Asia Pacific Academy of Science Pte. Ltd.

Metaverse 2026, 7(4), m260065.
https://doi.org/10.54517/m260065

Review

Digital Transformation and Local Cultural Innovation in the Metaverse Era: A Systematic Literature Review of Sustainable Development Pathways

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CITATION

Kristiani N, Samudro BR, Wahyudi L, et al. Digital Transformation and Local Cultural Innovation in the Metaverse Era: A Systematic Literature Review of Sustainable Development Pathways. Metaverse. 2026; 7(4): m260065. https://doi.org/10.54517/m260065

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Abstract: Digital transformation is reshaping how local cultural heritage is preserved, interpreted, and experienced. However, the extent to which metaverse-oriented applications contribute to sustainable development remains uncertain. This study systematically reviews metaverse-oriented and related immersive technologies in cultural heritage, education, and tourism contexts, focusing on technological applications, socio-cultural mechanisms, empirical outcomes, and contextual conditions. Drawing on a PRISMA-guided literature search that identified 1,954 records, the review employed two complementary analytical datasets comprising 45 publications for bibliometric analysis and technology mapping and 15 primary studies for thematic evidence synthesis and descriptive methodological quality appraisal. Bibliometric findings revealed increasing publication activity between 2021 and 2025, with virtual reality, cultural heritage, and metaverse emerging as prominent research themes. Article-level classification identified nine technology families across 23 publications documenting or analysing cultural applications. Among the 15 primary studies, six examined explicitly metaverse-framed cultural settings or adoption contexts, while nine examined adjacent immersive or interactive technologies. A hybrid deductive–inductive synthesis identified three interrelated pathways, including preservation–reinterpretation–experience, tradition–innovation and physical–digital convergence, and participatory knowledge co-creation. Reported outcomes primarily concerned technological feasibility, cultural learning, engagement, satisfaction, and behavioural intentions. However, methodological limitations and insufficient longitudinal evidence restricted conclusions concerning sustained cultural preservation, community empowerment, and measurable Sustainable Development Goal attainment. The review proposes an evidence-informed conceptual framework integrating technological affordances, cultural mechanisms, and contextual conditions, including accessibility, authenticity, community agency, and institutional governance. These findings position metaverse-oriented cultural innovation as a socio-technical process with potential sustainability contributions that require further empirical validation.

Keywords: Metaverse; Local cultural innovation; Immersive technologies; Cultural heritage; Sustainable development; Systematic literature review

1. Introduction

The intersection of local cultural innovation and digital transformation has become increasingly relevant to sustainable development, particularly as communities and cultural institutions seek new ways to preserve, interpret, and communicate cultural heritage. The United Nations 2030 Agenda recognizes the importance of inclusive development, while cultural sustainability emphasizes the continuity of local knowledge, identity, and cultural expression across generations [1-5]. Digital technologies can support these objectives by expanding access to cultural resources,

enabling new forms of heritage education, and connecting cultural practices with tourism and creative activities. However, technological adoption alone does not guarantee sustainable outcomes. The extent to which digital transformation benefits local communities depends on how cultural assets are represented, who participates in their development, and whether digital initiatives generate accessible and enduring forms of cultural and social value.

The emergence of the metaverse introduces a more interactive dimension to digital cultural innovation. Beyond conventional digitization, metaverse environments involve immersive three-dimensional spaces, avatar-mediated participation, networked interaction, and potential continuity between physical and virtual settings. Interoperability and persistent virtual identity are important but not universally implemented characteristics of these environments [6, 7]. In cultural heritage settings, these capabilities can be expressed through navigable virtual museums, interactive heritage environments, avatar-mediated exhibitions, immersive storytelling, and digitally enhanced cultural tourism. Nevertheless, virtual reality (VR), augmented reality (AR), and other immersive technologies should not automatically be equated with fully developed metaverse systems. For this review, a distinction is made between applications explicitly developed and evaluated as metaverse environments and adjacent immersive or phygital applications that demonstrate relevant experiential capabilities without necessarily incorporating persistent, interconnected, or socially shared virtual worlds. This distinction establishes an operational basis for examining technological convergence without treating all forms of cultural digitalization as metaverse applications.

Recent empirical studies suggest that immersive cultural environments may influence learning, visitor engagement, technology acceptance, cultural attachment, and intentions to participate in virtual or physical heritage experiences. He and Qin [8], for example, examined relationships among perceived benefits, perceived risks, metaverse engagement intentions, and intentions to pursue offline cultural experiences. Jiang et al. [9] investigated authenticity, immersion, cultural attachment, satisfaction, and reuse intentions in virtual cultural tourism; notably, immersion did not directly predict satisfaction in their model. Zhu et al. [10] examined associations between VR-based heritage experiences, awe, attitudes, and self-reported pro-sustainable behavior. These studies collectively highlight the roles of user experience and cultural meaning. However, evidence concerning actual long-term heritage protection, equitable community benefits, and measurable progress against SDG indicators remains more limited than evidence concerning users' perceptions and behavioral intentions.

The relationship between metaverse-oriented cultural innovation and the Sustainable Development Goals (SDGs) must therefore be considered carefully. Digital heritage initiatives may be relevant to SDG 4 through cultural education, SDG 8, particularly Target 8.9, through sustainable tourism and local cultural products, and SDG 11, particularly Target 11.4, through cultural heritage safeguarding [11]. Accessibility and equitable participation also raise issues relevant to SDG 10. Although potential connections to SDG 12 may be discussed in relation to responsible cultural production, consumption, and sustainable tourism monitoring, direct environmental and resource-use outcomes have rarely been established in the reviewed immersive heritage studies. A conceptual link to an SDG is not evidence that its target has been achieved. Moreover, implementation may be constrained by digital inequality, infrastructure and maintenance costs, technological obsolescence,

intellectual property concerns, inaccurate cultural representation, and insufficient participation by cultural custodians [12, 13].

Several literature reviews have examined related aspects of this research area. Johri et al. [14] synthesized the broader relationship between the metaverse and sustainable development through bibliometric and systematic review approaches. Buragohain et al. [13] examined metaverse applications in cultural heritage preservation, while Dordio et al. [15] reviewed extended reality for heritage education. Sánchez-Amboage et al. [16] analyzed metaverse technologies and marketing applications in tourism. Together, these studies provide important evidence on technological developments, preservation, education, and tourism. Nevertheless, their different disciplinary emphases leave room for an integrated, outcome-sensitive synthesis of metaverse-oriented cultural innovation. It is one that distinguishes direct metaverse applications from adjacent immersive systems, examines the experiential and socio-cultural mechanisms connecting technology to cultural outcomes, and separates observed effects from proposed sustainability benefits. Terminological variation among metaverse, virtual heritage, immersive technology, and phygital innovation further complicates comparison across studies.

Addressing these issues requires a perspective extending beyond technology adoption. Research on digital transformation and social innovation foregrounds organizational capabilities, cultural adaptation, and stakeholder participation [17-19]. Complementary experience-oriented and technology-acceptance research draws attention to mechanisms such as interactivity, spatial presence, narrative engagement, cultural attachment, and physical–digital continuity [8-10]. These perspectives are integrated here through a socio-technical lens connecting technological affordances, experiential and cultural mechanisms, reported outcomes, and enabling or constraining conditions. Governance, accessibility, cultural authenticity, and community participation are treated as essential considerations when assessing the potential for sustainable cultural innovation. Where direct empirical evidence is unavailable, suggested relationships are identified as propositions for future investigation rather than established causal effects.

Against this background, this systematic literature review aims to synthesize empirical evidence on metaverse-oriented and related immersive applications in locally situated cultural heritage and innovation contexts, identify the mechanisms through which these technologies may support cultural and sustainability-related outcomes, and develop an integrative conceptual framework that distinguishes demonstrated findings from prospective development pathways. The review explicitly differentiates metaverse applications from adjacent immersive technologies to clarify the scope and maturity of the evidence. It addresses the following research questions:

RQ1. What forms of metaverse-oriented and related immersive technologies have been applied in local cultural heritage and innovation contexts?

RQ2. Through what technological, experiential, and socio-cultural mechanisms do these applications support cultural preservation, learning, participation, and sustainability-related outcomes?

RQ3. What empirical outcomes have been demonstrated, and to what extent do the available findings support proposed contributions to the Sustainable Development Goals?

RQ4. What contextual, governance, accessibility, and cultural authenticity factors enable or constrain these applications, and how can their relationships be integrated into a conceptual framework for sustainable cultural innovation?

Previous reviews have examined metaverse applications, immersive cultural heritage technologies, heritage education, and tourism from different disciplinary perspectives. However, their primary analytical emphases differ from the outcome-sensitive and socio-technical synthesis developed in the present study. **Table 1** compares these contributions and identifies the specific research gap addressed by this review.

Table 1. Comparison of Previous Reviews and the Present Study

Previous review	Primary focus and contribution	Remaining research gap
Bekele et al.[20]	Surveys augmented, virtual, and mixed reality applications in cultural heritage, emphasizing technologies, application domains, and interaction interfaces.	Does not principally examine metaverse-specific characteristics or link cultural experiences to sustainability-related outcomes.
Johri et al.[14]	Integrates bibliometric and systematic analyses of metaverse research for sustainable development, identifying major themes and research directions.	Provides a broad sustainability perspective without a focused synthesis of locally situated cultural innovation mechanisms and their empirical outcomes.
Buragohain et al.[13]	Reviews metaverse applications for cultural heritage digitalization and preservation, including authenticity, accessibility, and sustainability challenges.	Concentrates on heritage digitalization and preservation rather than systematically distinguishing proximal empirical findings from longer-term SDG contributions across multiple cultural pathways.
Dordio et al.[15]	Reviews extended reality applications in heritage education, emphasizing educational settings, technological approaches, and learning-related findings.	Primarily addresses educational applications rather than the broader relationships among cultural innovation, physical–digital participation, governance, and sustainable development.
Sánchez-Amboage et al.[16]	Reviews metaverse technologies and foundational components of tourism marketing, including technological applications and sectoral development opportunities.	Focuses on tourism marketing rather than integrating cultural safeguarding, community participation, evidence quality, and sustainability-related outcomes.
Present review	Combines bibliometric mapping of 45 publications with empirical synthesis and methodological appraisal of 15 primary studies. Identifies three socio-cultural pathways and develops an evidence-informed conceptual framework.	Distinguishes metaverse-framed from adjacent immersive applications, observed findings from prospective SDG contributions, and technological mechanisms from contextual governance conditions.

Taken together, previous reviews provide valuable technological, educational, preservation-oriented, and sectoral perspectives. The present review extends this literature by integrating these perspectives within a common socio-technical

framework and explicitly differentiating documented cultural outcomes from prospective sustainability contributions. This distinction provides a more cautious and analytically traceable basis for understanding metaverse-oriented cultural innovation.

2. Materials and methods

This systematic literature review (SLR) examined metaverse-oriented and related immersive applications in locally situated cultural heritage, education, and tourism. Its reporting was guided by PRISMA 2020 [21]. Because many studies lacked comparison groups, PICO was unsuitable as a mandatory eligibility rule. SPIDER [22] instead structured the retrospective reassessment (**Table 2**), not the original database searches.

Table 2. SPIDER logical framework

Component	Scope
Sample (S)	Users, communities, practitioners, or institutions associated with identifiable local cultural heritage or cultural experiences.
Phenomenon of Interest (PI)	Evaluated metaverse settings and related VR, AR, interactive 3D, or phygital cultural applications.
Design (D)	Empirical surveys, experiments, case studies, and assessable technology implementations.
Evaluation (E)	Cultural learning, preservation, participation, engagement, user experience, adoption, or sustainability-related findings.
Research Type (R)	Primary quantitative, qualitative, mixed-methods, or documented implementation evidence.

2.1. Search strategy and study selection

The original searches were conducted in August 2025 using Scopus, Web of Science, and ScienceDirect, supplemented by Google Scholar in early September 2025. English-language publications from 2015 to 2025 were searched using concepts related to local culture, digital transformation, and sustainability. "Metaverse" was not a mandatory search term. Complete database-specific search strings, exact export dates, and deduplication records were not retained, preventing full independent replication of the original search under PRISMA-S [23].

A retrospective two-stage eligibility assessment was applied. The first stage retained publications relevant to local cultural contexts and metaverse-oriented or adjacent immersive technologies, including empirical, implementation, adoption-focused, review, and conceptual studies. Metaverse relevance was evaluated through documented characteristics such as immersion, avatar interaction, persistence, interoperability, and physical–virtual continuity. Generic digitization and unrelated applications were excluded. The second stage restricted the empirical synthesis to primary studies reporting original observations or assessable technological implementations. Independent dual screening and formal disagreement resolution were not documented. The selection process is presented in **Figure 1**.

2.2. Quality appraisal and evidence synthesis

Methodological quality was descriptively assessed across six domains: research design, sampling or data sources, technology implementation, outcome measurement, bias control or triangulation, and sustainability-related evidence. An adapted domain-

based framework was used rather than a validated JBI or MMAT instrument. For D4, judgments considered the reporting of outcomes appropriate to each study design, including participant outcomes in user studies, case findings in qualitative investigations, and clearly documented technical outputs in implementation or reconstruction studies. A positive D4 judgment indicates adequately reported design-specific outcomes, not necessarily measured visitor learning, user experience, or effectiveness. Assessments informed evidence interpretation without numerical scoring (**Supplementary Table S1**). Data were extracted on study characteristics, technologies, cultural contexts, mechanisms, outcomes, and limitations. A hybrid deductive–inductive thematic approach combined research-question-informed coding with emerging patterns across studies. Related codes were consolidated into three pathways: preservation–reinterpretation–experience (P1), tradition–innovation and physical–digital convergence (P2), and participatory knowledge co-creation (P3). Findings were interpreted according to their empirical strength, distinguishing observed outcomes from perceptions, intentions, and prospective sustainability claims. Coding and pathway assignments are documented in **Supplementary Tables S2 and S3**.

2.3. Two Analytical Datasets and Research-Question Alignment

Two nested analytical datasets were derived from the same retrospective screening process. Dataset 1 (n = 45) included eligible empirical, technological, adoption-focused, review, and conceptual publications for bibliometric analysis and technology mapping (RQ1). Dataset 2 (n = 15) comprised primary studies meeting additional empirical eligibility criteria for thematic synthesis and methodological appraisal (RQ2–RQ4). The remaining 30 publications contributed only to the broader mapping. This distinction separates research trends from primary empirical evidence without implying separate literature searches.

3. Results

3.1. Study Selection and Analytical Datasets

The literature search identified 1,954 records from Scopus (n = 916), Web of Science (n = 275), ScienceDirect (n = 383), and Google Scholar (n = 380). After removing 56 duplicates and 233 records with incomplete bibliographic information, 1,665 records underwent title and abstract screening, resulting in 1,537 exclusions. Of the 128 reports sought for retrieval, 23 were unavailable, leaving 105 full-text reports for eligibility reassessment. Sixty reports were excluded due to irrelevant cultural contexts (n = 14), insufficient relevance to metaverse or immersive technologies (n = 11), insufficient evidence of cultural technology applications (n = 3), and ineligible publication types (n = 32). Consequently, 45 publications were retained as Dataset 1 for bibliometric analysis and technology mapping. Of these, 15 primary studies met the additional empirical eligibility criteria and formed Dataset 2 for thematic synthesis and methodological quality appraisal, while the remaining 30 publications contributed exclusively to broader mapping. The selection process is illustrated in **Figure 1**.

3.2 Bibliometric Analysis

The bibliometric dataset comprised 45 publications published between 2021 and 2025. Annual scientific production increased from one publication in 2021 to two in 2022, five in 2023, twelve in 2024, and twenty-five in 2025. Publications from 2025 accounted for 55.6% of the dataset, representing the largest annual share. As

illustrated in **Figure 2**, the selected literature showed increasing research activity concerning metaverse-oriented and related immersive technologies in cultural heritage, cultural education, and cultural tourism contexts.

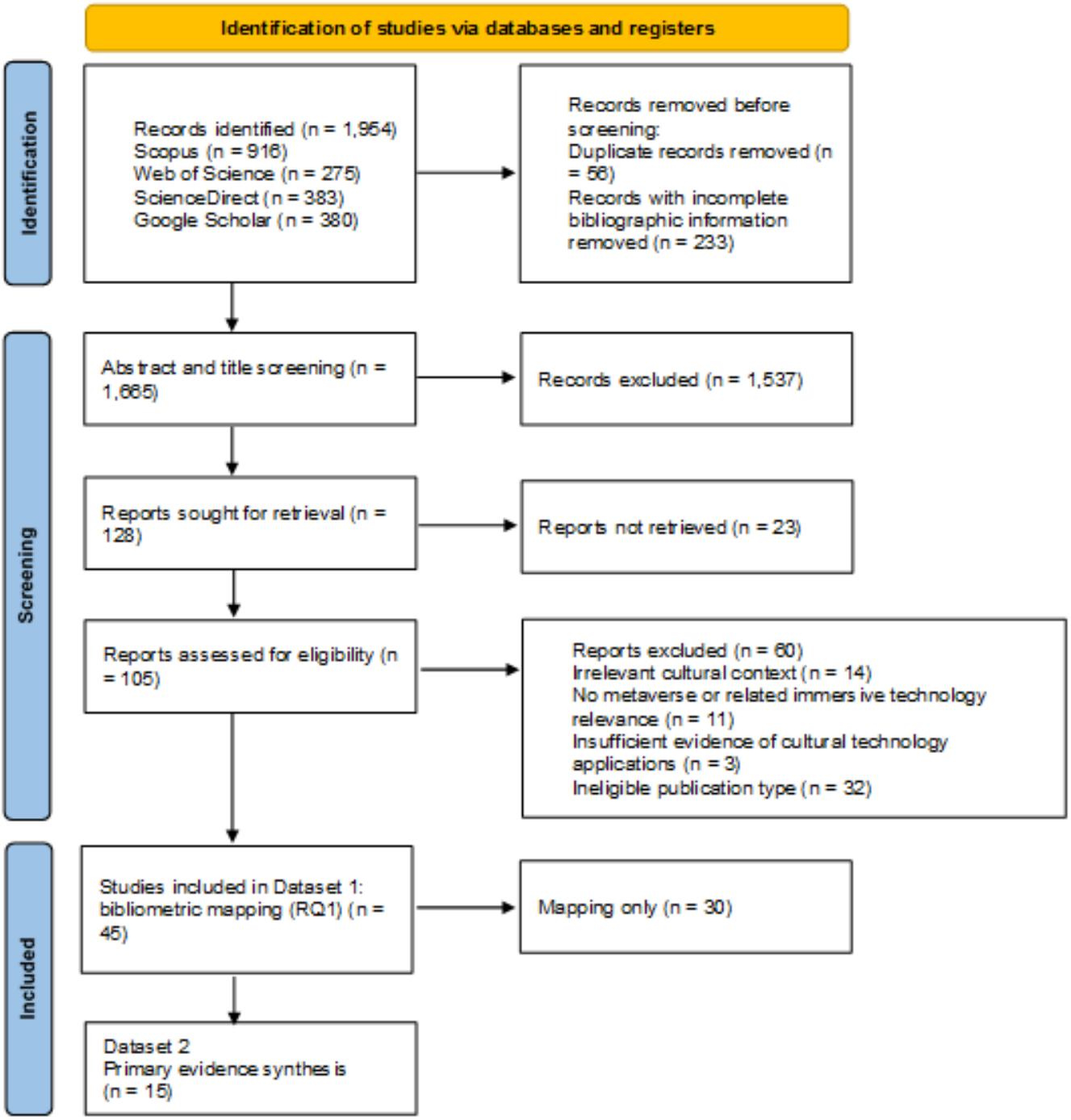


Figure 1. Prisma Flow Diagram

Author keywords were available for 43 of the 45 publications, representing 95.6% of the bibliometric corpus. Following the normalization of equivalent keyword expressions, virtual reality was the most frequently occurring term, followed by cultural heritage, metaverse, and intangible cultural heritage. Digital twin and sustainable tourism appeared four times each, while artificial intelligence and augmented reality appeared three times each. These findings, presented in

Figure 3, demonstrate the prominence of immersive visualization, cultural heritage interpretation, and metaverse-related research terminology within the selected literature.

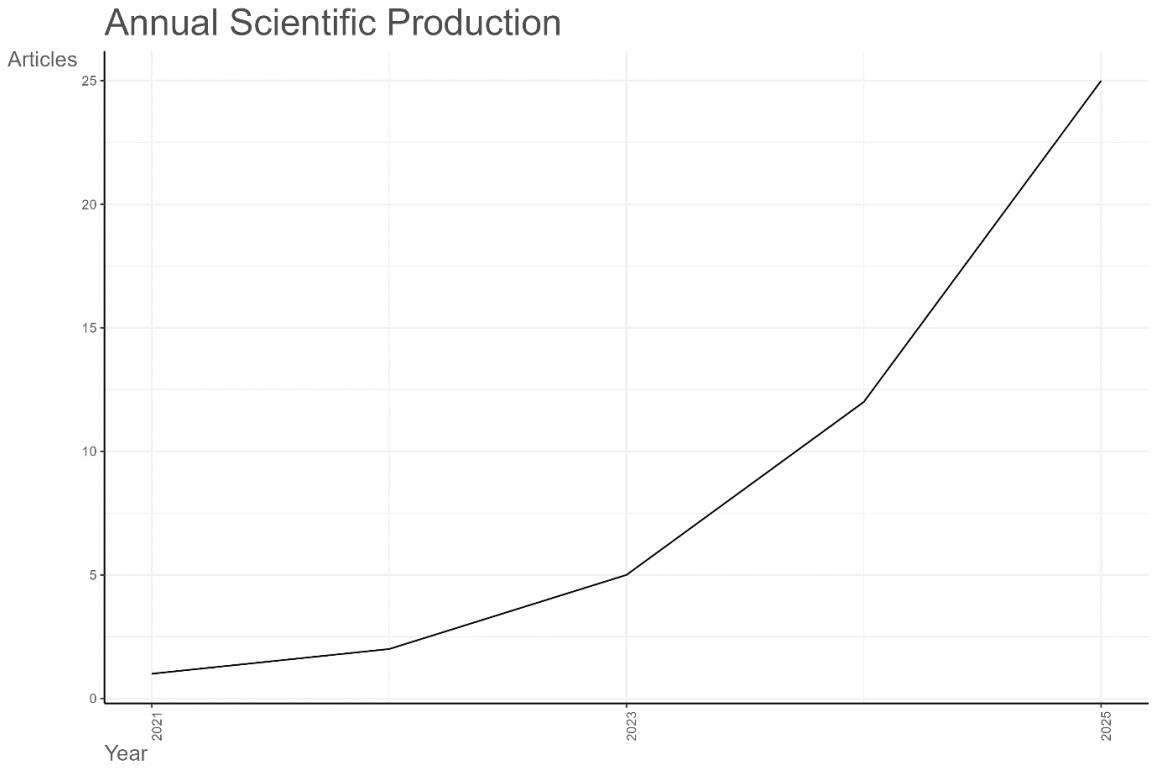


Figure 2. Annual scientific production of metaverse-oriented cultural research from 2021 to 2025

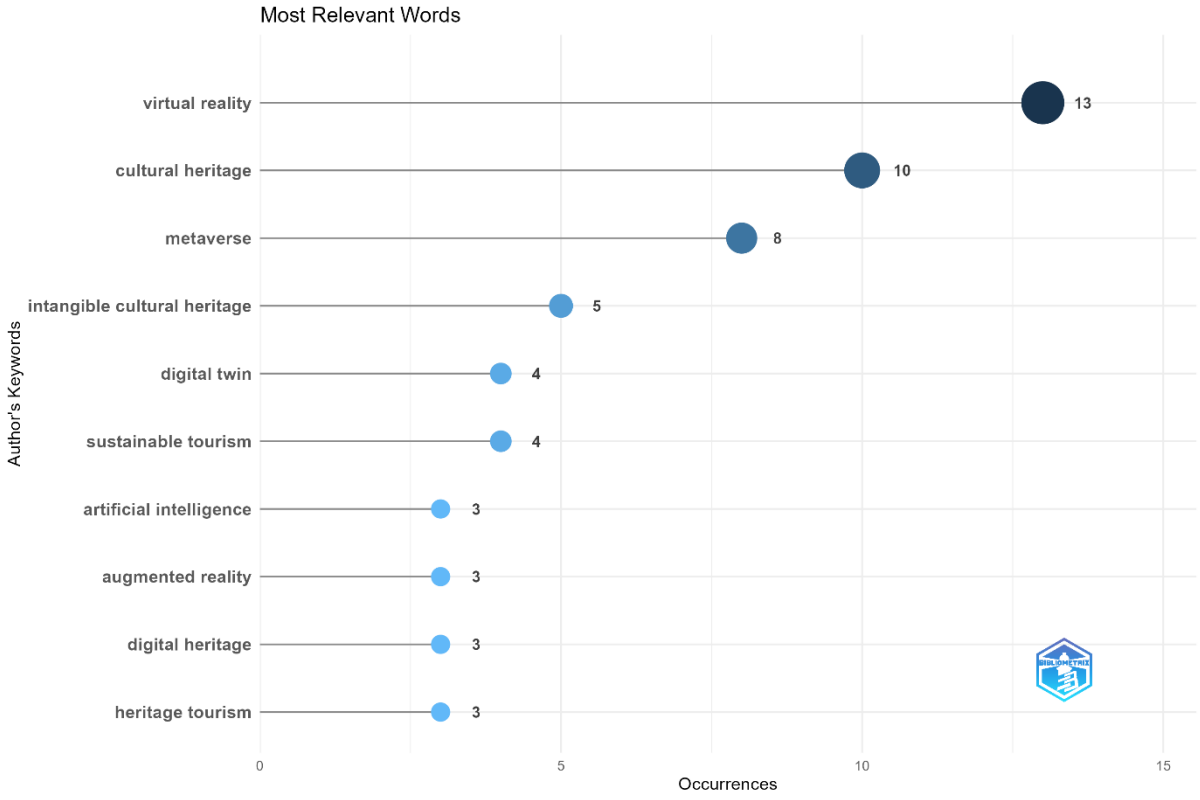


Figure 3. Most frequent normalized author keywords in the bibliometric dataset

The author-keyword co-occurrence analysis identified 11 displayed nodes organized into three clusters, as presented in **Figure 4**. The first cluster comprised virtual reality, augmented reality, artificial intelligence, intangible cultural heritage, and digital preservation. The second cluster connected metaverse, cultural heritage, and digital tools. The third cluster consisted of immersive technologies, digital museums, and sustainable tourism. Virtual reality exhibited the highest betweenness centrality, followed by cultural heritage, indicating their prominent connecting positions within the displayed network. The sustainable tourism cluster formed a separate component under the selected network parameters. These relationships represent patterns of keyword co-occurrence rather than direct evidence of technology implementation or sustainability outcomes.

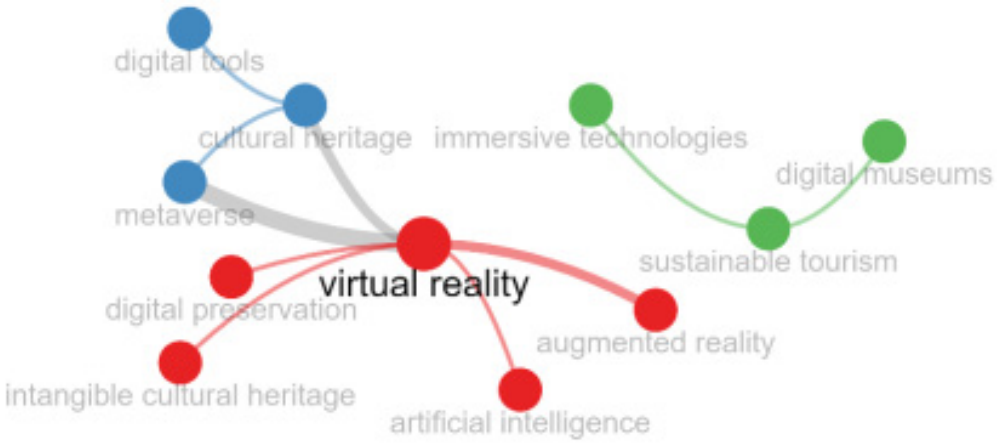


Figure 4. Author-keyword co-occurrence network of metaverse-oriented and immersive cultural research

3.3. Technology Families and Cultural Applications

To complement the bibliometric findings, the 45 publications were classified according to their technological characteristics, cultural contexts, and reported application evidence. The classification identified 23 studies documenting or analysing specific cultural technology applications, comprising nine implemented and evaluated applications, seven prototype or technical-development studies, and seven analyses of existing applications. The remaining 22 publications consisted of nine adoption- or intention-focused studies, nine reviews or bibliometric analyses, two conceptual contributions, and two studies with insufficient information to determine implementation status. **Table 3** presents the technology families, cultural applications, supporting studies, and corresponding evidence boundaries identified in the application-related literature.

Table 3. Technology–Cultural Application Matrix of Documented Applications in the Bibliometric Dataset

Technology family	Cultural context and documented application	Ref.
Metaverse museum exhibitions	Avatar-accessible virtual museums, interactive cultural artefacts, and gamified exhibition experiences.	Cecere et al. [24], Lee et al. [25]
Metaverse heritage tourism	Interactive 3D heritage-tourism platform representing the cultural environment of Kayutangan, Indonesia.	Aditya et al.[26]

Continuation Table:

Technology family	Cultural context and documented application	Ref.
VR heritage learning and experiences	Immersive historical architecture learning, virtual heritage interpretation, multisensory cultural environments, and 360° virtual experiences.	Guo et al. [27], Zhang et al.[28], Jia et al.[29], Bao et al.[30], Murphy et al.[31], Buragohain et al.[32]
Panoramic intangible heritage interpretation	Binocular 180° panoramic visualization of traditional cultural practices and intangible heritage.	Yang et al.[33]
AR/MR cultural interpretation	Mixed-reality representation of intangible cultural heritage and immersive interpretation of religious architecture.	Yan [34], Allal-Chérif [35]
Virtual museums and interactive 3D heritage tours	Virtual cultural collections, archaeological exploration, digital museum experiences, and interactive reconstruction of historical paintings.	Ozdemir et al. [36], Guan et al. [37], Kyropoulou et al. [38], Capotorto et al. [39]
Digital-twin and 3D heritage documentation	Digital representation of traditional crafts and detailed three-dimensional documentation of cultural and archaeological resources.	Li et al. [40], Brumana et al.[41]
Phygital cultural platforms	Integration of physical cultural activities with digital heritage access, cultural tourism services, and platform-based experiences.	Greco et al. [42], Pesce and Franzè [43]
AI and interactive heritage learning	AI-assisted heritage interpretation, interactive cultural education, digital storytelling, and heritage-oriented serious games.	Wang et al.[44], Zhang et al.[45], Antoniou et al. [46]

The 23 studies are listed once according to their primary technology family. The classification distinguishes evaluated implementations, prototypes, and analyses of existing applications. It does not imply equivalent methodological quality or independently verified sustainability outcomes. A complete record-level classification of the 45 publications is provided in **Supplementary Table S2**.

The findings identified a diverse range of cultural applications, including metaverse-oriented museum exhibitions and heritage-tourism environments, VR-based cultural learning, AR/MR heritage interpretation, interactive 3D reconstruction, digital twins, phygital platforms, and AI-supported cultural education. These applications addressed tangible and intangible cultural heritage, historical architecture, museum collections, traditional crafts, and cultural tourism destinations. Explicitly metaverse-framed applications were distinguished from adjacent immersive and interactive technologies based on their documented functionalities. Accordingly, the bibliometric findings describe patterns of research attention, whereas the article-level classification identifies the specific forms of cultural technology application reported in the literature.

3.4. Characteristics of the Included Studies

The evidence synthesis included 15 primary studies, of which six examined explicitly metaverse-framed cultural settings or adoption contexts and nine investigated adjacent immersive or interactive technologies. The designs comprised user evaluations, cross-sectional surveys, qualitative and documentary cases,

comparative learning assessments, and technical reconstruction studies. The investigated contexts included virtual museums, intangible cultural heritage, historic architecture, cultural tourism, and physical–digital heritage platforms. **Table 4** summarizes the research designs, cultural applications, documented findings, and principal evidence limitations of each study. Study identifiers and direct/adjacent assignments are cross-referenced in **Supplementary Tables S2–S3**.

Table 4. Characteristics and key findings of the 15 included studies relevant to RQ2–RQ4

Article	Design and sample	Cultural technology and context	Mechanism and reported finding	Main constraint / evidence boundary
Zhang et al. [45]	3D serious game and user study n = 100	Xiannong agricultural heritage, China. Interactive first-person 3D role-playing heritage game	P1: 3D role-playing and interactive tasks for heritage knowledge transmission. Finding: Learning and engagement-related responses following the Xiannong serious-game experience.	Single setting, selected participants, short assessment with no sustained transmission evidence.
Murphy et al. [31]	Multi-case technical documentation Sources: Not reported as unified sample	Multiple heritage preservation and community cases. 3D reconstructions, VR, virtual tours, community engagement	P1: Community-facing virtual reconstructions, VR tours and digital documentation. Finding: Implemented heritage visualization and documented community engagement cases.	No common participant sample or comparative outcome measurements.
Pesce & Franzè [43]	Longitudinal case, interviews/documents Sources: Multiple interviews/ organizations; no unitary survey n	Google Arts & Culture digital ecosystem. Google Arts & Culture, virtual tour, AR/VR and phygital platform	P2: Linking physical cultural access, online platforms and multi-stakeholder value creation. Finding: Longitudinal case findings on platform relationships, access and potential value creation.	One platform ecosystem, no isolated metaverse contribution or SDG target measurement.
Ye et al.[47]	Cross-sectional survey, fsQCA/NCA n = 311	Gu embroidery intangible heritage, China. Interactive 3D digital embroidery heritage environment	P3: Immersion with configurational technology-acceptance conditions. Finding: Configurations associated with adoption of digital intangible heritage.	Cross-sectional convenience self-report, no verified long-term adoption.
Cecere et al. [24]	Metaverse museum case and feedback Sources: User n not clearly established in reviewed evidence	Museo dell'Artigianato Valdostano, Italy. Museum virtual space, avatar navigation, triggers, Oculus Quest 2	P1: Avatar navigation, virtual museum displays and visitor interaction triggers. Finding: Museum virtual environment developed and user-experience feedback reported.	User sample/ reporting incompleteness, limited outcome evaluation.

Continuation Table:

Article	Design and sample	Cultural technology and context	Mechanism and reported finding	Main constraint / evidence boundary
Zhu et al.[10]	Cross-sectional TAM survey n = 304	Palace Museum heritage tourism, China. VR-based heritage tourism at Palace Museum	P1: VR experience, awe and technology attitudes in heritage tourism. Finding: Survey associations with self-reported pro-sustainable behaviour.	Cross-sectional nonprobability self-report, no directly observed sustainable acts.
Yang et al. [33]	VR prototype and user evaluations Sources: 17 in initial experiment; additional evaluation groups described	Sanlin cultural practices, Shanghai, China. Binocular 180-degree VR map of Shanghai intangible traditions	P1: Binocular 180° mapping and visual demonstration of traditional skills. Finding: Working VR map, technical performance and small user evaluations reported.	Small initial evaluation group and no longitudinal transmission outcome.
Aditya et al. [26]	Prototype development and user survey n = 100	Kayutangan heritage tourism village, Indonesia. Kayutangan thematic tourism village, interactive 3D metaverse	P2: Interactive 3D heritage-village tourism prototype connecting place-based culture and remote visitors. Finding: Functional prototype and reported user satisfaction.	Single-site uncontrolled satisfaction survey, actual visits/income not tracked.
Lee et al.[25]	Exhibition design and user survey Sources: 110 valid responses to usage survey; convenience/ student sample	Gamified museum metaverse exhibition. Virtual exhibition with avatar, game quests, narrative interaction	P2: Avatar-guided quests and cultural storytelling across online/offline museum touchpoints. Finding: Survey-reported engagement and prospective offline visit relationship.	Convenience/ student sample and intentions not realized visits.
Hu et al.[48]	Factor development and SEM survey n = 298	Metaverse-based cultural heritage education. Cultural-education metaverse platform	P3: Presence, interactivity and flow in technology-acceptance framework. Finding: Cross-sectional associations with intention to use an educational metaverse.	Cross-sectional selection bias and intent-based rather than long-term learning.
Jiang et al.[9]	Cross-sectional survey, PLS-SEM n = 409	Cloud Tour Dunhuang digital heritage tourism, China. Cloud Tour Dunhuang, virtual cultural tourism	P2: Virtual-cultural experience and cultural attachment linked to sustained engagement. Finding: Survey associations with revisit/reuse intention and perceived social sustainability.	Purposive online sample, self-report, SDG target outcome not measured.

Continuation Table:

Article	Design and sample	Cultural technology and context	Mechanism and reported finding	Main constraint / evidence boundary
Cao et al.[49]	Survey, SEM/ regressions Sources: 239 valid / 500 distributed	Chinese Generation Z intangible heritage communication. Metaverse-enabled intangible heritage communication	P3: Flow-based experience and digital communication motivating participation. Finding: Self-reported participation intention linked to flow-related constructs.	Nonprobability recruitment and unobserved actual participation.
He & Qin [8]	Survey, SEM/ANN n = 989	Metaverse of Cultural Heritage platform and offline visiting, China. Metaverse of cultural heritage (MCH) platform with avatars	P2: Avatar engagement and perceived metaverse experience linked to physical-site interest. Finding: Modelled associations between MCH engagement and offline visit intentions.	Intention outcomes without verified later visitation or causal design.
Guo et al.[27]	Comparative VR learning assessment Sources: 60 architecture and planning students, 3 modality groups of 20	Cai clan historic buildings, Fujian, China. Immersive VR, desktop VR and 360-degree panorama for Cai clan historic buildings	P1: Comparative immersive VR, desktop VR and 360° panoramic historical architecture learning. Finding: Measured differences in learning, autonomy and presence, with some non-significant comparisons.	60 architecture/ planning students, single site and limited follow-up.
Capotorto et al. [39]	Technical reconstruction case Sources: One named historic painting with supporting geometric and art-historical sources, no participant sample	Historical painting by Gaspar Hovic (Last Supper), Italy. Interactive 3D reconstructed scene, 360-degree virtual tour and VR viewing	P1: Geometric art-historical reconstruction and interactive virtual tour with VR viewing. Finding: Documented navigable reconstruction and interpretative visualization.	Single painting, no participant evaluation or visitor-learning data.

The extraction of the 15 included studies identified three interrelated analytical pathways, namely preservation–reinterpretation–experience, tradition–innovation and physical–digital convergence, and participatory knowledge co-creation. Reported outcomes varied across research designs, encompassing technological feasibility, heritage interpretation, learning-related responses, user engagement, satisfaction, and behavioural intentions concerning technology adoption, cultural participation, and future visitation. However, evidence of sustained cultural preservation, actual behavioural change, community empowerment, and measurable contributions to Sustainable Development Goal targets remained limited. Several contextual factors were also identified or discussed across the studies, including technological accessibility, usability, cultural authenticity, community participation, institutional governance, and digital infrastructure. These findings highlight differences in

the forms and strength of available evidence, particularly between documented technological implementations, user-reported experiences, and prospective sustainability-related outcomes.

3.5. Methodological Quality of the Included Studies

The methodological quality of the 15 included studies was evaluated descriptively across six domains using an adapted, design-sensitive appraisal framework. **Table 5** summarizes the domain-level appraisal judgments for each included study. Research design transparency was adequately documented in 14 studies, whereas one study provided partial methodological information. Sampling procedures or data sources were adequately reported in 10 studies and partially documented in five. All 15 studies provided sufficient documentation of the investigated technological application or exposure for their respective designs. Outcome measurement was adequately documented in 12 studies, although the nature of the reported outcomes varied from technical implementation findings to learning-related measures, user perceptions, and behavioural intentions. Bias control or triangulation represented the most prominent methodological limitation, with 14 studies receiving partial judgments due to limitations involving participant selection, cross-sectional designs, self-reported outcomes, insufficient comparison procedures, or limited validation. Sustainability-related evidence was predominantly indirect. Two studies assessed sustainability-related perceptions or behavioural proxies, while the remaining 13 primarily discussed prospective benefits or conceptual implications without directly measuring SDG target achievement. These appraisal findings informed the interpretation of evidence strength and methodological limitations without assigning numerical quality scores or statistical weights.

Table 5. Methodological Quality Appraisal of the 15 Included Primary Studies Across Six Assessment Domains

Study	D1	D2	D3	D4	D5	D6
Zhang et al. [45]	Y	Y	Y	Y	P	I
Murphy et al. [31]	P	P	Y	P	P	I
Pesce & Franzè [43]	Y	Y	Y	Y	Y	I
Ye et al.[47]	Y	Y	Y	Y	P	I
Cecere et al. [24]	Y	P	Y	P	P	I
Zhu et al.[10]	Y	Y	Y	Y	P	P
Yang et al. [33]	Y	P	Y	Y	P	I
Aditya et al. [26]	Y	P	Y	P	P	I
Lee et al.[25]	Y	P	Y	Y	P	I
Hu et al.[48]	Y	Y	Y	Y	P	I
Jiang et al.[9]	Y	Y	Y	Y	P	P
Cao et al.[49]	Y	Y	Y	Y	P	I
He & Qin [8]	Y	Y	Y	Y	P	I
Guo et al.[27]	Y	Y	Y	Y	P	I

Continuation Table:

Study	D1	D2	D3	D4	D5	D6
Capotorto et al. [39]	Y	Y	Y	Y	P	I

Note: D1 = Research design transparency; D2 = Sampling procedures/data sources; D3 = Technology implementation; D4 = Outcome measurement; D5 = Bias control/triangulation; D6 = Sustainability-related evidence. For D1–D5, Y = adequately documented and P = partially documented. For D6, P = measured proxy and I = indirect or prospective evidence.

4. Discussion

4.1. Metaverse Relevance and the Contribution of the Review

The present synthesis suggests that the relationship between local cultural innovation and the metaverse is best understood as a spectrum of technological and socio-cultural arrangements rather than a single, uniform type of application. The 45-record bibliometric mapping identifies a research landscape in which virtual reality, cultural heritage, and metaverse terminology frequently intersect. However, the article-level classification shows that these terms refer to substantially different forms of application, including avatar-mediated exhibitions, immersive learning environments, 3D reconstructions, digital twins, virtual tourism, and phygital platforms. Among the 15 primary studies, six addressed explicitly metaverse-framed cultural settings or adoption contexts and nine examined adjacent immersive or interactive technologies. This distinction matters because a navigable virtual representation, an isolated VR experience, or an online cultural platform does not necessarily demonstrate persistence, interoperability, shared virtual identity, or sustained multiuser interaction.

Relative to existing reviews concentrating on broad metaverse–sustainability relationships, heritage preservation technologies, extended-reality education, or tourism applications, the contribution of this review lies in connecting three levels of evidence that are often conflated: the technological application that was documented, the experiential or socio-cultural process that was investigated, and the cultural or sustainability-related outcome that was actually measured. The bibliometric results indicate where research attention is concentrated, while the 15-study synthesis supports more circumscribed claims about implementation, learning-related experiences, user satisfaction, adoption, and intentions. This evidence-sensitive distinction prevents the retrospective metaverse framing from converting studies of ordinary digitization or adjacent technologies into proof of functioning, fully interoperable metaverse ecosystems.

4.2. Interpreting the Three Pathways of Cultural Innovation

The first pathway, preservation–reinterpretation–experience (P1), connects the digital representation of cultural resources to interactive encounters with cultural meaning. Studies of heritage-oriented serious games, virtual architecture, panoramic intangible heritage, virtual museums, and historical reconstruction show how artefacts, places, and practices can become navigable or educational digital experiences. Guo et al. [27], for example, compared different VR presentation modes for architectural learning, although not all comparisons were statistically significant. Zhang et al. [45] examined responses to a heritage serious game, whereas Capotorto et al. [39] demonstrated a technically implemented reconstruction without

testing visitor learning. These differences suggest an important distinction between making heritage digitally accessible, facilitating a meaningful encounter with it, and demonstrating durable knowledge retention or cultural transmission. The pathway is therefore supported most directly at the levels of representation, technological feasibility, and proximal experience rather than long-term safeguarding.

The second pathway, tradition–innovation and physical–digital convergence (P2), describes connections between virtual engagement and place-based cultural settings. Metaverse-framed museum or tourism applications and phygital platforms can create additional points of contact with heritage, but the resulting value depends on whether online encounters are meaningfully connected to physical sites, institutions, and cultural actors. Aditya et al. [26] reported user satisfaction with a heritage tourism prototype, Lee et al. [25] investigated engagement with a gamified exhibition, and Pesce and Franzè [43] analysed a digital platform ecosystem and its stakeholder relationships. Jiang et al. [9] and He and Qin [8] examined perceptions and intentions concerning virtual engagement and later use or visitation. Importantly, Jiang et al. did not find a direct relationship between immersion and satisfaction in the reported model. This inconsistency cautions against a universal assumption that greater immersion automatically produces more favorable cultural experiences. Moreover, reported visit intentions do not establish that physical visits, local revenue, or equitable tourism benefits occurred.

The third pathway, participatory knowledge co-creation (P3), concerns the conditions under which cultural users may move from passive reception toward interaction, adoption, and potentially collaborative interpretation. Ye et al. [47], Hu et al. [48], and Cao et al. [49] investigated combinations of acceptance-related factors, presence, flow, and participation intentions in digital heritage settings. Together, they indicate that users' willingness to engage depends on more than access to a technical platform. Nevertheless, evidence of willingness to participate is not the same as evidence that cultural custodians exercised decision-making authority, jointly produced knowledge, or controlled its reuse. Accordingly, co-creation is treated here as an emerging socio-cultural possibility whose institutional and community-level realization requires further empirical investigation.

The pathways are neither mutually exclusive nor ordered as a universal developmental sequence. A virtual museum may support reinterpretation and prospective destination engagement, while an interactive heritage platform may simultaneously involve learning, visitor intention, and stakeholder participation. Their analytical value is to distinguish the principal mechanisms foregrounded by each study, while preserving overlaps and variations in evidence strength.

4.3. Theoretical Integration: Adoption, Experience, and Social Innovation

The three pathways can be interpreted through a socio-technical perspective integrating digital transformation, innovation diffusion, experience-oriented research, and social innovation. Innovation diffusion and technology-acceptance perspectives help explain why perceived usefulness, usability, social interaction, and user readiness are frequently associated with willingness to engage. The survey findings of Ye et al. [47], Hu et al. [48], Cao et al. [49], and He and Qin [8] are consistent with the importance of such acceptance-related processes. Yet these models predominantly address adoption or intention at the user level. They should not be extended without additional evidence to claims about enduring cultural transmission, institutional change, or sustainable development.

Experience-oriented interpretations add a second layer by considering how spatial presence, storytelling, interactive tasks, cultural attachment, and affective responses shape encounters with heritage. In P1, these affordances can make cultural information easier to explore and interpret. In P2, they may influence the perceived relationship between virtual experiences and place-based cultural destinations. The divergent results reported by Jiang et al. [9] underscore that immersion is not a sufficient explanatory condition by itself. Cultural meaning, authenticity, and other mediating relationships must be considered, and the available observational evidence does not justify treating the proposed pathways as established causal chains.

Digital transformation and social innovation perspectives provide the institutional dimension that individual adoption models lack. They direct attention to organizational capability, stakeholder coordination, cultural legitimacy, and the distribution of authority over cultural resources. Under this interpretation, P3 requires more than a technically interactive interface. Meaningful knowledge co-creation would entail participation by cultural custodians in decisions about representation, access, consent, ownership, and future adaptation. Cultural context should therefore be treated as a situated design and governance consideration, not as a fixed national characteristic presumed to determine technology acceptance. Taken together, these perspectives support a conditional rather than technologically deterministic account of metaverse-oriented cultural innovation.

4.4. An Evidence-Informed Conceptual Framework

Figure 5 integrates the review findings into an evidence-informed conceptual framework linking cultural resources, technological affordances, socio-cultural pathways, proximal outcomes, and prospective sustainability outcomes. Tangible and intangible heritage, local narratives, cultural places, and the knowledge of community custodians provide the substantive resources. Metaverse-framed applications and adjacent VR, AR, interactive 3D, digital-twin, or phygital technologies offer different combinations of navigation, presence, simulation, storytelling, social interaction, and physical–digital connection. These affordances may support P1 through interpretation and experiential learning, P2 through connections between online and place-based cultural participation, and P3 through engagement and potentially collaborative knowledge practices.

The framework deliberately separates outcomes observed or reported in the included studies from longer-term outcomes that remain hypothetical. The proximal evidence consists mainly of operational applications, usability and experience assessments, selected learning responses, self-reported attitudes, and intentions. More distal propositions include sustained heritage safeguarding, realized destination participation, equitable creative-economic value, and verifiable SDG progress. The transition between these levels is not presumed to occur automatically. Accessibility, infrastructure, cultural authenticity, intellectual property, informed consent, community agency, institutional stewardship, privacy, and technical sustainability may enable or constrain the translation of experiential benefits into durable cultural value. These conditions are presented as analytically relevant factors rather than empirically established causal moderators in the current corpus.

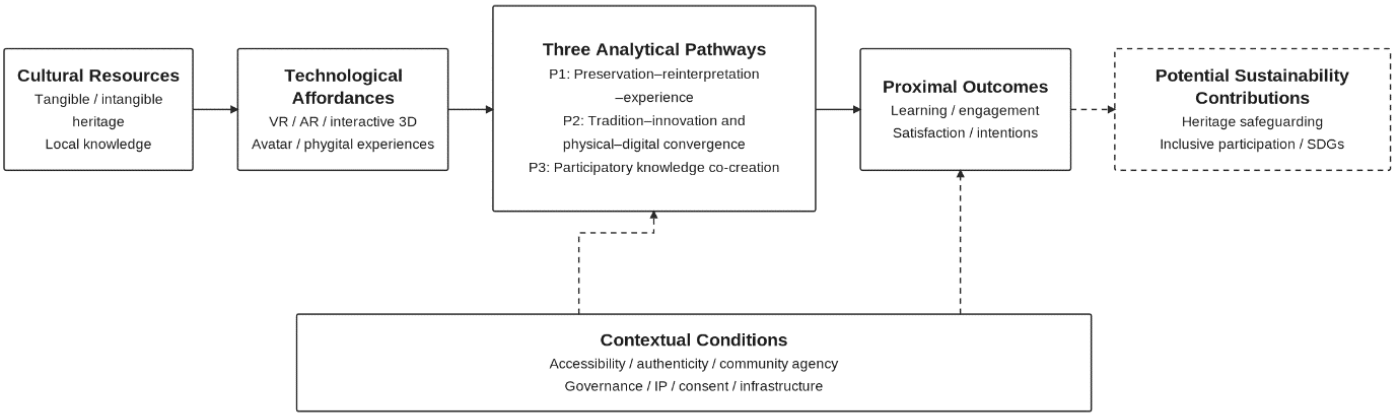


Figure 5. Evidence-informed conceptual framework for metaverse-oriented cultural innovation and potential sustainability contributions.

Note: The framework links cultural resources, technological affordances, three socio-cultural pathways, proximal reported outcomes, and potential long-term sustainability contributions, while incorporating contextual conditions. Solid arrows indicate proposed analytical relationships informed by the review synthesis, rather than established causal effects. Dashed arrows indicate prospective sustainability links and hypothesized contextual influences requiring empirical validation.

The framework's central theoretical proposition is that local culture shapes technological design, participation, and governance beyond its representation as digitized content. Cultural custodians, meanings, and governance practices inform how cultural resources are represented, how participation is organized, and how sustainability-related outcomes are defined and evaluated. The conceptual relationships depicted in **Figure 5** are propositions for future empirical testing, rather than path coefficients or effect estimates derived from this review.

4.5. Interpreting Contributions to the Sustainable Development Goals

The distinction between proximal outcomes and longer-term impact is particularly important when interpreting the Sustainable Development Goals. Of the potential linkages identified, SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities), including heritage safeguarding under Target 11.4, are most closely aligned with the cultural learning and digital heritage applications documented in the included studies. Even here, digital access and short-term learning responses should not be equated with sustained educational improvement or verified protection of cultural practices. Metaverse and immersive infrastructure may also be relevant to SDG 9, although the construction of a digital platform does not itself establish inclusive infrastructure or innovation benefits at population level.

Physical–digital tourism applications provide plausible links to SDG 8, particularly sustainable tourism under Target 8.9. However, satisfaction, cultural attachment, and intention to visit are intermediate indicators, not observations of tourist expenditure, employment, or local livelihoods. Similarly, SDG 10 (Reduced Inequalities) is relevant to accessibility and equitable cultural participation, but unequal device access, digital skills, language provision, and control over cultural representations may reproduce rather than reduce exclusion. Potential relevance to SDG 12 (Responsible Consumption and Production) remains more speculative because the synthesis did not identify sufficiently robust measurements of material

consumption, digital energy demands, or environmental savings attributable to the reviewed applications.

The methodological appraisal reinforces this cautious interpretation. Although technological implementation was documented sufficiently for the respective designs, 14 of the 15 studies received partial judgments for bias control or triangulation. Only two studies examined sustainability-related perceptions or behavioral proxies, and neither established achievement of an SDG target. The review therefore identifies credible connections to sustainability-relevant mechanisms and questions for evaluation, not a demonstrated causal contribution to SDG attainment.

4.6. Governance, Authenticity, Accessibility, and Practical Implications

The findings suggest that successful digital cultural innovation cannot be evaluated solely through interface performance, immersion, or user satisfaction. From a practical perspective, cultural institutions and technology developers should align digital formats with clearly specified cultural purposes. Projects intended for learning require educational and retention measures, while virtual tourism initiatives require follow-up evidence on actual visits and distribution of economic benefits. When safeguarding intangible heritage is the stated objective, evaluation should include cultural custodians' judgments about accuracy, contextual integrity, consent, and the ability to update or withdraw representations over time.

Access and governance should be designed into projects from the outset rather than treated as secondary technical adjustments. Device cost, connectivity, disability access, language options, digital literacy, platform dependence, maintenance responsibilities, data privacy, and intellectual property arrangements are likely to shape who participates and who benefits. The existing studies identify some of these issues as contextual concerns, but few test how alternative governance arrangements change outcomes. Thus, participatory stewardship, fair attribution, and community oversight are recommendations derived from the socio-technical interpretation of the evidence, not interventions already proven effective by the 15 studies.

For future metaverse-focused applications, a more discriminating implementation standard is also needed. Authors should report whether avatar interaction, shared virtual presence, persistence, interoperability, digital identity, and physical–virtual continuity are actually implemented and evaluated. This would allow readers to distinguish mature networked virtual environments from isolated immersive demonstrations and would strengthen comparisons across settings.

4.7. Limitations and Future Research Direction

Several limitations should be considered when interpreting the findings of this review. First, the original search was restricted to English-language publications from 2015 to 2025, while the bibliometric dataset covered studies published between 2021 and 2025. Missing database-specific search strings, exact export dates, deduplication logs, and detailed screening-decision records prevent full reconstruction of the original search, despite the reported PRISMA counts and retrospective eligibility assessment; reproducibility of Google Scholar searches also remains limited. The retrospective application of a metaverse-focused analytical framework also introduces potential classification bias, particularly for studies that did not explicitly conceptualize their applications as metaverse environments. Second, the included studies varied substantially in research designs, technologies, cultural contexts, and outcome measurements, limiting direct comparability and preventing quantitative synthesis. The adapted six-domain quality appraisal identified limitations in bias

control and triangulation, while independent dual screening and coding were not established. Furthermore, the geographical concentration of empirical studies, reliance on self-reported perceptions and behavioural intentions, and limited longitudinal evidence restrict the generalizability of the findings. Consequently, the proposed sustainability pathways and conceptual framework should be interpreted as evidence-informed analytical propositions rather than established causal relationships or demonstrated contributions to SDG attainment.

Future research should prioritize more rigorous, comparative, and longitudinal investigations to establish how metaverse-oriented technologies contribute to cultural innovation and sustainable development. Studies should operationally distinguish fully developed metaverse environments from adjacent immersive technologies by documenting persistence, interoperability, embodied interaction, virtual identity, and physical–digital continuity. Experimental and longitudinal designs involving diverse cultural settings and participant populations are needed to examine whether immersive experiences produce sustained learning, cultural transmission, actual visitation, and meaningful community participation beyond short-term satisfaction or behavioural intentions. Future evaluations should also incorporate measurable sustainability indicators aligned with relevant SDG targets, including cultural safeguarding, inclusive education, local economic benefits, accessibility, and environmental impacts. Particular attention should be given to participatory governance, cultural authenticity, intellectual property, informed consent, digital equity, and the involvement of local communities in designing and managing cultural technologies. Testing the proposed conceptual framework across different institutional and geographical contexts would further clarify the relationships among technological affordances, socio-cultural mechanisms, contextual conditions, and long-term sustainability outcomes.

5. Conclusion

This systematic literature review examined metaverse-oriented cultural innovation through bibliometric analysis of 45 publications and thematic synthesis of 15 primary studies. The findings identified nine technology families and three interrelated pathways encompassing preservation–reinterpretation–experience, tradition–innovation and physical–digital convergence, and participatory knowledge co-creation. Although immersive technologies demonstrated potential for cultural interpretation, learning, engagement, and participation, evidence of long-term cultural preservation and measurable contributions to the Sustainable Development Goals remained limited. The study proposes an evidence-informed conceptual framework linking cultural resources, technological affordances, socio-cultural mechanisms, and sustainability-related outcomes, with accessibility, cultural authenticity, community agency, and institutional governance as important contextual conditions. Future research should prioritize longitudinal evaluations and measurable sustainability indicators to establish whether these technologies generate enduring and equitable cultural benefits.

Author contributions: Conceptualization, NK and BRS; methodology, NK, LW, and AIS; literature search, data curation, and formal analysis, NK; writing—original draft preparation, NK; writing—review and editing, all authors; supervision, BRS, LW, and AIS. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors acknowledge Sekolah Tinggi Ilmu Ekonomi YKPN

and the Faculty of Economics and Business, Sebelas Maret University, for their institutional support and academic encouragement in preparing this study.

Ethical approval: Not applicable. This study is a systematic literature review based exclusively on previously published literature and did not involve human participants, animals, or the collection of primary personal data.

Informed consent statement: Not applicable. This study did not involve human participants or the collection of identifiable personal information.

Conflicts of interest: The authors declare no conflicts of interest.

Supplementary Materials:
The supplementary materials associated with this article are available on Zenodo at: https://doi.org/10.5281/zenodo.24027615
These materials include Supplementary Table S1, Supplementary Table S2, and Supplementary Table S3.

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