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Modeling digital visualization for vernacular heritage: A case study of Chengzi Yi Village

Yinchuan Yang [1], Jing Ding [2, *]

[1]Faculty of Art and Communication, Kunming University of Science and Technology, Kunming, China
[2]School of Art, Kunming City University, Kunming, China

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ABSTRACT

This study develops and validates a Perception-Engagement-Sustainability (PES) model to assess cultural understanding in digital immersion at vernacular heritage sites. Using Chengzi Yi Village in Yunnan, China as a case study, the model integrates cultural memory, sense of place theory, and system success theory to examine symbolic perception, emotional engagement, and intergenerational transmission. A sequential mixed-methods approach, combining ethnographic observation, expert interviews, and a user survey (n = 270), shows that cultural value perception is strongly associated with user satisfaction ($\beta = 0.65$, $p < 0.001$). Qualitative results further indicate that symbolic fidelity and spatial immersion foster emotional attachment. Unlike earlier models that emphasize usability or aesthetics, the PES model provides a culture-based framework that supports both meaningful interpretation and the long-term sustainability of rural heritage sites. While geographically limited, the study offers a replicable and empirically grounded approach for participatory and community-centered digital heritage design.

1. Introduction

With the acceleration of modernization, changes in population structure, and the intensification of cultural homogenization trends, the urgency of protecting traditional architecture in rural ethnic minority communities has become increasingly evident. These traditional buildings are not only constructed using local materials and techniques but also carry profound cultural memories, ecological wisdom, and intangible cultural heritage value (Yang et al., 2024). However, these cultural heritage sites are currently facing severe threats. The modernization of infrastructure, urban expansion, and tourism-oriented design often prioritize efficiency over the cultural significance of traditional buildings. In this process, protective measures may become symbolic, leading to a disconnect between preservation efforts and daily life practices (González Martínez, 2022). When these spaces no longer meet the functional needs of daily life, the effectiveness of preservation efforts is called into question.

The lack of community participation only exacerbates the situation. The protection project in Ghoufi Valley, Algeria, is a great example of how to fail due to top-down approaches without taking the voice and needs of local people into account. This example illustrates that in rural planning, respect for cultural identity and participatory protection models are necessary (Rajkovic et al., 2022). Research from Stara Planina and other areas indicates that traditional design can promote sustainable architectural systems that are culturally relevant. The transfer of traditional knowledge is being impeded by youth out-migration, knowledge retirements in generation terms, and the lack of engagement of youth in shaping policy, which detracts from the vibrancy of traditional systems (Hu et al., 2023). There needs to be action, because significant amounts of living heritage may never return without it. Underscore that effective heritage for living but immobile conservation must be grassroots-based, and sustainable heritage conservation must underpin community empowerment. To maintain and develop the rich heritage of rural architecture, it would be beneficial for local communities to consider broader development agendas that prioritize the conservation of heritage.

* Corresponding Author.
Email Address: dingjing@kmcc.edu.cn (J. Ding)
https://doi.org/10.21833/ijaas.2025.11.018
Corresponding author's ORCID profile:
https://orcid.org/0009-0001-8845-2946

To respond to these issues, this study proposes a digitally mediated preservation approach grounded in immersive visualization and community-centered evaluation. The research addresses four main objectives:

1. To examine how immersive digital visualization influences users' perceptions of symbolic meaning and spatial cultural value.
2. To analyze the statistical relationship between perceived cultural resonance and users' satisfaction with the digital platform.
3. To test the proposed theoretical model using both quantitative data and qualitative insights.
4. To establish a transferable framework for applying digital tools to rural heritage preservation within national and international policy contexts.

This study makes three main contributions to the field of digital heritage and cultural visualization:

1. Theoretical Advancement – It introduces a conceptual model that connects digital visualization strategies with users' cognitive and emotional engagement in heritage environments.
2. Empirical Validation – It provides both statistical and thematic evidence demonstrating how digital platforms mediate cultural meaning and shape user experiences of heritage.
3. Applied Framework – It offers a replicable model for integrating immersive digital tools into community-based preservation strategies, contributing to the sustainable transmission of rural vernacular heritage.

2. Literature review

2.1. Digital heritage frameworks and theoretical foundations

Digital heritage has shifted from static documentation to interactive, participatory systems that emphasize cultural identity and collective memory (Dipasquale et al., 2024). This evolution reflects broader changes in museology and digital culture, underscoring user agency, narrative immersion, and emotional engagement.

Heritage is now seen as a dynamic social process rather than a static archive. Frameworks like social museography and participatory heritage highlight co-creation and community input, especially for sustaining knowledge among marginalized groups (Liew et al., 2022). Yet, few models examine how such frameworks adapt across varied sociocultural settings.

Vernacular architecture plays a key role as both a material artifact and a cultural knowledge system. Projects like VerSus+ show the value of integrating local knowledge into preservation (Bolognesi and Fiorillo, 2023), but scalable tools to assess symbolic depth and relevance remain limited.

Immersive technologies—particularly XR—can foster empathy and cultural connection, though theoretical links to memory, identity, and long-term preservation remain underexplored.

Overall, despite a turn toward participatory and affective approaches, key gaps persist: limited focus on rural contexts, weak metrics for symbolic fidelity, and poor alignment between immersive experiences and cultural sustainability. This study addresses these challenges through a more integrated, community-sensitive evaluation model.

2.2. Immersive visualization and cultural cognition

Immersive technologies—such as 3D modeling, VR, and panoramic reconstruction—are reshaping cultural heritage from passive artifacts into symbolic, affective, and spatial experiences. These tools embed sensory and symbolic cues that support embodied interaction with cultural memory. While emotional benefits are well documented, their cognitive impacts—like long-term retention and identity formation—remain insufficiently explored.

Studies suggest immersive environments enhance empathy and autobiographical memory, particularly when linked to ancestral practices (Vinodan and Meera, 2024). Yet, the pathways connecting immersion to cultural cognition lack theoretical clarity. Although the affective potential of XR is widely recognized, few works assess whether it fosters sustained engagement or preservation behavior.

Another issue is limited generalizability. Most successful cases occur in urban or well-funded settings, raising doubts about effectiveness in rural or vernacular contexts—where cultural continuity is often most fragile. Visual reconstructions risk symbolic inaccuracy or cultural detachment if lacking community input, as seen in top-down simulations (Amelio and Zarri, 2024).

Thus, while immersive visualization shows strong promise for cultural cognition, it needs firmer theoretical grounding and context-sensitive evaluation. This study addresses that gap by integrating immersive methods with participatory validation in a rural heritage setting.

2.3. User engagement and interface satisfaction in digital heritage

User engagement in digital heritage goes beyond usability, encompassing interface clarity, emotional impact, and symbolic relevance. Narrative structure, visual design, and cultural authenticity significantly influence how users interpret, recall, and emotionally connect with heritage content (Banfi and Oreni, 2025).

Interfaces are no longer seen as neutral tools but as agents of meaning. Structural equation modeling (SEM) shows that emotional tone, narrative coherence, and perceived authenticity drive satisfaction and symbolic understanding (Srdanović et al., 2025). However, most UX frameworks remain generalized, with limited attention to vernacular or

marginalized cultural contexts. Narrative design is especially effective in fostering engagement. Gamified and VR platforms with adaptive storytelling promote empathy and cultural awareness, particularly for underrepresented groups. Yet, such emotional responses rarely translate into long-term actions like cultural advocacy or preservation.

Embodied interaction and emotional responsiveness can trigger memory and identity resonance, though few models assess their role in sustaining cultural meaning across varied audiences.

This study addresses these gaps by conceptualizing engagement as part of a broader cycle tied to perception and sustainability. This perspective forms the foundation of the PES model, which serves as a context-aware framework aimed at assessing digital interfaces and guiding the design of heritage systems that prioritize meaningful and engaging user experiences.

2.4. Participatory heritage and community-driven validation

Participatory heritage theory argues that individuals need to contribute actively to creating instead of being represented within online records of cultural identification. Strategies such as co-archiving, symbolic annotation, and digital storytelling help with representational legitimacy alongside trust-building.

There is empirical support for this view. Bala et al. (2024) stated that co-published migrant tales functioned as "boundary objects" between personal story and common discourse. Rural Heritage Hubs kept participating in digital-physical co-creation spaces. In Scotland, film archives kept intergenerational storytelling, while co-design with excluded groups kept story ownership and countered symbolic exclusion (Loignon et al., 2021).

Despite these advances, most models remain tacit about scaling and sustaining participation. Ethical concerns, digital inequity, and knowledge gaps often undermine wider use.

This study chases these aims by including community validation as a core element of the PES approach. Situating localized voice and symbolic thinking enables cultural authenticity and emotional connection conducive to broader interests in democratizing digital heritage and embracing knowledge pluralism.

2.5. Theoretical gaps and model development rationale

While digital heritage research has advanced, several key gaps remain. First, few frameworks link immersive tools like 3D modeling and panoramic simulations with users' cognitive, emotional, or behavioral outcomes. Most focus on visual fidelity and usability, neglecting how symbolic coherence and narrative immersion influence memory, empathy, and preservation intent.

Second, studies on Southwest China's ethnic and rural architecture are limited. Although Zhang et al. (2022, 2025) affirmed that culturally rooted design supports identity and sustainability, few adaptable models exist for diverse rural settings.

Third, while symbolic fidelity and narrative depth are known to foster emotional engagement, their link to user satisfaction is underexplored.

Fourth, immersive platforms' role in national strategies like China's Digital Countryside is undertheorized. Though some local efforts exist, standardized evaluation tools remain scarce. Dipasquale et al. (2024) emphasized that integrating vernacular knowledge is vital for cultural resilience.

To address these gaps, this study proposes the PES model—linking perception, engagement, and sustainability. Community narrative validation elevates symbolic legitimacy and emotional impact, ultimately providing a socially scalable way to meaningfully preserve vernacular heritage.

2.6. Theoretical framework and model foundations

The PES model—Perception, Engagement and Sustainability— is presented in this research as a new model to understand how immersive digital heritage platforms transmit symbolic meaning, emotional resonance, and a sense of intergenerational continuity. PES is distinct from previous models that address usability or narrative immersion (Pujol and Champion, 2012) by offering a combined approach that embraces cultural legitimacy that is founded on community-validated symbolic continuity. As shown in Fig. 1, Perception (P) includes how users derive meaning from symbolic and spatial characteristics; Engagement (E) denotes the depth of emotional and cognitive experience; Sustainability (S) means when intergenerational continuity takes precedent over platform sustainability. A new contribution is Community Narrative Validation, which uses participatory storytelling and co-authored participatory annotation to facilitate a condition for epistemic inclusion and symbolic fidelity in the mediated representation of heritage.

In the context of the PES model, perception drives cultural cognition, which leads to engagement that can sensitize us to sustainability. Community legitimization bolsters this cycle and guides us away from interpretive disassociation while also enhancing local ownership.

To demonstrate the distinctiveness of the PES model, we conducted a systematic comparison with five representative SCI-indexed frameworks in digital heritage visualization. As shown in Table 1, while other models excel in technological interactivity or data-driven modeling, they often lack mechanisms for symbolic validation, co-creation, or sustainable community engagement. The PES model bridges this gap through a triadic logic loop—where perception leads to engagement, and engagement cultivates sustainability—grounded in participatory

heritage practices. thereby advancing both theoretical integration and empirical applicability.

As shown in Table 1, existing SCI-indexed frameworks such as those proposed by Amelio and Zarri (2024) and Jiang et al. (2025) focused predominantly on technological immersion and visualization fidelity, with little emphasis on community-validated symbolism or long-term sustainability. In contrast, the PES model integrates immersive interfaces with participatory cultural validation and sustainable heritage continuity, offering a unique closed-loop architecture that significantly advances interpretive depth and contextual sensitivity in vernacular heritage preservation. As shown in Table 2, these instances demonstrate the synergy of the PES model dimensions: Digital Liangzhu illustrates perception via the tonality of knowledge in the academy; Digital Dunhuang illustrates engagement via immersive and the prioritization of curation; and the Jiangnan AR Tour illustrates engagement via sustained interaction through localizing narrative design.

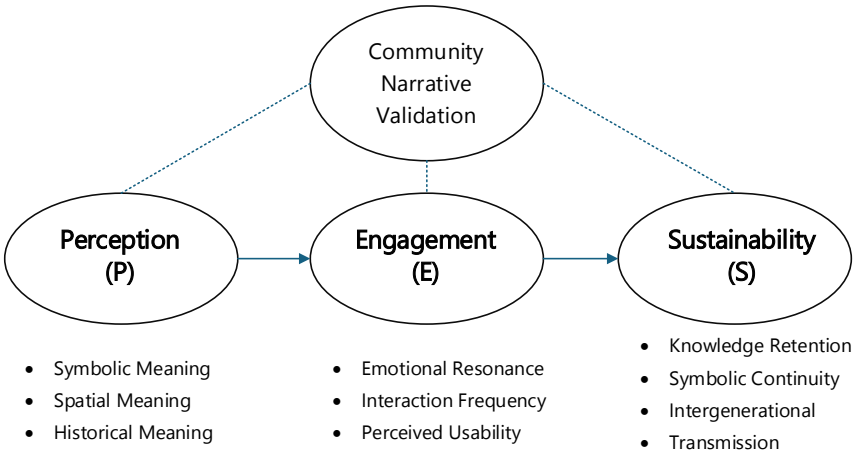

Fig. 1: PES visual communication model for digital cultural heritage

Table 1: Comparative features of the PES model vs. existing SCI-indexed models

Dimension/feature	PES model (this study)	Amelio and Zarri (2024)	Aljaafreh et al. (2023)	Ferreira et al. (2023)	Banfi and Oreni (2025)	Jiang et al. (2025)
Community participation	✓	X	✓	✓	X	X
Cultural legitimacy/symbolic validation	✓	X	✓	✓	X	X
Symbolic continuity	✓	X	X	✓	X	X
Sustainability integration	✓	X	✓	✓	X	X
Immersive/XR visualization	✓	✓	X	✓	✓	✓
Stakeholder co-creation method	✓	X	✓	✓	X	X
Closed-loop triadic logic	✓	X	X	X	X	X
Mixed-method empirical validation	✓	X	X	✓	X	✓

Table 2: Sample composition by group and data type

Case	Location	Technology	Cultural focus	Key innovation
Digital Liangzhu	Zhejiang	Virtual reconstruction + Knowledge graph	Ancient archaeological ruins	Emphasizes academic restoration and educational integration
Digital Dunhuang	Gansu	Digital murals + VR navigation	Buddhist grotto heritage	Build global sharing platforms to enhance cultural reach
Jiangnan AR tour	Jiangsu	Augmented reality + Spatial narrative	Vernacular water town culture	Enhances visitor immersion through real-time interaction

They collectively show how perception, participation, and sustainability work in practical heritage design. Inclusion of community story validation augments cultural relevance and local credibility. PES hence provides a scalable, context-aware digital heritage evaluation framework that is particularly appropriate for underserved vernacular contexts.

3. Methodology

This study adopts a sequential mixed-methods approach, integrating qualitative and quantitative techniques to explore how immersive digital visualization supports the preservation of vernacular architecture and intangible heritage in Southwest China. Grounded in participatory heritage theory and user-centered design, the methodology links spatial documentation, cultural interpretation, and experiential validation.

The procedure starts with digital documentation of ethnic architecture through photogrammetry and 3D modeling, which is confirmed by specialists as well as local skilled people. Merging low-cost photogrammetry with Heritage Building Information Modeling (H-BIM) allows the workflow to achieve material accuracy with structured representation (Murphy et al., 2022).

The cultural connotations present in these buildings are explored using semi-structured interviews, oral histories, and storytelling workshops, consistent with participatory digitization approaches centering on community involvement and locally led authentication (Aljaafreh et al., 2023).

Next, we develop an experimental digital platform based on both panoramic and AR-based 3D reconstructions. Questionnaires and observation are used to assess user interaction, emotional engagement, and understanding of the platform's symbolic value in the community. As this research can evaluate intergenerational transmission via follow-up interviews and symbolic fidelity tests evaluating the platform's effects on memory and cultural knowledge, we are helping to compare the impacts. Cultural validation and field trials will ensure cultural and technological integrity and applicability to China's Digital Countryside Strategy, leading to a transportable model of research for the same while looking at vernacular heritage sites.

3.1. Research design

This study follows an exploratory sequential mixed-methods design. It investigates how immersive visualization affects heritage interpretation and preservation. The design merges ethnographic methods, architectural analysis, and user experience tools. This allows the study to balance cultural depth with empirical rigor. In the qualitative phase, we gathered data through field visits, photography, and semi-structured interviews. Participants included artisans, village elders, and cultural experts. These insights guided the development of a digital platform that features 3D reconstructions and panoramic simulations. The co-creation process invited broader community involvement. Participatory immersion is especially effective for expressing intangible cultural values (McShane et al., 2021).

From these findings, we developed a quantitative questionnaire. It focused on four key areas: cultural perception, emotional engagement, symbolic accuracy, and usability. This two-phase design allowed us to triangulate the data and increase the reliability of our interpretations. Kara (2024) emphasized that combining storytelling with formal evaluation deepens cultural understanding and symbolic memory on digital heritage platforms. Vinodan and Meera (2024) supported this method. They argue that exploratory designs help include community-defined indicators, which strengthen heritage conservation and inform better policy.

3.2. Research site and sample

The field research took place in a vernacular ethnic town in Southwest China, famous for its distinct rammed earth building style, spatial arrangement of ancestors, as well as comprehensive intangible cultural heritage practices. It was selected due to its high cultural value as well as not being covered by major national digital heritage initiatives.

A stratified and purposive sampling strategy was adopted, as with traditional methods in participatory heritage studies, as well as user experience (UX) evaluation. As Liang et al. (2022) revealed, digital participatory methods have been effective in capturing people's sentiment as well as local cultural insight in Chinese heritage sites (Li et al., 2024a; 2024b; 2024c).

The participants were divided into three:

- Tourist Group (n = 270): Both international visitors and domestic visitors who utilized the digital medium on-site or remotely were covered under this group. Stratified sampling was adopted to obtain a diverse group both in terms of age, sex, as well as education, as per UX profiling methods used in earlier heritage interaction studies.
- Local Cultural Stakeholders (n = 5): They were selected with purposive sampling, including elders, craftspeople, and ritual specialists who practice heritage transmission. This aligns with inclusive data modeling for digital heritage platforms with a focus on stakeholders.
- Expert Group (n = 5): Made up of academic specialists and professionals with digital heritage or architectural conservation backgrounds who all possessed fieldwork related to community-based heritage practice in China.

Although the number of stakeholders and experts involved was small, the sample size is consistent with other qualitative heritage studies. Such studies often prioritize depth and relational insight over statistical generalization (Waterton and Smith, 2010).

Each interview lasted between 60 and 120 minutes. Some participants were involved in multiple phases of the project. Their roles included content validation and cultural annotation. The continuous engagement aided us in reaching thematic saturation as well as guaranteeing active involvement as opposed to superficial reporting.

Theory-driven and locally contextualized, this research design merges ethnographic depth with quantitative precision. Such a context provides an appropriate setting for an evaluation of PES model implementation in virtual environments for digital cultural heritage.

3.3. Instruments and data collection

The researcher for both qualitative as well as quantitative dimensions of user experience, three chief tools in this research, each conceptually guided by conventional methods corresponding to cultural interpretation, symbolic evaluation, as well as digital engagement.

The first tool consisted of a 5-point Likert-scale 20-item standardized questionnaire that was to gauge two core constructs: cultural perception and platform satisfaction. Cultural Perception Scale (20 items) gauged users' perception of symbolism, spatial intelligence, emotion, as well as perceived authenticity. The Platform Satisfaction Scale (18 items) gauged usability, interactivity, narrative coherence, as well as emotion. Both tools were constructed with reference to current literature on digital storytelling as well as user research on

experience (Vert et al., 2021). The second method was semi-structured interviews with expert respondents as well as cultural stakeholders. Interviews explored the symbolic significance of vernacular constructions, attitudes towards digital reconstructions, as well as perceptions regarding coherence as well as authenticity of the platform's narrative. This approach borrows templates from participatory heritage research as well as symbolic evaluation (Bala et al., 2024).

The third tool was a field observation carried out over four separate site visits. Researchers observed users' activity in real time, including time spent on specific tasks, vocal response, movement, and signs of emotive engagement. This fieldwork protocol followed user-focused evaluation methods common in experiments of immersive heritage platforms (Petousi et al., 2022).

Together, they provided a comprehensive insight into users' cognitive, emotional, and social engagement with the digital cultural site. Each of the instruments was pilot-tested for reliability, construct validity, as well as cultural sensitivity prior to its full implementation.

3.4. Instrument validity

To ensure the reliability and validity of the research instruments, a multi-step validation process was implemented. This process included expert evaluation, pilot testing, and internal consistency analysis, each grounded in recognized procedures from digital heritage and cultural perception research.

Content validity was assessed using the Index of Item-Objective Congruence (IOC). Three experts specializing in digital heritage and psychometric evaluation reviewed all questionnaire items. Both the Cultural Perception Scale (20 items) and the Platform Satisfaction Scale (18 items) achieved IOC scores exceeding 0.67, indicating a strong alignment between the items and their intended constructs. This procedure aligns with psychometric standards for validating tools used in assistive and cultural technology studies (Aledda et al., 2024).

A pilot study involving 30 participants (n = 30), including tourists, cultural experts, and community members, was conducted to refine the clarity, sequence, and cultural appropriateness of the survey items. This step followed best practices for adapting instruments in cross-cultural contexts (Facchinetti et al., 2021).

Internal consistency was evaluated using Cronbach's alpha. The Cultural Perception Scale achieved an alpha coefficient of 0.89, while the Platform Satisfaction Scale scored 0.91. Both values indicate high levels of reliability and are consistent with reliability metrics reported in immersive user experience studies (Santana-Berlanga et al., 2024; Risco et al., 2020).

Collectively, these validation measures confirm the robustness of the instruments and their suitability for assessing cultural perception and user satisfaction within immersive digital heritage environments.

3.5. Data analysis techniques and sampling strategy

The study adopted a mixed-methods analytical framework to investigate user interaction with the immersive digital heritage platform. This approach was designed to capture both quantifiable usage patterns and deeper, interpretive insights into symbolic meaning and cultural engagement.

Quantitative analysis involved descriptive statistics, Pearson correlation, and linear regression to examine the relationship between users' perceived cultural value and their overall satisfaction with the platform. These techniques are widely recognized in UX research within the heritage field for evaluating emotional engagement and cognitive outcomes in immersive digital environments (Elliott, 2022). Prior to regression analysis, normality, linearity, and homoscedasticity assumptions were tested and satisfied. No multicollinearity was detected (VIF < 2.0).

The qualitative data, involving interview transcripts as well as field observations, were analyzed with NVivo 14.0. As shown in Fig. 2, thematic coding was done with both open as well as axial coding methodologies so that repeating patterns related to spatial memory, perceptions of authenticity, as well as emotional response could be determined. NVivo's multimedia functionality, along with its highly structured environment for coding, allows consistency as well as depth in ethnographic analysis. To improve coding reliability, intercoder agreement between two separate coders was assessed with Cohen's Kappa (κ = 0.83), reporting substantial agreement (Elliott, 2022).

Through a combination of statistical modeling with thematic interpretation, analysis provides a triangulated perspective that includes behavioral, perceptual, and emotional aspects. This combined approach encompasses both methodological sophistication and cultural sensitivity—essential demands for assessing digital heritage systems that seek to reach scholarly standards while being locally relevant.

3.5.1. Sampling and statistical power

Between January 2024 and March 2025, the research made use of purposive and stratified sampling in a vernacular village in Southwest China to obtain both cultural relevance and demographic diversity. As shown in Table 3, the end sample consisted of 280 respondents who fell into the following groups:

- Tourists (n = 270): Chosen via stratified sampling to achieve variation in age, schooling level, as well as geographic origin.
- Cultural Stakeholders (n = 5): Consists of village elders and craftspeople with an extensive

understanding of cultural traditions, enrolled through purposive sampling.

- Experts (n = 5): Identified through snowball sampling based on their published research and direct involvement in heritage conservation projects. While small, this sample aligns with qualitative standards prioritizing expertise depth and iterative engagement in rural cultural research.

The total sample size was determined using standard population proportion formulas, ensuring adequate statistical power for subsequent regression analysis.

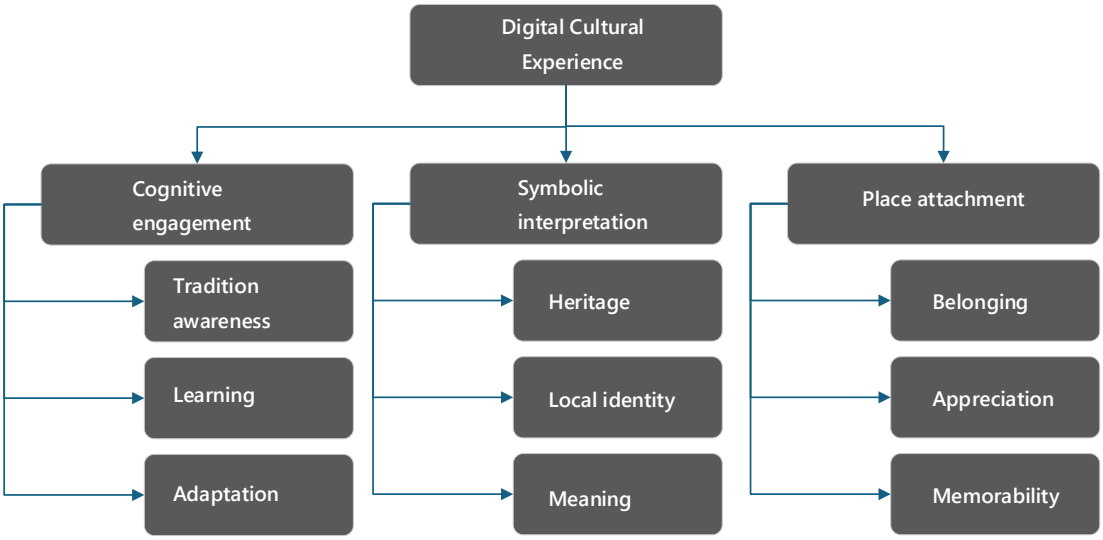

Fig. 2: NVivo coding of digital cultural experience

The sample size for the tourist group was calculated using the standard formula for estimating population proportions:

$$n = \frac{Z^2 \times p \times (1 - p)}{e^2}$$

where, Z = 1.96 (corresponding to a 95% confidence level), p = 0.5 (assumed maximum variability), and e = 0.06 (margin of error). Based on these parameters, the minimum required sample size was approximately 267, confirming that the final sample of 270 participants was sufficient to support statistically reliable analysis.

Furthermore, a statistical power analysis was conducted using G*Power 3.1 to validate the adequacy of the tourist sample for regression analysis. Assuming a medium effect size (R^2 = 0.41), a significance level of α = 0.05, and a desired power of 0.95, the minimum required sample size was determined to be 66.

The actual sample size of 270 thus ensures high statistical power and exceeds the threshold for inferential modeling. As shown in Table 4, the questionnaire consisted of two principal constructs—Perception of Cultural Value and Platform Satisfaction—with high internal reliability (Cronbach's alpha> 0.85).

Table 3: Sample composition by group and data type

Group	Description	Sample size	Sampling method	Data type
Tourists	Visitors who engaged with the digital platform on-site or online	270	Stratified sampling by age, education, and region	Questionnaire
Cultural stakeholders	Local heritage custodians (village elders, artisans, cultural leaders)	5	Purposive sampling based on experience and cultural knowledge	Interview + observation
Experts	Academic researchers and professional designers in cultural preservation	5	Snowball sampling based on reputation and publications	Interview

Tourists: Required a minimum of 5 minutes of interaction with the digital platform; Stakeholders: Must have resided in Chengzi Village for more than 18 years; Experts: Required to have published at least two peer-reviewed articles on digital heritage or preservation design

Table 4: Questionnaire constructs and Cronbach's alpha

Construct	Items	Purpose	Cronbach's α
Perception of cultural value	20	Measures of symbolic, spatial, and historical meanings	0.89
Platform satisfaction	18	Evaluates usability, immersion, and engagement	0.91

3.5.2. Interview and observation protocols

Semi-structured interview guides were tailored for each group. Representative prompts included: what features of the architecture evoke ancestral memory or ritual significance? and how accurately do you feel the digital reconstruction reflects local identity?

Observational data were collected during four field visits and recorded visitor engagement patterns, including gesture-based interaction, verbal responses, and dwell time. These were triangulated

with photographs and architectural sketches to support environmental interpretation.

3.5.3. Quantitative analysis procedures

1. Descriptive Statistics: Mean scores and standard deviations were calculated for all questionnaire items.
2. Pearson Correlation Analysis: Used to explore relationships between perceived cultural value and satisfaction scores.
3. Linear Regression Modeling: Assessed the predictive power of cultural perception on platform satisfaction at a 95% confidence level ($\alpha = 0.05$). Prior to analysis, assumptions of linearity, normality, and homoscedasticity were confirmed.

3.5.4. Qualitative analysis procedures

1. Open Coding: Transcripts were inductively coded to extract participant expressions related to identity, memory, and cultural resonance.
2. Axial Coding: Codes were clustered into emergent themes such as "symbolic continuity," "ritual atmosphere," and "narrative authenticity."
3. Thematic Mapping: Key codes were thematically mapped in NVivo to show relationships between symbolisms of architecture and emotional engagement that was experienced.

3.6. Digital platform design

The interactive digital environment was created with Unity3D, together with WebGL for cross-desktop and mobile compatibility. The framework for design kept three main aspects in focus: spatial immersion, cultural annotation, and multilingual access. This adheres to up-to-date best practices for user-centric digital cultural heritage interface development.

Photogrammetric 3D Models: More than 300 high-resolution photographs were captured using DSLR cameras under varying lighting conditions to document architectural details. These images were processed through RealityCapture for model reconstruction and further refined in Blender to enhance mesh accuracy and reduce noise. The finalized 3D assets were exported to Unity3D with optimized polygon counts and collision detection enabled to ensure smooth performance in WebGL environments (Ma, 2021; Lei et al., 2024).

360-Degree Panoramic Environments: Panoramic content was photographed at important cultural locations with an Insta360 One X2 camera. Stitching of images was achieved using PTGui Pro to achieve seamless panoramic scenes. The scenes were then integrated inside Unity via a WebGL interface that created real-time navigable environments with spatial immersion (Radanovic et al., 2021).

Interactive Cultural Hotspots: In every one of the immersion scenes, cultural hotspots were incorporated. They included bilingual (Chinese-English) oral history components, visual annotation, and locationally authenticated metadata from stakeholders. They aimed to enhance emotional learning as much as supply symbolic continuity.

User Interface (UI) Design: The interface was subject to heuristic evaluation and A/B testing with a panel of 30 users to enhance usability. Design guidelines targeted cognitive accessibility and WCAG 2.1 guidelines. Behavioral data, including click paths, interaction density, and dwell time, were tracked and studied to guide further improvements. Together, these elements facilitated an iteratively directed development process that prioritized symbolic fidelity, inclusiveness for end-user groups, and cultural memory preservation. Merging Unity3D-based functionality with spatial analysis and narrative mapping assured relevance for both scholarly investigation as well as participatory cultural heritage engagement.

4. Results and discussion

Here, we combine quantitative survey data with qualitative data from interviews and ethnographic fieldwork, locating our findings in relation to the wider literature on immersive heritage technologies, user participation, and participatory conservation.

4.1. Demographic profile of respondents

A total of 270 valid responses were obtained from both domestic and international users who engaged with the Chengzi Ancient Yi Village digital heritage platform between January and March 2025. The demographic composition of this cohort, summarized in Table 5, provides a solid empirical basis for analyzing users' cultural perceptions and experiential responses to immersive heritage environments.

The gender distribution of respondents was balanced (52.2% male, 47.8% female), supporting diverse perspectives in user experience interpretation. Most participants were within digitally fluent age groups: 34.0% aged 21–30 and 29.0% aged 31–40, totaling 63%. Only 21.0% were over 40, indicating a stronger appeal to younger, tech-savvy users.

Regarding education, 62% hold at least a bachelor's degree. These participants demonstrated greater sensitivity to symbolic meaning, spatial representation, and interface usability—reflecting prior research linking higher education with deeper engagement in digital heritage environments.

Table 5: Sample composition by group and data type

No.	Demographic variable	Category	Percentage
1	Gender	Male	52.2
		Female	47.8
2	Age	21–30	34.0
		31–40	29.0
		41 and above	21.0
3	Education	Tertiary Level	62.0

These results align with existing research showing that younger, well-educated users are the primary audience for immersive, symbolically rich digital heritage platforms. The demographic profile reinforces the need for tailored engagement strategies—such as interactive hotspots and bilingual audiovisual content—designed for digitally literate adults to enhance interpretation and usability.

Moreover, the findings underscore the value of remotely accessible platforms in broadening cultural education and memory transmission. The Chengzi Village case illustrates how virtual environments, when aligned with users' cognitive habits, can effectively convey symbolic meaning, spatial narratives, and intergenerational continuity.

4.2. Cultural perception results

One of the central aims of this study was to assess how effectively the digital heritage platform conveyed the cultural and educational dimensions of vernacular Yi traditions. Quantitative findings from the Cultural Perception Scale indicate a strong positive response among users. The overall mean score was 4.38 (SD = 0.62) on a 5-point Likert scale, suggesting that the platform significantly enhanced users' understanding of symbolic space, cultural atmosphere, and historical continuity associated with Yi heritage.

Items that received the highest agreement included: "The digital platform enhances my understanding of Yi culture." (Mean = 4.51, SD = 0.55), and "The 3D models made the village feel more vivid and engaging." (Mean = 4.42, SD = 0.60). These results align with previous research that established the potential of immersive visualization—3D modeling and panoramic narration in particular—to improve cognitive access to cultural meaning, produce emotional resonance, and augment symbolic understanding in digital cultural heritage environments (Kebir et al., 2025).

Beyond the quantitative measures, open-ended comments frequently invoked a sense of "digital realism." This was not simply a nod to visual realism, but an expression of a deeper sense of cultural immersion founded on the effective representation of symbolic content. Commentators referred to architectural aspects such as the inward-sloping rooftop that is generally interpreted as a symbol of ancestral protection, and tiered courtyard planning corresponding with family rank and social status. These remarks suggest that end-users noticed and appreciated the inherent cultural logic in the digital reconstruction.

The study thus points to the significance of integrating ethnographic knowledge with digital design. It was not photorealism that assisted so greatly, but the cultural coherence of spatial symbolization that allowed for perceptions of authenticity. When digital media imbue their virtual spaces with vernacular knowledge systems, they transition from being representational instruments to interpretation sites. In turn, they also enable transmission of intangible cultural heritage, like collective memory, kinship morality, and localized cosmology—emphasizing digital heritage systems' functionality as agents of cultural continuity as much as a platform for educating a society (Jangra et al., 2025).

4.3. User satisfaction with digital platform

User satisfaction was assessed along four key dimensions: interface design, navigational usability, content accessibility, and the quality of immersive experience. The overall satisfaction score was relatively high, with a mean of 4.26 (*SD* = 0.71) on a 5-point Likert scale. This suggests that most users viewed the platform positively in terms of both functional performance and cultural engagement.

Some of the items on the satisfaction scale achieved particularly strong ratings. For instance, "The 360-degree panoramic images generated a strong sense of spatial immersion" achieved a mean of 4.49 (SD = 0.51), while "The interface of the platform was easy to use as well as aesthetically pleasing" achieved a mean of 4.32 (SD = 0.64). Likewise, "The audio-visual content assisted me in emotionally engaging with the cultural environment of the village" achieved a mean of 4.28 (SD = 0.59). These findings align with previous research determining scene immersion, audiovisual coherence, and cultural symbolism as principal antecedents of user satisfaction in digital heritage environments (Zhou et al., 2025).

The high-resolution panoramas, easy navigation, and interactive hotspots played a critical role in stimulating user presence and interpretive behavior. They allowed not only observation but also symbolic interaction that elevated users' cognitive and emotional relationship with the content.

Iterative refinements of the design—e.g., streamline menus, dual-language audio, and icons for navigation—were made in response to usability testing and greatly enhanced exploratory behavior and user dwell time. This is a validation of narrative clarity and technical usability for sustaining interest (Roth and Koenitz, 2016). Satisfaction was related not simply to interface functionality but to cultural meaning being transmitted effectively by the platform. A good digital heritage system must marry technical simplicity with symbolic complexity so that users can both navigate easily yet meaningfully engage with heritage content.

4.4. Regression analysis

To identify a predictive relationship between user satisfaction with the Chengzi digital heritage platform and perceived cultural value, a linear regression analysis was undertaken (Fig. 3). The independent variable was the average user score on the Cultural Perception Scale and the dependent variable was a satisfaction score from ratings on interface design, interactivity, and symbolic

immersion. The regression model was statistically significant: R^2 = 0.42, meaning that perceived cultural value explained 42% of the variation in user satisfaction. The F-statistic for the model was F(1, 448) = 54.3, p < 0.001, confirming that the model was valid in an overall sense. The predictor variable's standardized beta coefficient was β = 0.65, t = 7.37, p < 0.001, suggesting a strong positive association between cultural perception and satisfaction.

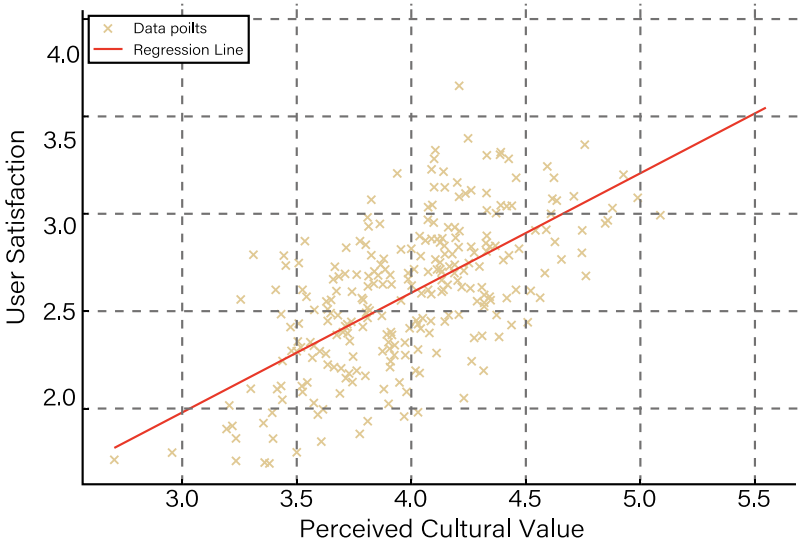

Fig. 3: Regression scatter plot of perceived cultural value and user satisfaction

These results empirically support one of this study's main hypotheses: symbolic relevance more than technical innovation or interface sophistication is the main predictor of user satisfaction with digital cultural heritage experiences. This aligns with recent research that virtual systems emphasizing symbolic fidelity, cultural depth, and narrative participation foster both engagement and perceived authenticity (Bertrand et al., 2021). A significant beta coefficient (β = 0.65) signifies that a one-point change in perceived cultural value was forecasted for a two-thirds-point gain in user satisfaction. This highlights the imperative of integrating localized symbolisms and coherent narrative formats into digital interfaces. The results also coincide with design methodologies from gamified cultural platforms and digital storytelling, whereby narrative immersion always beats visual realism in cultural understanding. Fig. 4 Standardized Beta Coefficient for Perceived Cultural Value.

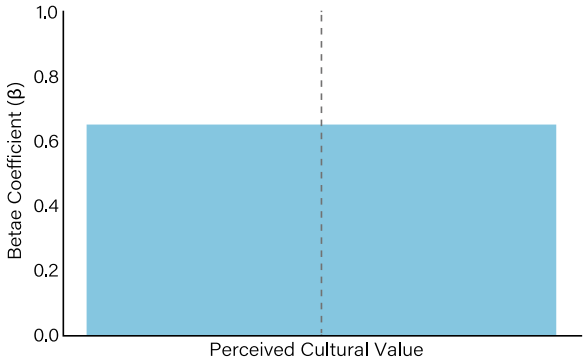

Fig. 4: Standardized beta coefficient for perceived cultural value

Furthermore, the regression results reinforce the value of participatory design practices, ethnographic alignment, and visual semiotics in heritage platform development. By prioritizing cultural resonance over surface-level interactivity, digital heritage systems can achieve not only higher levels of user satisfaction but also contribute meaningfully to the long-term transmission of vernacular knowledge and intangible heritage traditions across generations.

4.5. Interview and observation findings

Semi-structured interviews with cultural stakeholders, heritage specialists, and platform users, supplemented with ethnographic observations, brought to light three fundamental themes that influence the cultural impact of immersive visualization applied to the Chengzi Yi Village project.

Narrative Authenticity and Cultural Representation: Interviewees emphasized that maintaining narrative integrity is no less critical than visual accuracy. Although much praised for its platform's highly detailed 3D models, numerous interviewees warned that visual accuracy cannot communicate cultural essence by itself. According to one expert, "We're not simply recreating buildings—we're recovering belief systems and transmitted knowledge." This mirrors heritage literature concerns that digital projects focus more on form than meaning (Amelio and Zarri, 2024). Observational data supported this claim: visitors spent more time within hotspots supplemented with symbolic narratives and oral histories, indicating that interpretive content facilitated deeper investment (Pescarin et al., 2024).

Intergenerational Engagement and Cultural Resonance: Interviewees highlighted the platform's role in reconnecting youth with ancestral traditions.

Elders observed a renewed curiosity among younger generations toward traditional architecture after using the platform. As one artisan remarked, "My grandchildren used to ignore these old buildings. Now they ask about the meanings behind the carvings and courtyards." This finding aligns with recent studies showing that culturally symbolic storytelling fosters emotional bonds and transmits memory across generations (Echavarria et al., 2022).

Participatory Co-creation and Sustainable Duration: There was a call for increased participatory functionality—like rotating displays, allowing user-submitted histories, and interactive modules. Proposals like this point toward a larger trend in digital heritage towards content production that is driven by a sense of community. Studies indicate that co-creation is beneficial for both the epistemic legitimization and long-term sustainability of heritage sites (Silva et al., 2023). In promoting co-authorship and iteratively dialogic change, the Chengzi project shows how virtual heritage technologies might become living cultural continuity systems.

4.6. Integrated discussion

The investigation assessed how well the digital cultural heritage site communicated cultural and educational aspects of folk Yi traditions. Cultural Perception Scale achieved a robust total mean of 4.38 (SD = 0.62), suggesting that patrons felt an increase in cultural understanding of symbolic space, cultural atmosphere, and historical continuity.

Statements with the highest agreement were: "The digital platform helps improve my understanding of Yi culture" (M = 4.51, SD = 0.55) and "The 3D models brought the village more to life and made it more interesting" (M = 4.42, SD = 0.60). These findings are in line with earlier research on uses of immersive tools for heritage. Immersive media such as 3D modelling and panoramic narration have been shown to improve cognitive access, sense of connectedness, and symbolic intelligence (Kebir et al., 2025).

Some users mentioned their experience in terms of "digital realism." That name did not imply photorealistic fidelity alone. Instead, they used it for a sense of symbolic truthfulness. For example, some mentioned inward-sloping roofs as a symbol of protection from one's ancestors. Some mentioned tiered courtyards, which they personally felt represented social stratification. Those comments suggest that users felt cultural meaning in architectural elements.

These responses reflect that the site successfully incorporated vernacular logic into its aesthetics of images. More importantly, they reflect that authenticity for digital cultural heritage isn't about photorealism. Instead, it derives from symbolic coherence. If virtual spaces are developed with ethnographic insight and cultural value, they can be something more than a visualization tool. They can be interpretive spaces. In them, intangible heritage—such as memory, kinship, and indigenous perception of the world—may be shared and conserved more effectively (Jangra et al., 2025).

5. Theoretical and practical contributions

This study advances the field of digital heritage by proposing a multidimensional, community-anchored framework that integrates immersive visualization, participatory ethnographic methods, and empirical validation. In doing so, it offers both theoretical innovation and practical insights applicable to policy-making, platform governance, and cross-media heritage design.

5.1. Theoretical contributions

This study redefines digital heritage as a dialogical and interactive process that integrates spatial accuracy with cultural semiotics and embodied memory. In place of considering 3D modeling, panoramic photogrammetry, and digital narrative as distinct technologies with limited applications, the study reveals their combined potential when integrated with a common narrative framework that is centered on the user.

By integrating symbolic annotations and aboriginal viewpoints with immersive system designs, the study pushes beyond visual realism in digital heritage theory. It foregrounds emotional engagement, narrative authenticity, and experiential learning as central components of heritage perception. The strong correlation observed between perceived cultural value and user satisfaction ($\beta = 0.65$, $p < 0.001$) empirically substantiates the role of symbolic fidelity in shaping affective and cognitive responses, reinforcing theoretical positions rooted in semiotic immersion and symbolic cognition (Saariluoma and Rousi, 2015).

These findings support the development of a theory of cultural co-presence, wherein users engage not only with digital surrogates of built heritage, but with the symbolic ecologies, rituals, and belief systems they embody. This approach aligns with evolving perspectives in cognitive-symbolic interface research, which emphasizes the interpretive depth and participatory resonance of heritage experiences over mere technological sophistication (Planer, 2021). The proposed framework thus contributes to a growing body of scholarship that positions digital heritage not as a static archive, but as a living, co-created cultural ecosystem.

5.2. Practical contributions: Policy and governance

From a governance perspective, this study offers implementable strategies for localized execution of China's Digital Countryside Strategy, addressing a critical gap in rural heritage digitization policy. While national-level initiatives often prioritize

UNESCO-designated or iconic sites, the Chengzi Village case highlights how community-rooted systems—when designed inclusively—can also generate meaningful socio-cultural transformations.

By adopting a bottom-up participatory methodology, the Chengzi Village project demonstrates the feasibility of digital heritage systems in enhancing intergenerational transmission, identity reconstruction, and rural revitalization. The approach also aligns with early findings that digital policy can close urban–rural developmental gaps by quickening localized innovation, non-farm livelihoods, as well as cultural diversity (Wang et al., 2024). Studies also note that cultural co-creation made possible with digital infrastructures enriches localized legitimacy along with the sustainable transmission of knowledge.

These findings encourage policymakers and heritage managers to treat digital heritage not merely as tourism infrastructure, but as an infrastructure of empowerment and cultural resilience.

5.3. Design innovation and cross-media practice

Now in practice, this research offers a scalable methodological template suitable for practitioners who practice across disciplines. Through an integration of high-resolution panoramic photo tourism, 3D architectural models, and narrative annotation, the project showcases a next-generation technologically adaptive but culturally sensitive set of design practices.

Its hybrid interface—both exploratory browsing and structured learning—appeals equally to diverse user groups, both neighborhood elders as well as global researchers. Such a strategy highlights not only an ethical imperative of design for inclusion but, more importantly, for communities with both limited digital access as well as high cultural vulnerability.

6. Conclusions

The research investigated digital immersive technologies as a means for conserving as well as interpreting Chengzi Ancient Yi Village in Southwestern China. Both architectural aspects as well as symbolic heritage were taken into consideration. A mixture of methodologies was implemented. Ethnographic fieldwork, interviews of stakeholders, as well as user testing were all utilized. Each of them was utilized for assessing a custom-made digital heritage platform for that cultural environment.

6.1. Key findings

The research uncovered several significant findings: First, digital interactive media were successful in communicating Yi cultural symbolism. Participants gained better insight into spatial memory, ritual importance, and oral history. Second, statistical analysis showed that cultural importance alone was the greatest predictor of user satisfaction. It ranked more highly still than did visual novelty or interface design. Third, community stakeholders—e.g., elders, craftspeople—understood the platform as a tool of cultural preservation. They appreciated its shared, participatory emphasis. Fourth, panoramic view features, narrative hotspots, and multilingual guides helped to increase accessibility. Such features helped to increase immersion as well as emotive engagement. Finally, participatory methods played a central role. Community validation of platform narratives was required for achieving authenticity, depth of feeling, as well as long-term engagement.

6.2. Theoretical and methodological implications

The study here proposes a blended method. It integrates immersive technology with participatory ethnography along with user-centric evaluation. The study resists top-down digital heritage methodologies. It supports locally based methodologies that focus on meaning rather than mere aesthetics. It appreciates storytelling, community contributions, and symbolic accuracy. It allows for a respectful and practical way of developing digital cultural sites that are effective yet culture-aware. The study also introduces the PES model—Perception, Engagement, and Sustainability—as a new theoretical tool. This should not be confused with the Payment for Ecosystem Services model. Unlike the environmental version, this PES framework focuses on cultural understanding, emotional involvement, and long-term heritage continuity.

Future research can expand this model by comparing it with others, such as Cultural Ecosystem Services or digital engagement frameworks. Doing so may help clarify its distinct contributions and potential applications in heritage design (Tamborrino et al., 2022).

6.3. Concluding statement

In conclusion, this research affirms that digital heritage, when thoughtfully designed and ethically grounded, can transcend its archival function to become a living, interactive medium for cultural revitalization. By centering local voices and symbolic meaning in the design and implementation of immersive platforms, digital heritage initiatives can foster not only preservation but continuity, empowerment, and shared cultural futures.

6.4 Limitations and future research

The present study is subject to several limitations. Firstly, the research focuses on a single vernacular village in Southwest China, which limits the generalizability of its findings. While this localized approach offers profound cultural insight,

its applicability to more heterogeneous heritage settings is limited.

Secondly, the sampling strategy employed purposive and snowball techniques, particularly for engaging cultural stakeholders and experts. While these methods are well-suited for exploratory research, they are susceptible to selection bias and may not fully capture the diversity of community perspectives.

Thirdly, the study was conducted within a limited timeframe and primarily assessed users' immediate responses to the digital heritage platform. However, the study did not delve into long-term outcomes, including behavioral change, cultural memory retention, and intergenerational knowledge transfer. These factors are crucial for ensuring sustained engagement with heritage.

Fourthly, the employment of sophisticated digital instruments—including photogrammetry, panoramic interfaces, and NVivo software—facilitated the generation of high-fidelity reconstructions and the execution of robust analyses. Nevertheless, the dependence on technical infrastructure and expertise may present obstacles to the replication of these models in rural settings with limited resources.

Finally, despite the implementation of rigorous procedures to ensure coding reliability, qualitative interpretation remains inherently subjective. The influence of cultural context on emotional engagement and symbolic perception has the potential to introduce variability in the comparability of results across regions.

Future research should extend this study by incorporating multi-site case studies across different geographic and ethnic contexts, applying mixed sampling strategies for greater representativeness, and conducting longitudinal evaluations of cultural learning and user engagement. Exploration of adaptations of digital heritage platforms for low-tech environments and integration of participatory co-design approaches with local communities to enhance authenticity, inclusivity, and sustainability would also be beneficial.

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Compliance with ethical standards

Ethical considerations

This research was conducted in accordance with the ethical guidelines of Kunming University of Science and Technology. While the nature of the study—non-invasive cultural research involving adult participants—did not require formal ethics board approval, all ethical protocols were observed. Informational consent was obtained from all participants, who were assured of the voluntary nature of their participation and the confidentiality of their responses. These measures align with established ethical standards in cultural and social research.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Aledda S, Galeoto G, Fabbrini G, Lucibello L, Tofani M, Conte A, and Berardi A (2024). A systematic review of the psychometric properties of Quebec user evaluation of satisfaction with assistive technology (QUEST). Disability and Rehabilitation: Assistive Technology, 19(4): 1228-1235. https://doi.org/10.1080/17483107.2022.2161648 **PMid:36645802**

Aljaafreh A, Garaj V, and Choi Y (2023). Using a digital participatory approach to facilitate inclusivity in Jordanian heritage sites: Stakeholders’ requirements and a proposed system. Architecture Papers of the Faculty of Architecture and Design STU, 28(3): 3–9. https://doi.org/10.2478/alfa-2023-0014

Amelio A and Zarri GP (2024). Cultural heritage digital twin: Modeling and representing the visual narrative in Leonardo Da Vinci’s Mona Lisa. Neural Computing and Applications, 36: 11859–11876. https://doi.org/10.1007/s00521-024-10010-x

Bala P, Nisi V, and Nunes N (2024). Stories as boundary objects: Digital storytelling with migrant communities for heritage discourses. Proceedings of the ACM on Human-Computer Interaction, 8(CSCW1): 177. https://doi.org/10.1145/3641016

Banfi F and Oreni D (2025). Unlocking the interactive potential of digital models with game engines and visual programming for inclusive VR and web-based museums. Virtual Archaeology Review, 16(32): 44-70. https://doi.org/10.4995/var.2024.22628

Bertrand S, Vassiliadi M, Zikas P, Geronikolakis E, and Papagiannakis G (2021). From readership to usership: Communicating heritage digitally through presence, embodiment and aesthetic experience. Frontiers in Communication, 6: 676446. https://doi.org/10.3389/fcomm.2021.676446

Bolognesi CM and Fiorillo F (2023). Virtual representations of cultural heritage: Sharable and implementable case study to be enjoyed and maintained by the community. Buildings, 13(2): 410. https://doi.org/10.3390/buildings13020410

Dipasquale L, Ammendola J, Montoni L, Ferrari EP, and Zambelli M (2024). Harnessing vernacular knowledge for contemporary sustainable design through a collaborative digital platform. Heritage, 7(9): 5251-5267. https://doi.org/10.3390/heritage7090247

Echavarria KR, Samaroudi M, Dibble L, Silverton E, and Dixon S (2022). Creative experiences for engaging communities with cultural heritage through place-based narratives. ACM Journal on Computing and Cultural Heritage (JOCCH), 15(2): 33. https://doi.org/10.1145/3479007

Elliott J (2022). The craft of using NVivo12 to analyze open-ended questions: An approach to mixed methods analysis. The Qualitative Report, 27(6): 1673-1687. https://doi.org/10.46743/2160-3715/2022.5460

Facchinetti G, Piredda M, Ausili D et al. (2021). Information before discharge in geriatric patients in Italy: Cultural adaptation and validation of the patient continuity of care questionnaire. European Journal of Ageing, 18: 99-107. https://doi.org/10.1007/s10433-020-00576-5 **PMid:33746685 PMCid:PMC7925798**

Ferreira I, Lupp G, and Mahmoud I (2023). Guidelines for co-creation and co-governance of nature-based solutions: Insights from EU-funded projects. Publications Office of the European Union. https://doi.org/10.2777/157060

González Martínez P (2022). The 'preservation by relocation' of Huizhou vernacular architecture: Shifting notions on the authenticity of rural heritage in China. International Journal of Heritage Studies, 28(2): 200-215. https://doi.org/10.1080/13527258.2021.1955728

Hu M, Suh J, and Pedro C (2023). An integrated framework for preservation of Hawaii indigenous culture: Learning from vernacular knowledge. Buildings, 13(5): 1190. https://doi.org/10.3390/buildings13051190

Jangra S, Singh G, and Mantri A (2025). Evaluating user experience in cultural heritage through virtual reality simulations. Virtual Archaeology Review, 16(32): 17-31. https://doi.org/10.4995/var.2024.22556

Jiang L, Li J, Wider W, Tanucan JCM, Lobo J, Fauzi MA, Hidayat H, and Zou R (2025). A bibliometric insight into immersive technologies for cultural heritage preservation. NPJ Heritage Science, 13: 126. https://doi.org/10.1038/s40494-025-01704-z

Kara N (2024). A mixed-methods study of cultural heritage learning through playing a serious game. International Journal of Human–Computer Interaction, 40(6): 1397-1408. https://doi.org/10.1080/10447318.2022.2125627

Kebir A, Kacher S, Larabi MC, and Meneveaux D (2025). Engaging youth in Moorish architectural heritage through virtual 3D experience of the Bardo Palace of Algiers. ACM Journal on Computing and Cultural Heritage, 18(2): 24. https://doi.org/10.1145/3718089

Lei Y, Fiorillo F, and Fassi F (2024). 3D survey point cloud data as direct rendering assets for visualising complex heritage in virtual applications. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 48: 279-286. https://doi.org/10.5194/isprs-archives-XLVIII-2-W4-2024-279-2024

Li H, Feng B, Su M, and Liu Z (2024a). Design of interactive digital virtual display application for Chinese heritage traditional herbal medicine culture. In: Rauterberg M (Ed.), Culture and Computing. HCII 2024. Lecture Notes in Computer Science: 274-292. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-031-61147-6_19

Li J, Pan J, Dou Q, Fu F, and Shi Y (2024b). Digital footprint as a public participatory tool: Identifying and assessing industrial heritage landscape through user-generated content on social media. Land, 13(6): 743. https://doi.org/10.3390/land13060743

Li S, Yu Y, Yang H, Zhao J, and Shen M (2024c). Development and application of concentric lock platform under digital cultural tourism product innovation. Frontiers in Business, Economics and Management, 14(1): 218–222. https://doi.org/10.54097/k6e7xv62

Liang X, Hua N, Martin J, Dellapiana E, Coscia C, and Zhang Y (2022). Social media as a medium to promote local perception expression in China's world heritage sites. Land, 11(6): 841. https://doi.org/10.3390/land11060841

Liew CL, Goulding A, and Nichol M (2022). From shoeboxes to shared spaces: participatory cultural heritage via digital platforms. Information, Communication & Society, 25(9): 1293-1310. https://doi.org/10.1080/1369118X.2020.1851391

Loignon C, Dupéré S, Leblanc C et al. (2021). Equity and inclusivity in research: Co-creation of a digital platform with representatives of marginalized populations to enhance the involvement in research of people with limited literacy skills. Research Involvement and Engagement, 7: 70. https://doi.org/10.1186/s40900-021-00313-x **PMid:34610847 PMCid:PMC8491375**

Ma YP (2021). Extending 3D-GIS district models and BIM-based building models into computer gaming environment for better workflow of cultural heritage conservation. Applied Sciences, 11(5): 2101. https://doi.org/10.3390/app11052101

McShane N, Condell J, Alvarez J, and Miller A (2021). Virtual community heritage: An immersive approach to community heritage. The Journal of Media Innovations, 7(1): 4-18. https://doi.org/10.5617/jomi.8791

Murphy M, Fai S, Chow L et al. (2022). Virtual historic centers: Digital representation of archaeological heritage. In: D'Amico S and Venuti V (Eds.), Handbook of cultural heritage analysis: 1497-1528. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-030-60016-7_51

Pescarin S, Città G, and Spotti S (2024). Authenticity in interactive experiences. Heritage, 7(11): 6213-6242. https://doi.org/10.3390/heritage7110292

Petousi D, Katifori A, Servi K, Roussou M, and Ioannidis Y (2022). Interactive digital storytelling in cultural heritage: The transformative role of agency. In: Vosmeer M and Holloway-Attaway L (Eds.), Interactive Storytelling. ICIDS 2022. Lecture Notes in Computer Science: 48-67. Springer, Cham, Switzerland. https://doi.org/10.1007/978-3-031-22298-6_3

Planer RJ (2021). What is symbolic cognition? Topoi, 40: 233-244. https://doi.org/10.1007/s11245-019-09670-5

Pujol L and Champion E (2012). Evaluating presence in cultural heritage projects. International Journal of Heritage Studies, 18(1): 83-102. https://doi.org/10.1080/13527258.2011.577796

Rajkovic I, Bojovic M, Tomanovic D, and Akšamija LC (2022). Sustainable development of vernacular residential architecture: a case study of the Karuc settlement in the Skadar lake region of Montenegro. Sustainability 14(16): 9956. https://doi.org/10.3390/su14169956

Risco E, Sauch G, Albero A et al. (2020). Spanish validation of the "user reported measure of care coordination" questionnaire for older people with complex, chronic conditions. International Journal of Environmental Research and Public Health, 17(18): 6608. https://doi.org/10.3390/ijerph17186608 **PMid:32932760 PMCid:PMC7558675**

Roth C and Koenitz H (2016). Evaluating the user experience of interactive digital narrative. In the Proceedings of the 1st International Workshop on Multimedia Alternate Realities, ACM Multimedia Conference, Amsterdam, Netherlands: 31-36. https://doi.org/10.1145/2983298.2983302 **PMCid:PMC4878886**

Saariluoma P and Rousi R (2015). Symbolic interactions: towards a cognitive scientific theory of meaning in human technology interaction. Journal of Advances in Humanities, 3(3): 310-324. https://doi.org/10.24297/jah.v3i2.5145

Santana-Berlanga NDR, Romero-Sanchez JM, Botello-Hermosa A, Bergland A, Edvardsson D, and Porcel-Galvez AM (2024). Thriving of older people assessment scale (TOPAS):

Transcultural adaptation, psychometric evaluation, and refinement in a Spanish sample. Geriatric Nursing, 59: 431-439. https://doi.org/10.1016/j.gerinurse.2024.08.004 **PMid:39141951**

Silva C, Zagalo N, and Vairinhos M (2023). Towards participatory activities with augmented reality for cultural heritage: A literature review. Computers & Education: X Reality, 3: 100044. https://doi.org/10.1016/j.cexr.2023.100044

Srdanović P, Skala T, and Maričević M (2025). InHeritage—A gamified mobile application with AR and VR for cultural heritage preservation in the metaverse. Applied Sciences, 15(1): 257. https://doi.org/10.3390/app15010257

Tamborrino R, Dinler M, Patti E et al. (2022). Engaging users in resource ecosystem building for local heritage-led knowledge. Sustainability, 14(8): 4575. https://doi.org/10.3390/su14084575

Vert S, Andone D, Ternauciuc A et al. (2021). User evaluation of a multi-platform digital storytelling concept for cultural heritage. Mathematics, 9(21): 2678. https://doi.org/10.3390/math9212678

Vinodan A and Meera S (2024). Integrated management of heritage sites: Scale development and validation. Journal of Cultural Heritage Management and Sustainable Development, 14(3): 312-336. https://doi.org/10.1108/JCHMSD-09-2021-0158

Wang Z, Liu X, Qin Y, and Zhang Y (2024). How rural digitization promote coordinated urban–rural development: Evidence from a quasi-natural experiment in China. Agriculture, 14(12): 2323. https://doi.org/10.3390/agriculture14122323

Waterton E and Smith L (2010). The recognition and misrecognition of community heritage. International Journal of Heritage Studies, 16(1-2): 4-15. https://doi.org/10.1080/13527250903441671

Yang N, Chen J, Ban L, Li P, and Wang H (2024). Pre-planning and post-evaluation approaches to sustainable vernacular architectural practice: A research-by-design study to building renovation in Shangri-La's Shanpian House, China. Sustainability, 16(21): 9568. https://doi.org/10.3390/su16219568

Zhang A, Gong Y, Chen Q, Jin X, Mu Y, and Lu Y (2025). Driving innovation and sustainable development in cultural heritage education through digital transformation: The role of interactive technologies. Sustainability, 17(1): 314. https://doi.org/10.3390/su17010314

Zhang M, Wang L, and Zhang Q (2022). Research on subjective-cultural ecological design system of vernacular architecture. Sustainability, 14(20): 13564. https://doi.org/10.3390/su142013564

Zhou Q, Wang S, and Wang J (2025). Exploring user experience in virtual industrial heritage platforms: Impact of cultural identity, functional clarity, scene interactivity, and narrative quality. Buildings, 15(2): 253. https://doi.org/10.3390/buildings15020253