the dimensions of learner engagement and interaction and collaboration. Users can navigate shared 3D spaces, attend virtual exhibitions, and communicate with others through avatars, creating dynamic and socially rich heritage learning experiences (Longo & Faraci, 2023). These platforms also support content co-creation and expression, allowing users to customize avatars, contribute digital artifacts, or participate in community-curated exhibitions. However, the actual level of co-creation depends on platform openness and technical literacy requirements. Regarding autonomy and personalization, the metaverse offers freedom in exploration and identity representation, but structured educational guidance is often lacking, which may affect learning effectiveness. Inclusiveness and accessibility remain key challenges. Despite increasing availability of web-based metaverse experiences, performance often depends on high-bandwidth internet, powerful devices, and digital fluency, potentially excluding underrepresented or older user groups (Oliver et al., 2012). Moreover, motion sickness and cognitive overload can hinder sustained use.

### 4.4 Assessment of Digital Tools

Across the eight categories of digital tools analyzed, several common trends and limitations have emerged. Immersive and interaction-intensive tools—such as Virtual Reality, Augmented Reality, and serious games—demonstrate strong capacity to stimulate learner motivation and support experiential learning. These tools create emotionally engaging environments that are particularly effective for conveying complex heritage content through simulation and embodied interaction. In contrast, platform-based tools, including MOOCs and mobile applications, excel in providing flexible learning rhythms and broad accessibility. They allow learners to engage with content asynchronously and across diverse contexts, making them suitable for distance learning and outreach to underrepresented user groups (Table 3).

| No. | Tool Type | Strengths | Limitations |
|---|---|---|---|
| **1** | Virtual Reality (VR) | Engagement | Collaboration, Co-creation, Inclusiveness |
| **2** | Augmented | Engagement, | Interaction, |

| | | | |
|---|---|---|---|
| | Reality (AR) | Personalization | Co-creation, Inclusiveness |
| **3** | Serious Games | Engagement, Personalization, Collaboration | Co-creation, Inclusiveness |
| **4** | Web-based Learning Platforms | Personalization, Inclusiveness | Co-creation, Collaboration |
| **5** | Mobile Applications | Personalization, Engagement | Collaboration, Co-creation |
| **6** | Multimedia Installations | Engagement, Collaboration | Co-creation, Personalization, Inclusiveness |
| **7** | Semantic Web and AI-based Tools | Personalization, Co-creation | Collaboration, Inclusiveness |
| **8** | Metaverse Platforms | Engagement, Collaboration, Co-creation | Personalization, Inclusiveness |

Table 3. Assessment of Digital Tools. Source: Authors' elaboration.

## 5. Discussion and Findings

### 5.1 Challenges in the Current Use of Digital Tools for Education Process of Cultural Heritage

Despite the growing implementation of digital technologies in heritage education, multiple challenges continue to hinder their effective integration. Many digital platforms still fail to meet the accessibility needs of users with disabilities. Although some progress has been made, such as in designing gamified museum experiences for blind and partially sighted visitors, these remain isolated efforts rather than systemic improvements (Bavi & Gupta, 2022). Another challenge lies in learner engagement. Even during the pandemic-driven shift to digital environments, maintaining student motivation and active participation proved difficult, particularly when technological tools lacked interactivity or contextual depth (Mat Sood et al., 2023). Furthermore, while gamification and virtual exhibitions offer creative modes of engagement, their educational depth and integration into formal curricula are often limited (Mariotti, 2021). Finally, feedback mechanisms and co-creation features are underdeveloped in many heritage education tools. Without adaptive systems or participatory channels, learners remain passive recipients rather than active contributors.

### 5.2 Reflecting on Tool Performance Across Participatory Learning Dimensions

Digital tools used in heritage education demonstrate varied performance across the five participatory learning dimensions. Immersive technologies such as XR environments offer strong learner engagement by presenting multisensory experiences. However, their performance in collaboration and co-creation is limited, as these environments are typically designed for individual exploration (Silva, 2022). In contrast, game-based learning approaches have shown more success in fostering active collaboration and creativity among learners, particularly when co-creation toolkits are involved (Lu, 2024). Platforms using gamification have enhanced motivation through structured reward systems. Importantly, no single tool excels across all dimensions. Tools that offer rich engagement and personalization may not necessarily support collaboration or co-creation. As such, combining multiple tools with complementary strengths can better support the complex needs of participatory heritage education.

### 5.3 The Future Role of AI and Semantic Technologies

Artificial intelligence (AI) and semantic technologies are beginning to reshape the landscape of heritage education, offering promising tools for personalization, real-time interaction, and intelligent content delivery. AI-driven platforms are being used to enhance user experience through adaptive interfaces and computer vision, enabling learners to access contextual information and visual recognition features in heritage environments (Rachabathuni et al., 2025). These technologies allow content to be tailored to user preferences and behavior, supporting more autonomous and meaningful learning. However, the use of AI and semantic technologies is not without risks. Cultural bias embedded in algorithmic design may affect how heritage is represented, and over-automation could reduce opportunities for human reflection and co-creation. Moreover, the development and maintenance of such systems require considerable technical resources and institutional collaboration. Despite these limitations, AI-supported tools hold great potential for advancing participatory learning.

### 5.4 Limitation of the Study

Despite these insights, several limitations of this study must be acknowledged. The evaluation is based solely on existing literature and tool descriptions, without empirical testing or user feedback. Tool classifications rely on author interpretation, which may overlook hybrid forms or contextual variations. Future research should move toward more empirical approaches. User-centered investigations—such as classroom experiments and interviews—can uncover practical constraints and usability insights that literature alone cannot provide. A possible strategy is to apply this enhanced evaluation framework to different digital tools used for teaching the same heritage site or object.

## 6. Conclusion and Future Developments

This study set out to examine how digital tools support participatory learning in the context of cultural heritage education. By conducting a structured literature review of 140 articles retrieved from Scopus and analyzing them with CiteSpace, this study mapped the development of research themes, identified eight major categories of digital tools, and evaluated their performance across five participatory learning dimensions: engagement, collaboration, co-creation, personalization, and inclusiveness. The findings show that no single tool type performs strongly across all dimensions. Immersive tools such as VR and AR tend to excel in engagement and experiential depth but pose challenges in terms of accessibility and co-creation. Conversely, mobile platforms and MOOCs offer flexibility, reach, and personalization, but often lack interactive or collaborative features. Serious games, web-based archives, and AI-supported systems each reveal unique advantages and limitations, suggesting that a blended approach—combining complementary tools—may offer the most effective strategy for participatory heritage learning. As digital tools continue to transform the education process of cultural heritage, participatory learning fosters inclusive and co-creative experiences that not only deepen emotional engagement but also extend cultural connections beyond the screen. Future research may extend this work by incorporating empirical user studies, t applying the evaluation model to compare how different tools interpret the same cultural heritage, and exploring the evolving role of AI in heritage education.

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