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AI-Enhanced Immersive Learning for Intangible Cultural Heritage: The Case of Chinese Paper-Cutting

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Abstract

The preservation and transmission of intangible cultural heritage (ICH) face increasing challenges in the digital era, including declining participation and the erosion of traditional apprenticeship-based learning. While emerging technologies such as virtual reality (VR) and artificial intelligence-generated content (AIGC) offer new opportunities for cultural engagement, limited research has examined how their integration influences learning processes in ICH education. Addressing this gap, this study investigates how AI-enhanced immersive learning environments—combining VR interaction with AI-generated cultural content—shape learners' engagement, perceived learning experience, and cultural understanding. Using Chinese paper-cutting as a representative case, a qualitative research design was employed, involving semi-structured interviews and focus group discussions with nine participants. Data were analyzed using thematic analysis to identify key experiential and interpretive patterns. The findings reveal four major themes: immersive engagement, perceptions of AI-generated cultural content, authenticity interpretation, and system-level opportunities and challenges. The results demonstrate that VR interaction enhances engagement through embodied and experiential learning, while AI-generated content functions as a generative learning scaffold that supports creative exploration and pattern recognition. Importantly, the study finds that cultural authenticity operates as a mediating mechanism, shaping how learners interpret and internalize digitally mediated cultural experiences. Authenticity is constructed through the alignment of interaction realism, cultural-symbolic coherence, and user interpretation. This study contributes to digital heritage education by developing a theoretically integrated framework that combines experiential learning, generative learning, and authenticity theory to explain AI-enhanced immersive learning. Practically, the findings provide insights for educators, cultural institutions, and technology developers on designing culturally grounded, engaging, and scalable learning environments. The study also highlights the role of immersive and generative technologies in supporting innovation within the creative economy and digital cultural industries, thereby advancing sustainable approaches to ICH transmission.

Keywords : Intangible Cultural Heritage; Virtual Reality; Generative AI; Immersive Learning; Cultural Authenticity; Digital Heritage Education

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1. Introduction

1.1 Background of the study

Intangible cultural heritage (ICH) encompasses living cultural expressions, practices, skills, and knowledge that are continuously recreated by communities and transmitted across generations. It plays a crucial role in sustaining cultural diversity, reinforcing social identity, and preserving collective memory. However, under the pressures of globalization, modernization, and shifting socio-cultural dynamics, many forms of ICH are increasingly at risk. These challenges include declining numbers of cultural practitioners, weakened intergenerational transmission, and reduced engagement among younger populations (Lv et al., 2024; Zhao & Kim, 2024). Traditional preservation approaches—such as documentation, archiving, and exhibition—are no longer sufficient to sustain the experiential and participatory nature of ICH.

In response, digital technologies have emerged as transformative tools for heritage preservation and transmission. Recent developments in digital innovation have shifted the focus from static preservation toward interactive, participatory, and experience-driven cultural engagement (Jiang et al., 2025; La Guardia et al., 2025). Technologies such as virtual reality (VR), artificial intelligence (AI), and 3D modeling enable users not only to access cultural content but also to actively engage with and reinterpret heritage practices in immersive environments. This paradigm shift reflects a transition from object-centered preservation to user-centered, learning-oriented digital heritage systems.

Among these technologies, virtual reality (VR) has demonstrated significant potential in cultural heritage education due to its capacity to support immersive and embodied learning. Drawing on experiential learning theory (Kolb, 1984) and presence theory in virtual environments, VR enables learners to actively participate in simulated cultural practices, thereby enhancing engagement, cognitive processing, and skill acquisition. Prior research indicates that VR-based heritage systems can improve learners' understanding and emotional connection by enabling direct interaction with cultural processes that are otherwise constrained by time, space, or resource limitations (Zhao & Kim, 2024; Zhao, 2025). Importantly, VR facilitates not only observation but also procedural learning, which is essential for craft-based ICH such as paper-cutting.

Simultaneously, advances in generative artificial intelligence (AI)—particularly diffusion models and Low-Rank Adaptation (LoRA)—have introduced new possibilities for the scalable representation and reinterpretation of cultural heritage. Generative AI enables the creation of culturally consistent visual content that preserves stylistic and symbolic characteristics of traditional art forms while allowing adaptive variation and personalization (Dai et al., 2024; Zou et al., 2025). From a constructivist learning perspective, AI-generated content can function as a cognitive scaffold, supporting learners' exploration, creativity, and understanding of complex cultural patterns. However, existing research on generative AI in ICH contexts has largely focused on technical performance and output quality, with limited attention to its pedagogical implications and its role in shaping learning experiences.

Despite the growing body of literature on VR-based heritage learning and AI-generated cultural content, these two technological domains are predominantly studied in isolation. VR research primarily emphasizes immersion, interaction design, and user experience, while AI research focuses on algorithmic development and content generation (Dai et al., 2024; Zhao & Kim, 2024). Consequently, there is a critical gap in understanding how the integration of VR interaction and AI-generated content jointly influences learning processes in ICH education. In particular, limited empirical research has examined how such integration affects learners' engagement, cultural understanding, and interpretations of authenticity.

Addressing this gap is theoretically and practically significant. From a theoretical perspective, integrating VR and generative AI requires a reconceptualization of learning mechanisms in digital heritage contexts, combining experiential learning, generative learning, and interpretive authenticity frameworks (Pescarin, 2024; Jiang, 2026). From a practical perspective, effective ICH learning environments must balance technological innovation with cultural authenticity, ensuring that digital representations remain meaningful, contextually grounded, and pedagogically effective.

Therefore, this study aims to examine how AI-enhanced immersive learning environments, defined as systems that integrate VR-based interaction with AI-generated cultural content, reconfigure learning experiences in intangible cultural

heritage education. Using Chinese paper-cutting as a representative case, this research explores how such environments influence learners' engagement, perceived learning experience, and cultural understanding. By bridging immersive technology and generative AI within a unified framework, this study contributes to advancing both theoretical and practical knowledge on the sustainable transmission of intangible cultural heritage in the digital era.

In addition, the study extends the discussion to the creative economy and digital cultural industries, where immersive and generative technologies play an increasingly important role in enabling new forms of cultural production, innovation, and value creation (Jiang et al., 2025). This positioning strengthens the relevance of the study within the broader domain of business and creative technology management.

1.2 Research Objectives

1.2 Research Objectives

The objectives of this study are to:

- (1) To explore learners' lived experiences of engaging with intangible cultural heritage through an AI-enhanced immersive virtual reality environment.
- (2) To examine participants' perceptions of AI-generated cultural content, particularly in relation to cultural authenticity, representation, and meaning.
- (3) To analyze how the integration of virtual reality interaction and AI-generated content influences learners' engagement, cultural understanding, and perceived learning experience.
- (4) To identify the opportunities and challenges associated with AI-enhanced immersive learning systems in the context of intangible cultural heritage education.
- (5) To develop theoretical and practical implications for the design of immersive digital learning environments that support sustainable cultural heritage transmission and innovation in the creative economy.

1.3 Research Questions

This study is guided by the following research questions:

- (1) How do participants describe their learning experiences when engaging with intangible cultural heritage through an AI-enhanced immersive virtual reality environment?
- (2) How do learners perceive AI-generated cultural content in terms of authenticity, representation, and cultural meaning within a VR-based learning system?
- (3) In what ways does the integration of virtual reality interaction and AI-generated content influence learners' engagement and cultural understanding?
- (4) How do participants interpret authenticity in AI-enhanced immersive heritage environments?
- (5) What opportunities and challenges do learners identify in the use of immersive and generative technologies for intangible cultural heritage learning?

2. Literature Review

2.1 Intangible Cultural Heritage and the Shift toward Learning-Centered Digital Preservation

Intangible cultural heritage (ICH) preservation has undergone a significant transformation from static documentation toward learning-centered and participatory transmission models. Traditionally, preservation strategies focused on archiving cultural artifacts through textual records, images, or exhibitions. However, contemporary scholarship emphasizes that ICH is

inherently processual, encompassing skills, practices, and embodied knowledge that require active engagement for effective transmission (La Guardia et al., 2025).

Recent research highlights that digital innovation strategies—such as digital platforms, collaborative systems, and interactive media—are not merely preservation tools but mechanisms for cultural reinterpretation and creative regeneration (Jiang et al., 2025). Within this framework, digital literacy functions as a mediating factor that enables users to engage meaningfully with cultural content, thereby enhancing both preservation outcomes and the development of creative cultural products.

From a theoretical perspective, this shift aligns with constructivist learning theory, which posits that knowledge is actively constructed through interaction and experience. In the context of ICH, this implies that effective digital preservation must move beyond representation toward experiential and participatory learning environments, where users can actively engage with cultural practices rather than passively observe them.

2.2 Virtual Reality for ICH Learning: Immersion, Interaction, and Embodied Transmission

Virtual reality (VR) has emerged as a key enabling technology for ICH learning due to its ability to support immersive, interactive, and embodied experiences. Unlike traditional media, VR enables users to engage directly with simulated cultural environments, facilitating procedural learning and skill acquisition—critical components of craft-based heritage practices such as paper-cutting (Zhao & Kim, 2024).

The educational value of VR can be understood through experiential learning theory (Kolb, 1984) and presence theory, which suggest that learning is enhanced when individuals actively engage in realistic and immersive environments. Empirical studies indicate that VR-based heritage systems can improve user engagement, emotional involvement, and knowledge retention by enabling first-hand interaction with cultural processes (Zhao, 2025).

In addition, systematic reviews in the field demonstrate a growing emphasis on human–computer interaction (HCI) factors, including interaction fidelity, navigation design, and cognitive load management, as critical determinants of learning effectiveness in VR environments (Rodriguez-Garcia et al., 2024; Zhang et al., 2024). However, VR’s effectiveness is not automatic; it depends on the alignment between technological design and pedagogical objectives.

Importantly, scholars argue that VR-based ICH systems must represent not only cultural outputs but also cultural processes, capturing the “doing” and “performing” aspects of heritage practices (Chen, 2026). Without this, digital representations risk reducing ICH to static visual artifacts, thereby undermining its experiential and cultural depth.

2.3 User Experience Mechanisms: Presence, Engagement, and Authenticity

Within virtual heritage research, user experience constructs—particularly presence, engagement, and authenticity—are central to understanding learning outcomes.

Presence, defined as the psychological sense of “being there,” is widely recognized as a foundational mechanism that enhances attention, emotional involvement, and cognitive processing in immersive environments (Zhao & Kim, 2024; Zhao, 2025). Higher levels of presence are associated with deeper engagement and more meaningful learning experiences.

Authenticity, however, is a more complex construct. Contemporary scholarship conceptualizes authenticity not as an objective property of digital content but as a subjective and interpretive experience co-constructed by users (Jiang, 2026; Pescarin, 2024). In digital heritage contexts, authenticity encompasses multiple dimensions, including:

- 1) Visual fidelity
- 2) Cultural accuracy
- 3) Symbolic meaning
- 4) Contextual coherence

For ICH learning, authenticity plays a critical role in shaping learners' cultural understanding. If digital representations lack cultural grounding, they may increase engagement but weaken cultural meaning. Conversely, overly rigid representations may preserve authenticity but reduce accessibility and learner engagement. This tension highlights the need for balanced design strategies that integrate immersion with cultural integrity (La Guardia et al., 2025).

2.4 Generative AI for ICH: From Representation to Learning Scaffolding

Generative AI represents a significant advancement in digital heritage by enabling the scalable creation of culturally consistent content. Technologies such as diffusion models and LoRA fine-tuning allow for the generation of visual artifacts that preserve stylistic and symbolic features of traditional cultural forms (Dai et al., 2024).

Recent studies demonstrate that generative AI can produce detailed and culturally aligned outputs, particularly in applications such as Chinese paper-cutting (Dai et al., 2024; Zou et al., 2025). Beyond technical capabilities, emerging research emphasizes that generative AI should be evaluated based on:

- 1) Semantic accuracy
- 2) Cultural fidelity
- 3) Ethical considerations
- 4) User interpretability (Ming, 2025)

From a theoretical standpoint, generative AI can be understood through generative learning theory, where learners actively construct knowledge by interacting with dynamically generated content. In this context, AI-generated outputs function as cognitive scaffolds, supporting exploration, creativity, and pattern recognition.

However, existing literature remains largely content-centric, focusing on model performance rather than learning processes. There is limited empirical research examining how AI-generated cultural content influences learners' interpretation, engagement, and cultural understanding—particularly within immersive environments.

2.5 Integration of VR and AI: Toward a Convergent Learning System

The integration of VR and generative AI represents a convergent learning system, combining embodied interaction with adaptive content generation. This integration has the potential to fundamentally reconfigure ICH learning in several ways.

First, it enables a shift from fixed to adaptive learning materials, where AI-generated content provides dynamic and personalized cultural representations, supporting differentiated learning experiences (Dai et al., 2024; Ming, 2025).

Second, it transforms learners from passive recipients to active co-creators, allowing them to generate and manipulate culturally grounded artifacts within immersive environments. This aligns with broader innovation frameworks in the creative economy, where user participation drives cultural value creation (Jiang et al., 2025).

Third, it introduces a dual-layered concept of authenticity:

- Content authenticity (accuracy of AI-generated outputs)
- Experiential authenticity (meaningfulness of interaction)

This duality reflects contemporary authenticity theory, which emphasizes interpretive and experiential dimensions rather than purely technical accuracy (Pescarin, 2024; Jiang, 2026).

However, integration also introduces risks, including:

- (1) Cultural distortion due to generative variability
- (2) Overemphasis on novelty over cultural meaning
- (3) Reduced depth of cultural interpretation

These challenges highlight the need for empirical research examining how learners interpret authenticity and meaning within AI-enhanced immersive systems.

2.6 Qualitative Evaluation: Capturing Meaning and Experience

Given the interpretive and experiential nature of ICH learning, qualitative research methods are particularly appropriate. Semi-structured interviews and focus groups enable in-depth exploration of learners' perceptions, experiences, and meaning-making processes.

Interviews provide detailed insights into individual experiences, including immersion, engagement, and cultural interpretation. Focus groups, in contrast, facilitate the exploration of collective meaning construction, which is particularly relevant in cultural heritage contexts where authenticity is socially negotiated (Krueger & Casey, 2015).

Previous studies in VR and cultural heritage research demonstrate that qualitative methods are effective for capturing nuanced experiential dimensions, such as realism, usability, and interpretive engagement (Romano et al., 2025). Furthermore, user-centered evaluation frameworks emphasize the importance of moving beyond technical metrics toward meaning-oriented assessment, particularly in heritage education (Rodriguez-Garcia et al., 2024; Zhao, 2025).

2.7 Synthesis and Research Gap

The literature reveals two well-established but largely independent research streams:

- (1) VR-based ICH learning, focusing on immersion, interaction, and embodied experience
- (2) Generative AI for cultural content, focusing on scalable and adaptive representation

However, there remains a critical gap in understanding how the integration of these technologies' influences learning processes. Specifically, existing research lacks:

- (1) Empirical evidence on learner experience in AI-enhanced VR environments
- (2) Theoretical integration of experiential learning and generative learning mechanisms
- (3) Insight into how learners interpret authenticity, meaning, and engagement in such systems

Addressing this gap is essential for advancing both theory and practice. Theoretically, it contributes to a more integrated understanding of digital heritage learning by combining immersive and generative paradigms. Practically, it provides design implications for developing culturally responsible, engaging, and effective learning environments within the broader context of the creative economy and digital cultural industries.

3. Research Methods and Materials

3.1. Research Design

This study adopts a qualitative exploratory research design to investigate how AI-enhanced immersive technologies—specifically the integration of virtual reality (VR) interaction and AI-generated cultural content—reconfigure learning experiences in intangible cultural heritage (ICH) education. A qualitative approach is appropriate because the study seeks to examine participants' lived experiences, perceptions, interpretations, and meaning-making processes, rather than to test causal relationships or quantify predefined variables (Creswell & Poth, 2018).

From a theoretical perspective, qualitative inquiry aligns with the interpretivist paradigm, which emphasizes the socially constructed nature of knowledge and is particularly relevant in heritage contexts where learning involves cultural interpretation, authenticity perception, and experiential engagement (La Guardia et al., 2025). In this study, the focus is placed on perceived learning experience, rather than objective learning outcomes, to capture the subjective and experiential dimensions of immersive heritage learning.

The study employs semi-structured interviews and focus group discussions as complementary data collection methods. This methodological triangulation enables both in-depth individual insights and collective meaning construction, which are

critical for understanding how learners interpret cultural authenticity and engagement in AI-enhanced immersive environments.

Figure 1 illustrates a theoretically grounded model in which VR interaction (experiential learning) and AI-generated content (generative learning) jointly enhance engagement, which in turn influences perceived learning experience and cultural understanding, mediated by learners' interpretations of authenticity.

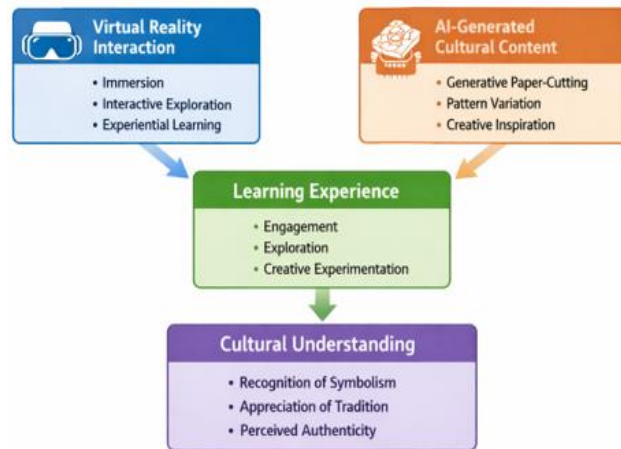


Figure 1. Conceptual Model of AI-Enhanced Immersive Learning for Intangible Cultural Heritage Education

Source. Constructed by authors

3.1.1 Conceptual Model Development and Theoretical Justification

Figure 1 presents the conceptual model of AI-enhanced immersive learning for intangible cultural heritage (ICH) education, which integrates virtual reality (VR) interaction and AI-generated cultural content as key technological antecedents shaping learners' experiences. Unlike a purely descriptive framework, this model is grounded in three complementary theoretical perspectives: experiential learning theory, generative learning theory, and authenticity theory in digital heritage contexts.

(1) Virtual Reality Interaction → Engagement and Experiential Learning

The first component of the model posits that VR interaction enhances learner engagement and experiential learning. This relationship is theoretically grounded in experiential learning theory (Kolb, 1984), which emphasizes that knowledge is constructed through active experience, reflection, and interaction. VR enables learners to engage in embodied and situated learning, allowing them to participate directly in cultural practices rather than passively observe them.

In addition, presence theory suggests that immersive environments increase the psychological sense of “being there,” which in turn enhances attention, emotional involvement, and cognitive processing (Zhao, 2025). Empirical studies in virtual heritage contexts confirm that higher levels of immersion and interactivity are associated with increased engagement and deeper learning experiences (Zhao & Kim, 2024). Therefore, VR interaction is conceptualized as a key driver of learner engagement, which mediates the relationship between technological experience and learning outcomes.

(2) AI-Generated Cultural Content → Generative Learning and Cognitive Scaffolding

The second component of the model proposes that AI-generated cultural content supports generative learning processes. This relationship is informed by generative learning theory, which posits that learners actively construct knowledge by organizing, integrating, and transforming information.

AI-generated content—such as dynamically created paper-cutting patterns—functions as a form of cognitive scaffolding, providing learners with diverse examples, variations, and creative stimuli. These generative outputs enable learners to explore

cultural structures, recognize patterns, and experiment with design elements, thereby enhancing both cognitive engagement and creative exploration.

Recent studies demonstrate that diffusion-based AI models can generate culturally consistent artifacts while maintaining stylistic fidelity (Dai et al., 2024; Zou et al., 2025). However, the educational value of such content lies not only in its visual quality but also in its ability to support interpretive learning and meaning construction (Ming, 2025). Accordingly, AI-generated content is positioned in the model as a key mechanism that enhances learning through exploration and co-creation.

(3) Integration of VR and AI → Enhanced Engagement and Perceived Learning Experience

The model further proposes that the integration of VR interaction and AI-generated content creates a convergent learning system that amplifies engagement and enhances the perceived learning experience.

This integration can be understood through a constructivist learning perspective, where knowledge emerges from the interaction between learners, tools, and environments. VR provides embodied interaction, while AI contributes adaptive and generative content, resulting in a dynamic learning environment that supports both experiential and generative learning processes simultaneously.

Specifically, the integration enables:

- (1) Interactive exploration (through VR immersion)
- (2) Creative co-creation (through AI-generated content)
- (3) Iterative learning cycles (through experimentation and reflection)

This synergy transforms learners from passive recipients into active participants and co-creators, thereby enhancing engagement and deepening learning experiences. Consequently, engagement is conceptualized as a mediating variable linking technological features to perceived learning outcomes.

(4) Cultural Authenticity as an Interpretive Mechanism

A critical component of the model is cultural authenticity, which functions as an interpretive mechanism influencing how learners evaluate and internalize their experiences.

Drawing on authenticity theory in digital heritage (Pescarin, 2024; Jiang, 2026), authenticity is conceptualized not as an objective property of digital representations but as a subjectively constructed perception shaped by users' interpretations. In AI-enhanced immersive environments, authenticity operates at two levels:

- (1) Content authenticity – the cultural accuracy and symbolic coherence of AI-generated outputs
- (2) Experiential authenticity – the extent to which the immersive interaction reflects meaningful cultural practice

Learners assess authenticity based on multiple criteria, including visual fidelity, cultural symbolism, interaction realism, and contextual meaning. This perception of authenticity influences both engagement and cultural understanding, as learners are more likely to engage deeply with content they perceive as culturally credible and meaningful.

(5) Engagement → Cultural Understanding (Outcome Relationship)

The model posits that learner engagement leads to deeper cultural understanding, which represents the primary educational outcome of the study. This relationship is supported by experiential learning theory and prior research in immersive learning environments, which demonstrate that active engagement enhances comprehension, retention, and meaning-making (Zhao & Kim, 2024).

In this study, cultural understanding is conceptualized as:

- (1) Recognition of cultural symbols and meanings
- (2) Awareness of traditional practices and processes
- (3) Interpretation of cultural authenticity within digital environments

Importantly, consistent with reviewer feedback, this study focuses on perceived learning experience and cultural understanding, rather than objective learning outcomes, acknowledging the interpretive nature of qualitative inquiry.

3.2 Research Context and Learning Environment

The study is situated within an AI-enhanced VR learning environment developed to support the learning of traditional Chinese paper-cutting, a representative form of craft-based intangible cultural heritage. The VR system enables participants to interact with simulated paper-cutting processes in an immersive environment, while AI-generated cultural content—produced using diffusion-based generative models with LoRA fine-tuning—provides dynamically generated patterns that reflect traditional stylistic and symbolic characteristics (Dai et al., 2024).

This integrated environment allows learners to:

- (1) Engage in embodied interaction with cultural practices through VR
- (2) Explore AI-generated cultural variations as creative learning scaffolds
- (3) Reflect on authenticity, usability, and cultural meaning

The research context is particularly suitable for examining how immersive and generative technologies jointly influence engagement, interpretation, and perceived learning experience in ICH education.

3.3 Participants and Sampling Strategy

Participants were recruited using purposive sampling, a widely accepted strategy in qualitative research for selecting individuals who can provide rich and relevant insights into the phenomenon under investigation (Patton, 2015). The sample consisted of learners with an interest in cultural heritage, digital learning, or creative technologies.

3.3.1 Inclusion Criteria

Participants were selected based on the following criteria:

- (1) No professional-level expertise in traditional paper-cutting (to ensure a novice learning perspective)
- (2) Willingness to engage with VR-based learning activities
- (3) Ability to participate in interviews or focus group discussions

3.3.2 Sample Size Justification

The final sample included nine participants, which is consistent with qualitative research standards emphasizing depth over breadth. The sample size was determined based on the principle of thematic saturation, defined as the point at which no substantially new themes emerge from additional data (Guest et al., 2012).

Previous qualitative studies suggest that saturation in relatively homogeneous samples can be achieved within 6–12 participants (Guest et al., 2012). In this study, saturation was observed after the eighth participant, with the ninth interview confirming thematic consistency. Therefore, the sample size is considered sufficient for exploratory qualitative analysis, while acknowledging its limitations in generalizability.

3.4 Data Collection Methods

3.4.1 Semi-Structured Interviews

Semi-structured interviews were conducted to capture participants' individual experiences, perceptions, and reflections on the AI-enhanced VR learning environment. This method ensures both comparability across participants and flexibility to explore emergent themes (Kallio et al., 2016).

- Each interview lasted approximately 30–45 minutes and was audio-recorded with participants' consent.
- Interview Protocol (Added for Transparency)

Key guiding questions included:

- (1) How would you describe your overall experience using the VR learning environment?

- (2) How did the AI-generated designs influence your understanding of paper-cutting?
- (3) To what extent did the system enhance your engagement and learning experience?
- (4) How do you perceive the authenticity of the AI-generated cultural content?
- (5) What challenges or limitations did you encounter during the experience?

3.4.2 Focus Group Discussions

Focus group discussions were conducted to explore collective interpretations and socially constructed meanings, particularly regarding cultural authenticity and the integration of AI-generated content. This method is particularly suitable for heritage research, where cultural understanding is often shaped through social interaction (Krueger & Casey, 2015).

- Each focus group consisted of 4–6 participants and lasted approximately 60–90 minutes.
- Focus Group Themes (Added for Clarity)

Discussions focused on:

- (1) Shared perceptions of immersion and engagement
- (2) Interpretations of cultural authenticity
- (3) Comparisons between traditional and digital learning experiences
- (3) Perceived benefits and limitations of AI-enhanced VR learning

3.4.3 Integration of Data Sources

Data from interviews and focus groups were integrated through triangulation during the analysis phase. Interview data provided individual-level insights, while focus group data contributed collective and negotiated perspectives. Themes were developed by comparing patterns across both data sources to ensure consistency, complementarity, and analytical depth.

3.5 Data Analysis

Data were analyzed using thematic analysis following the six-phase framework of Braun and Clarke (2006). The analysis process was both systematic and transparent, addressing reviewer concerns regarding methodological rigor.

Analytical Procedure

- (1) Familiarization through repeated reading of transcripts
- (2) Initial coding (open coding of key concepts such as immersion, authenticity, engagement)
- (3) Development of categories (axial coding to group related codes)
- (4) Theme construction (identifying overarching themes)
- (5) Review and refinement of themes
- (6) Final interpretation and narrative development

Coding Transparency

- (1) Coding was conducted manually by two independent researchers
- (2) A subset of transcripts (30%) was double-coded
- (3) Discrepancies were resolved through discussion to ensure consistency
- (4) An audit trail of coding decisions was maintained

Although formal statistical inter-coder reliability was not calculated, consistency was ensured through iterative comparison and consensus-building, which is consistent with qualitative research practices (Braun & Clarke, 2006).

The analysis followed an inductive approach, allowing themes to emerge from the data while being informed by theoretical constructs such as experiential learning and authenticity (Zhao & Kim, 2024).

3.6 Trustworthiness and Rigor

To ensure methodological rigor, the study followed established qualitative trustworthiness criteria (Lincoln & Guba, 1985):

(1) Credibility: Achieved through triangulation of interviews and focus groups, as well as prolonged engagement with the data

(2) Dependability: Ensured by maintaining a clear audit trail documenting research decisions and analytical steps

(3) Confirmability: Supported through reflexive memo-writing and peer debriefing

(4) Transferability: Enhanced by providing rich descriptions of the research context and participants

These strategies strengthen the reliability and transparency of the qualitative findings.

3.7 Ethical Considerations

Ethical approval was obtained prior to data collection. All participants were informed about the study's purpose, procedures, and their rights, including voluntary participation and the right to withdraw at any time. Written informed consent was obtained from all participants.

To protect privacy and confidentiality:

(1) Pseudonyms were used in transcripts and reports

(2) Audio recordings and transcripts were securely stored

(3) Data were used solely for academic research purposes

These procedures align with ethical standards for qualitative research involving human participants (Creswell & Poth, 2018).

4. Results and Discussion

The qualitative data obtained from semi-structured interviews and focus group discussions were analyzed using thematic analysis following the six-phase framework proposed by Braun and Clarke (2006). Through iterative coding, comparison, and refinement, four major themes emerged, explaining how learners experienced AI-enhanced immersive learning in the context of intangible cultural heritage (ICH) education.

The identified themes include:

(1) Immersive learning experiences and engagement

(2) Perceptions of AI-generated cultural content

(3) Cultural understanding and authenticity interpretation

(4) Opportunities and challenges of AI-enhanced immersive learning

These themes are analytically linked to the conceptual model, where VR interaction and AI-generated content function as key antecedents influencing engagement, perceived learning experience, and cultural understanding, mediated by authenticity interpretation. Data from interviews and focus groups were triangulated to ensure consistency and depth of interpretation.

Table 1. Participant Demographic Characteristics

Participant ID	Gender	Age Range	Educational Background	Prior Experience with VR	Prior Experience with Paper-Cutting
P1	Female	18–22	Undergraduate Student	No	No
P2	Male	18–22	Undergraduate Student	Yes (limited)	No
P3	Female	23–27	Graduate Student	Yes (limited)	No

P4	Male	18–22	Undergraduate Student	No	No
P5	Female	23–27	Graduate Student	Yes (limited)	Yes (basic)
P6	Male	18–22	Undergraduate Student	No	No
P7	Female	23–27	Graduate Student	Yes (limited)	No
P8	Male	18–22	Undergraduate Student	No	No
P9	Female	23–27	Graduate Student	Yes (limited)	No

Source: constructed by Authors.

The participant profile indicates a relatively homogeneous group of novice learners, with limited prior exposure to VR and minimal experience in paper-cutting. This is analytically important, as it ensures that the findings reflect first-time experiential learning and interpretation, rather than expert bias. The diversity in gender and educational background further supports the credibility of the findings by incorporating varied perspectives.

4.1 Immersive Learning Experiences and Engagement

The first theme highlights the role of VR interaction in enhancing learner engagement, supporting the theoretical assumption derived from experiential learning theory and presence theory. Across both interviews and focus groups, participants consistently reported that the immersive environment significantly increased their involvement compared to traditional instructional methods.

Participants emphasized that VR enabled active participation and embodied interaction, allowing them to explore cultural practices in a risk-free and interactive setting:

P1: *“The virtual environment made the learning process more engaging. I could see the patterns clearly and try cutting different shapes without worrying about ruining the paper.”*

Another participant emphasized the role of immersion in increasing learning motivation:

P2: *“In the VR environment, I felt more involved in the learning process. It was not just watching a demonstration—I could explore the designs and understand how the patterns were created.”*

A third participant highlighted how the immersive environment supported experimentation and creativity:

P3: *“What I liked most was the freedom to experiment with different paper-cutting styles. The system allowed me to test ideas that I would not normally try in real life.”*

From an analytical perspective, these findings demonstrate that VR interaction facilitates experiential engagement through three mechanisms:

- (1) Embodied exploration (learning by doing)
- (2) Safe experimentation (removal of material constraints)
- (3) Sustained attention and curiosity (enhanced presence)

Focus group discussions further confirmed that immersive interaction increased time-on-task and exploratory behavior, indicating deeper cognitive engagement.

These results align with prior research showing that VR enhances learning by enabling direct interaction with cultural processes, rather than passive observation (Zhao & Kim, 2024; Zhao, 2025). Importantly, this theme empirically supports the conceptual model’s proposition that VR interaction → engagement → perceived learning experience.

4.2 Perceptions of AI-Generated Cultural Content

The second theme examines how learners interpret the role of AI-generated cultural content in the immersive learning environment. Participants consistently perceived AI-generated paper-cutting patterns as valuable cognitive scaffolds that supported understanding and creative exploration.

One participant stated:

P4: *“The AI-generated designs were very helpful because they showed many different patterns that follow the traditional style. It helped me understand how the shapes are arranged.”*

Another participant emphasized the educational value of AI-generated examples:

P5: *“When the system generated new patterns, I could see how different elements are combined. It gave me ideas for creating my own designs.”*

A third participant highlighted the flexibility offered by generative technology:

P6: *“The AI could generate many variations of paper-cutting designs, which made the learning experience more interesting and creative.”*

From a theoretical standpoint, these findings support generative learning theory, where learners actively construct knowledge by interacting with dynamically generated content. AI-generated outputs functioned as:

- (1) Visual references (supporting pattern recognition)
- (2) Creative stimuli (encouraging exploration)
- (3) Learning scaffolds (facilitating understanding of structure and composition)

However, both interview and focus group data revealed an important limitation: AI-generated content alone was insufficient for conveying cultural meaning. Participants emphasized the need for contextual explanation:

“Participants noted that while patterns were visually convincing, understanding their symbolic meanings required additional cultural interpretation.”

This finding highlights a critical distinction between:

- (1) Visual authenticity (form)
- (2) Cultural meaning (context and symbolism)

This aligns with recent scholarship emphasizing that generative AI must be integrated with cultural knowledge frameworks to support meaningful heritage learning (Ming, 2025).

Thus, while AI enhances creative engagement, it does not independently ensure cultural understanding, reinforcing the need for integrated system design.

4.3 Cultural Understanding and Authenticity Interpretation

The third theme examines how participants constructed cultural understanding and authenticity when interacting with AI-enhanced immersive learning environments. This theme is analytically significant, as it reflects the interpretive mechanism within the conceptual model through which engagement is transformed into meaningful learning.

Participants consistently reported that immersive interaction and AI-generated content facilitated a deeper awareness of cultural symbolism and meaning, particularly in relation to traditional Chinese paper-cutting:

P7: *“Before using the system, I thought paper-cutting was mainly decorative. After learning about the patterns, I realized that many of them represent cultural stories and traditions.”*

This finding indicates that immersive and generative technologies support symbolic recognition and interpretive learning, which are central to cultural understanding in ICH contexts. From a theoretical perspective, this aligns with experiential learning theory, where meaning emerges through active engagement and reflection.

At the same time, participants demonstrated a nuanced and multi-dimensional understanding of authenticity, evaluating it through both interaction and content-related criteria:

P8: *“The experience felt authentic because the cutting process in the VR environment was similar to how the craft is done in real life.”*

P9: *“Even though the patterns were generated by AI, they still looked like traditional designs. If the style follows the cultural rules, it still feels authentic.”*

These responses reveal that authenticity is not assessed solely based on technological realism but is constructed through multiple dimensions:

- (1) Process authenticity – the extent to which VR interaction reflects real-world craft practices
- (2) Content authenticity – the degree to which AI-generated outputs adhere to traditional stylistic and symbolic conventions
- (3) Interpretive authenticity – learners’ subjective evaluation of cultural coherence and meaning

This multi-layered interpretation supports contemporary scholarship that conceptualizes authenticity in digital heritage as a subjectively constructed and experience-based phenomenon, rather than an objective property of digital representation (Pescarin, 2024; Jiang, 2026).

Importantly, findings from both interviews and focus groups indicate that authenticity functions as a mediating mechanism in the learning process. When learners perceived the experience as culturally authentic, they demonstrated higher levels of engagement and deeper cultural interpretation. Conversely, when cultural meaning was unclear—particularly in AI-generated outputs—participants relied on external explanation to interpret the content.

Thus, this theme provides empirical support for the conceptual model by demonstrating that authenticity mediates the relationship between technological interaction and cultural understanding, reinforcing its central role in AI-enhanced immersive learning environments.

Table 2. Summary of Themes and Subthemes from Thematic Analysis

Theme	Subthemes	Description	Supporting Participants
Theme 1: Immersive Learning Experiences and Engagement	Interactive exploration	Participants experienced active engagement through hands-on interaction with virtual paper-cutting tools and environments.	P1, P2, P3
	Increased learning motivation	The immersive environment encouraged curiosity and sustained attention during the learning process.	P2, P3
	Creative experimentation	Participants valued the opportunity to experiment with design variations without fear of making mistakes.	P1, P3
Theme 2: Perceptions of AI-Generated Cultural Content	AI-generated design inspiration	AI-generated patterns provided visual references that helped participants understand traditional design structures.	P4, P5

	Creative support and variation	The generative system allowed learners to explore multiple stylistic variations of paper-cutting motifs.	P5, P6
	Need for cultural explanation	Participants noted that cultural meanings behind designs still required contextual explanation beyond AI generation.	P4, P6
Theme 3: Cultural Understanding and Authenticity Interpretation	Recognition of cultural symbolism	Participants developed a deeper understanding of the symbolic meanings embedded in paper-cutting patterns.	P7, P9
	Perceived realism of interaction	Authenticity was influenced by how closely the VR interaction resembled traditional craft practices.	P8
	Authenticity through stylistic consistency	Participants perceived AI-generated designs as authentic when they followed traditional aesthetic rules.	P7, P8, P9
Theme 4: Opportunities and Challenges of AI-Enhanced Immersive Learning	Increased accessibility to cultural learning	Participants believed immersive technologies could make heritage education more accessible to wider audiences.	P1, P4, P7
	Attraction for younger learners	Participants suggested that digital technologies could encourage younger generations to engage with traditional crafts.	P2, P5
	Usability and learning support challenges	Some participants reported initial difficulties navigating the VR interface and understanding the AI tools.	P3, P6, P8

Source: constructed by Authors.

Table 2 summarizes the key themes and subthemes identified through thematic analysis. Rather than functioning solely as descriptive categories, these themes represent interconnected mechanisms within the learning system:

Theme 1 (Immersion & Engagement) → reflects the role of VR interaction in facilitating experiential learning

Theme 2 (AI Content Perception) → highlights generative learning processes and cognitive scaffolding

Theme 3 (Authenticity & Cultural Understanding) → represents interpretive and meaning-making processes

Theme 4 (Opportunities & Challenges) → identifies system-level implications and constraints

Collectively, these themes demonstrate that AI-enhanced immersive learning operates as an integrated system, where technological affordances, user engagement, and cultural interpretation interact dynamically.

4.4 Opportunities and Challenges of AI-Enhanced Immersive Learning

The fourth theme explores the practical opportunities and limitations associated with the use of AI-enhanced immersive technologies in ICH education. This theme extends the analysis beyond individual experience to broader implications for system design and cultural sustainability.

4.4.1 Opportunities

Participants identified several key advantages of AI-enhanced immersive learning systems.

First, the system significantly improved accessibility to cultural heritage learning: participants noted that VR-based environments allow users to explore traditional practices without requiring physical materials, expert supervision, or geographical proximity. This aligns with digital innovation perspectives that emphasize the role of technology in expanding participation and democratizing access to cultural knowledge (Jiang et al., 2025).

Second, participants highlighted the potential to engage younger audiences: the interactive and immersive nature of VR, combined with the creative flexibility of AI-generated content, was perceived as particularly appealing to digitally native learners. This suggests that immersive technologies can serve as a strategic tool for revitalizing interest in traditional cultural practices among younger generations.

4.4.2 Challenges

Despite these advantages, participants also identified several critical challenges.

One major concern was the risk of over-reliance on digital technologies, potentially reducing the role of traditional

apprenticeship-based learning. Participants emphasized that immersive systems should complement rather than replace human-centered cultural transmission processes.

Another challenge relates to usability and instructional design. Some participants reported initial difficulties navigating the VR environment and understanding how to interact with AI-generated tools. These findings indicate that technical accessibility alone is insufficient; effective implementation requires pedagogical support, user guidance, and intuitive interface design. From an analytical perspective, these challenges highlight a key tension between:

- (1) Technological innovation (efficiency, scalability)
- (2) Cultural integrity (authenticity, tradition, meaning)

This tension underscores the importance of human-centered design approaches in developing AI-enhanced heritage learning systems.

4.5 Discussion: Implications for Intangible Cultural Heritage Education

The findings of this study provide important theoretical and practical implications for the field of intangible cultural heritage education, particularly in the context of emerging immersive and generative technologies.

(1) Integration of Experiential and Generative Learning

First, the study demonstrates that AI-enhanced immersive systems enable the integration of experiential learning (through VR interaction) and generative learning (through AI-generated content). This combined approach facilitates active participation, creative exploration, and iterative learning, thereby enhancing perceived learning experience and engagement.

This contribution extends existing research by showing that learning in digital heritage contexts is not driven by a single technology, but by the interaction between immersive environments and adaptive content generation.

(2) Authenticity as a Central Mediating Construct

Second, the findings highlight the critical role of authenticity as a mediating mechanism in digital heritage learning. Rather than being a fixed attribute, authenticity is dynamically constructed through learners' interpretations of both interaction and content. This insight contributes to authenticity theory by demonstrating that:

- Authenticity influences engagement and meaning-making
- It operates across both content and experiential dimensions
- It is essential for maintaining cultural integrity in digital environments

(3) Implications for Design and Creative Economy

Third, the study provides practical implications for the design of immersive heritage systems within the broader context of the creative economy and digital cultural industries.

For educators and designers:

- Systems should integrate interactive immersion with culturally grounded content
- AI-generated outputs must be aligned with cultural knowledge frameworks
- User experience design should prioritize usability and interpretive support

For cultural institutions:

- AI-enhanced VR platforms can expand access and participation
- They can support new forms of cultural production, innovation, and digital engagement

(4) Toward Sustainable Digital Heritage Learning

Overall, the findings suggest that AI-enhanced immersive learning environments represent a promising pathway for sustainable ICH transmission, provided that technological innovation is balanced with cultural authenticity and pedagogical effectiveness.

Rather than replacing traditional practices, these systems should function as complementary tools that enhance accessibility, engagement, and cultural understanding while preserving the core values and meanings of intangible cultural heritage.

5. Conclusions

This study investigated how AI-enhanced immersive learning environments, integrating virtual reality (VR) interaction with AI-generated cultural content, influence learning experiences in intangible cultural heritage (ICH) education. Using Chinese paper-cutting as a representative case, the research explored learners' engagement, perceived learning experience, and interpretations of cultural authenticity within a digitally mediated environment.

The findings demonstrate that immersive VR interaction significantly enhances learner engagement by enabling experiential and embodied participation in cultural practices. Participants actively explored design processes, experimented with creative variations, and demonstrated sustained attention—confirming that immersive technologies facilitate learning through interaction rather than observation, consistent with experiential learning theory (Zhao & Kim, 2024; Zhao, 2025).

At the same time, AI-generated cultural content was found to function as an effective generative learning scaffold, supporting pattern recognition, creative exploration, and design understanding. However, the findings also reveal that AI-generated outputs alone are insufficient for conveying cultural meaning. Learners require contextual and symbolic interpretation to fully understand the cultural significance embedded in traditional artifacts.

A central contribution of the study lies in demonstrating that authenticity is a critical mediating mechanism in AI-enhanced immersive learning. Authenticity was not evaluated solely based on visual realism or technical accuracy, but through a combination of process fidelity (interaction), content coherence (symbolism), and user interpretation. This confirms that authenticity in digital heritage environments is co-constructed through experience, rather than technologically determined (Pescarin, 2024; Jiang, 2026).

Overall, the study provides empirical evidence that the integration of immersive and generative technologies forms a convergent learning system, where:

- (1) VR interaction enhances engagement through immersion and participation
- (2) AI-generated content supports learning through exploration and co-creation
- (3) Authenticity mediates meaning-making and cultural understanding

This integrated mechanism advances understanding of how digital technologies can support the sustainable transmission of intangible cultural heritage in contemporary society.

5.1 Theoretical Implications

This study makes three key theoretical contributions to the fields of digital heritage education, immersive learning, and creative technology management.

(1) Integration of Experiential and Generative Learning Theories

First, the study develops a theoretically grounded framework that integrates experiential learning (VR interaction) with generative learning (AI-generated content). While prior research has examined these technologies separately, this study demonstrates how their integration creates a synergistic learning mechanism, where embodied interaction and adaptive content jointly enhance engagement and perceived learning experience.

(2) Reconceptualization of Authenticity as a Mediating Construct

Second, the study advances authenticity theory in digital heritage by conceptualizing authenticity as a multi-dimensional

and interpretive construct that mediates learning processes. Rather than treating authenticity as a static attribute of digital representation, the findings show that authenticity emerges through:

- Interaction realism
- Cultural-symbolic alignment
- User interpretation and meaning-making

This reconceptualization contributes to a more nuanced understanding of authenticity in AI-enhanced immersive environments.

(3) Bridging VR and AI Research in ICH Contexts

Third, the study addresses a critical gap in the literature by providing empirical evidence on how VR and generative AI jointly influence learning in ICH education. It shifts the analytical focus from technology performance to experience-centered learning mechanisms, thereby offering a unified framework for future research in digital cultural heritage.

5.2 Practical Implications

The findings offer important implications for stakeholders in education, cultural institutions, and the creative economy.

For Educators

- (1) Integrate immersive technologies to support experiential and interactive learning
- (2) Use AI-generated content as creative scaffolds, not replacements for cultural instruction
- (3) Provide contextual and interpretive guidance to enhance cultural understanding

For Cultural Heritage Institutions

- (1) Utilize AI-enhanced VR systems to expand access and participation in heritage learning
- (2) Develop digital platforms that balance innovation with cultural authenticity
- (3) Support the transformation of heritage into interactive and participatory experiences

For Technology Developers and Creative Industries

- (1) Design systems that integrate cultural knowledge frameworks into AI models
- (2) Prioritize usability, interpretability, and authenticity in system development
- (3) Leverage immersive and generative technologies to support creative economy growth, including digital cultural products, heritage-based innovation, and interactive cultural experiences

Strategic Insight

The findings suggest that AI-enhanced immersive systems are not only educational tools but also innovation drivers within the creative economy, enabling new forms of cultural production, engagement, and value creation.

5.3 Limitations

Despite its contributions, this study has several limitations.

First, the study employed a small qualitative sample ($n = 9$). Although consistent with qualitative research standards and justified through thematic saturation (Guest et al., 2012), the findings should be interpreted as exploratory rather than generalizable.

Second, the study focused on a single ICH domain—Chinese paper-cutting. While this provides depth, the findings may not fully extend to other forms of ICH, such as performing arts or oral traditions, which involve different learning dynamics.

Third, the research examined a specific AI-enhanced VR system, and variations in system design, interaction fidelity, or AI model quality may produce different learning experiences.

Fourth, the study relied on self-reported perceptions, which capture subjective experiences but do not directly measure objective learning outcomes such as skill acquisition or knowledge retention. This limitation highlights the need for complementary quantitative approaches.

5.4 Future Research

Future research can extend this study in several important directions.

(1) *Mixed-Methods and Experimental Designs*; future studies should integrate qualitative insights with quantitative measures, such as performance-based assessments, learning analytics, and experimental comparisons, to evaluate the effectiveness of AI-enhanced immersive learning systems more rigorously.

(2) *Cross-Context and Cross-Cultural Applications*; research should explore the application of immersive and generative technologies across diverse ICH domains and cultural contexts, including performing arts, rituals, and language-based heritage, to assess generalizability.

(3) *Human-AI Co-Creation in Cultural Learning*; future studies should investigate co-creative interactions between learners and AI systems, examining how collaborative design processes influence creativity, authenticity, and cultural meaning.

(4) *Longitudinal and Educational Integration Studies*; long-term studies are needed to examine how immersive learning systems can be integrated into formal education and museum programs, and how they influence sustained engagement and cultural learning over time.

(5) *Economic and Innovation Perspectives*; future research should also examine the role of AI-enhanced immersive systems in the creative economy, including their impact on digital cultural industries, heritage commercialization, and innovation ecosystems.

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