

Digital Transformation of Intangible Cultural Heritage Museums: Design and User Experience Evidence from Henan, China

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ABSTRACT

This study innovates the design of Henan local Intangible Cultural Heritage Museum with the help of modern AIGC digital intelligence technology. The study takes the digital museum in Yellow River Transportation College, draws on the relevant literature of the core functions of the museum, and discusses the influencing factors affecting the use experience of the museum. This study combines the results of interviews with museum visitors and experts to define the eight impact factors of the digital museum, and makes an in-depth analysis of the user experience of the Henan Intangible Cultural Heritage Digital Museum. And from the eight core dimensions of Usability, Self-efficacy, Learnability, Interaction Quality, Interface Design, Visual Guidance, Philosophical Sociality, and Economic, the hypothesis was tested by correlation analysis, multiple regression analysis, the results show that, Interaction quality and interface design are two key factors in determining user satisfaction, User engagement depends on the combined action of multiple variables. According to this study put forward the future from AI interaction optimization, VR / AR technology, intangible original design.

Keywords: intangible cultural heritage; digital museum; digital transformation

INTRODUCTION

Under the influence of modern and contemporary design concepts, digital design concepts, media forms, design techniques and aesthetic concepts have made great progress. Facing the turning point of the era of digital technology, contemporary Chinese traditional culture urgently needs the penetration of contemporary digital theories and forms (Jing, 2022). As a new technical means, digitization can effectively inherit and protect the creative dimension of intangible cultural heritage in visual design (Yan, 2023). Traditional museums have always had the disadvantages of not being able to fully display the information of the collected items and not being able to show the cultural connotations of the relevant collections to the audience in multiple dimensions or angles. The application of digital museum technology makes digital display more possible, which greatly improves its viewing, entertainment and interactivity, making it easier for the audience to accept and understand (Li, 2022). Based on this point of view, this paper innovatively proposes the idea of creating a digital museum of intangible cultural heritage in Henan Province, striving to make up for the

shortcomings of traditional museums such as weak interactivity, incomplete information acquisition, and poor offline display effects through the advantages of digital technology. At the same time, this study emphasizes that digital transformation should balance technological innovation with cultural authenticity, accessibility, and long-term sustainability in order to avoid excessive technological dependence and preserve the original cultural meaning of intangible heritage.

Henan Province is located in the middle and lower reaches of the Yellow River and has a long history. It is regarded as the birthplace of Chinese civilization. Many dynasties in history have built their capitals here. Therefore, Henan Province is rich in cultural relics, cultural resources and historical resources, and is regarded as the main birthplace of Chinese civilization. Intangible cultural heritage is created by the people of the Central Plains in their production and life. It is called the "living fossil" of people's life, artistic exploration, and cultural history, and occupies a very important position in Henan's excellent traditional cultural system. Therefore, we deeply explore and explore the rich cultural composition and design concepts contained in the excellent traditional intangible cultural heritage, which is of great significance to improving the creation and design capabilities of traditional crafts and the product hierarchy, improving the variety of traditional crafts, and then promoting the cultivation of Henan's local industry brands and arts and crafts artists, and improving the application degree and application space of traditional crafts in modern production and life.

Intangible cultural heritage is not only the cultural achievements left by mankind in the long historical development, but also engraved with the memory of the nation. Intangible cultural heritage has eternal aesthetic charm in the long history of history, carries the historical development context, and carries cultural origins. It is not only the common cultural treasure of mankind, but also the "living" continuation of human civilization. Chinese intangible cultural heritage is not only a treasure of the world's ancient culture, but also adds a colorful Chinese color to world culture. The museum carries the memory of human history and civilization. It is an important palace to protect and inherit human civilization. It is a gorgeous feast flowing in time and space, and it is also a bridge connecting the past, present and future. The era of digital intelligence and information is presented to the audience through rich and diverse digital forms, which has become an important symbol and development direction of the digital construction of modern museums. Vigorously develop smart museums, with business needs as the core and modern science and technology as the support, and gradually realize smart services, smart protection, and smart management. Digitizing museums has become an important topic of research today.

LITERATURE REVIEW

Digital Museums and Functional Enhancement of Museum Services

Digital technologies have significantly improved the functionality and accessibility of museums. Research on museum mobile guides demonstrates that digital tools can replicate and even extend traditional human-guided services, such as spatial navigation, exhibit interpretation, and advanced storytelling through digital narratives and gamification (Antoniou et al., 2021). In addition, virtual access to museum websites has become increasingly popular, enabling users to engage with museum content beyond physical constraints (Cunliffe et al., 2001). Recent studies further indicate that online virtual exhibitions are widely adopted by public museums; however, users' cognitive perceptions and responses to such digital experiences remain insufficiently explored (Gilani et al., 2023). To address diverse user needs, customized information retrieval systems have also been developed. For instance, a distributed vertical search engine based on Hadoop cloud computing has been proposed to enhance personalized information services (Zu & Liu, 2017). These advancements highlight the growing role of digital technologies in improving museum usefulness and service efficiency.

User Experience Dimensions: Self-Efficacy, Learning, and Interaction

Digital museums play a crucial role in enhancing user experience across multiple dimensions, including self-efficacy, learning outcomes, and interaction quality. From a user-centered perspective, studies on virtual exhibitions emphasize the importance of usability evaluation frameworks, employing descriptive statistics and factor analysis to examine user perceptions and behavioral responses (Gilani et al., 2023). These findings suggest that digital platforms can strengthen users' confidence in their learning abilities and improve engagement.

In terms of learning, digital museums provide enriched educational experiences by integrating advanced media technologies. Art education research shows that museum outreach programs and digital tools significantly enhance early learners' engagement and learning outcomes (Mansi et al., 2022). In the post-pandemic era, the integration of digital media into museum environments has been shown to reshape visitor experiences and support deeper cognitive engagement, including observation, discussion, and creative expression (Lei, 2023). Collaborative models involving educators and museum professionals further promote meaningful learning experiences and improved educational performance. Interaction quality is another critical factor. Digital museums leverage VR, AR, and multimedia technologies to create immersive environments that enhance user participation and sensory experience (Qu, 2024; Ji & Li, 2024). Especially in the context of online learning during the pandemic, interactive digital environments have proven effective in overcoming spatial and temporal limitations while improving accessibility (Feng & Huo, 2023). These findings collectively demonstrate that user experience in digital museums is shaped by the combined effects of usability, learning support, and interaction design.

Interface Design and Visual Guidance in Digital Museums

Interface design and visual guidance are key determinants of user engagement and information accessibility in digital museums. With the acceleration of digital transformation, museums increasingly emphasize the integration of regional cultural elements into interface design to strengthen brand identity and communication effectiveness (Du, 2023).

Based on emotional design theory, interface design can be structured across three levels: instinctive, behavioral, and reflective. At the instinctive level, visual elements such as color, layout, icons, and text should be clear, simple, and appealing; at the behavioral level, interfaces should provide timely feedback and intuitive navigation; at the reflective level, design should enhance immersion and emotional connection through storytelling and character representation (Feng & Huo, 2023). Visual guidance further supports user interaction by improving spatial perception and information organization. Research on virtual museum design highlights the importance of visual perception parameters in creating immersive and coherent virtual environments, facilitating the interaction between virtual and physical spaces (Tang et al., 2023). Additionally, digital visual media, including video and cultural imagery, play an essential role in conveying cultural values and enhancing international cultural communication (Jin & Gao, 2025).

Cultural, Social, and Economic Values of Digital Museums

Beyond functional and experiential improvements, digital museums also contribute to broader cultural, social, and economic development. Museums have traditionally played a vital role in preserving cultural heritage, and their role has expanded to include the safeguarding of intangible cultural heritage (ICH) through digital documentation and dissemination (Kandil, 2023). Intangible cultural heritage embodies rich philosophical and humanistic values, as exemplified by traditional practices such as Taijiquan, which reflect deep cultural meanings and contemporary relevance (Li, 2023; Bi et al., 2023).

Digital technologies further enhance accessibility to cultural heritage. Virtual reality applications enable broader public engagement with both tangible and intangible cultural assets (Selmanovic et al., 2020). Moreover, the integration of digital technology with cultural industries promotes the reconstruction and regeneration of cultural resources, facilitating the convergence of culture and tourism sectors (Tian & Zhang, 2025). From an economic perspective, digital museums support the development of cultural industries by transforming cultural resources into marketable assets, fostering cultural branding and regional economic growth (Liu, 2025; Zhao, 2025). This integration of cultural preservation with economic development creates a synergistic effect, achieving both social and economic benefits.

RESEARCH METHODOLOGY

This topic adopts quantitative research methods and combines quantitative data analysis to ensure the breadth and depth of the data, while providing more accurate conclusions and suggestions. The quantitative part mainly uses descriptive statistical analysis, correlation analysis and SPSS regression analysis to measure the user experience, learning effect and satisfaction of the Henan Local Intangible Cultural Heritage Online Museum. Through questionnaire surveys, feedback from trial users is collected to more comprehensively understand user needs, operating habits and platform optimization directions.

Data Collection

The formal survey was conducted using a combination of online and offline methods, resulting in a total of 280 valid questionnaires. The sample achieved a balanced gender distribution, with 140 male and 140 female respondents. Participants were drawn from diverse groups, including college students (43.0%, 120 respondents), social learners (28.6%, 80 respondents), design professionals (17.8%, 50 respondents), and cultural researchers (10.6%, 30 respondents). Among them, cultural researchers and design professionals were treated as expert participants, while college students and social learners represented general visitors, ensuring a balanced combination of expert and user perspectives. This diverse sample structure ensures the representativeness and reliability of the data for analyzing user experience in the digital museum context. The questionnaire was designed based on eight core dimensions, capturing users' perceptions of platform usability, learning effectiveness, and cultural value. These dimensions include usability (ease of operation, loading speed, and content accessibility), self-efficacy (users confidence in their learning ability), learnability (efficiency and intuitiveness of knowledge acquisition), interaction quality (performance of VR/AR, AI guidance, and multimodal interaction), interface design (layout, aesthetics, and information logic), visual guidance (clarity of information organization), philosophical sociality (cultural identity and historical resonance), and economic factors (acceptance of NFT transactions, membership systems, and online ticketing).

The collected data were analyzed using SPSS and further visualized through Matplotlib and Tableau to enhance interpretability. Several types of visual outputs were generated, including user frequency distribution graphs to illustrate access patterns across different groups, correlation analysis graphs examining the relationship between learning efficiency and interaction quality, and user satisfaction charts reflecting evaluations of various functional modules. In addition, an economic analysis table was developed to assess users' acceptance of emerging business models such as NFT transactions and membership systems. These analytical and visualization approaches provide a comprehensive understanding of user behavior, preferences, and satisfaction, thereby supporting subsequent empirical analysis and model validation.

User Experience Method

In different scenes, users have significant differences in their sensitivity to scene scaling. The user's perception

depends largely on the characteristics of the scene itself. The smaller the size of the virtual scene and the higher the density of objects in the environment, the narrower the user's perception threshold range of scaling gain (Du et al., 2025). Using the user experience honeycomb model as an analysis framework, we widely collect user experience and opinions from university libraries, use Nvivo14 and grounded theory to analyze the data of semi-structured interviews, extract key categories and logical relationships, and build a theoretical model of the impact of AIGC on the user experience of university libraries.

By analyzing the model, we explain the advantages of introducing AIGC in university libraries to improve user experience from the dimensions of resources, services, and interactions. With reference to the innovation diffusion theory and the social technology system theory, we put forward three suggestions for the introduction of AIGC in libraries: user demand research and technology trend analysis, user participation and co-evolution, and continuous innovation and optimization development (Zhang & Zhang, 2025). In today's era of rapid digital development, traditional museums are facing a series of challenges. First, due to geographical limitations, many museums can only provide exhibitions for local or specific regional audiences, and find it difficult to serve a wider group; second, the exhibition space of physical museums is limited, and it is impossible to display all the collections for a long time. Many precious exhibits can only be stored in warehouses and rarely have the opportunity to meet the public; in addition, the way of information dissemination is also easily limited. Traditional museums mainly rely on display boards, text descriptions and tour guides to convey knowledge. The way for audiences to obtain information is also relatively single, lacking personalized learning paths and interactive experiences.

Innovative Design

The way people enjoy museums and cultural heritage sites has changed significantly over the past century. Museums and cultural heritage sites used to focus on the preservation of sites, objects and exhibits, while activities focused on spreading knowledge about sites and objects. Activities and exhibitions revolved around sites and objects. For visitors, this usually meant that they could watch and read, but not touch and interact. In the second half of the 20th century, museums became more user-centered and invited visitors to actively think about sites and objects, draw their own conclusions and interact with the materials (Lehn et al., 2001). In today's era of rapid digital development, traditional museums are facing a series of challenges. First, due to geographical limitations, many museums can only provide exhibitions for local or specific regional audiences, and find it difficult to serve a wider group; second, the exhibition space of physical museums is limited, and it is impossible to display all the collections for a long time. Many precious exhibits can only be stored in warehouses and rarely have the opportunity to meet the public; in addition, the way of information dissemination is also easily limited. Traditional museums mainly rely on display boards, text descriptions and tour guides to convey knowledge. The way for audiences to obtain information is also relatively single, lacking personalized learning paths and interactive experiences.

Digital collection and storage

This topic will use three-dimensional high-definition scanning new technology. Digital collection is the first step in digital inheritance. The purpose of digital collection is to convert other information into digital signals for digital storage and digital display. This is the traditional data collection method for hand drawing and camera shooting. Hand-drawing and camera shooting are traditional digital collection methods, which are also delicate and tedious work. Through hand-drawing, the patterns, colors, textures and other details of intangible cultural heritage can be expressed very clearly. Manual drawing takes a lot of time and energy, and taking pictures with a camera can only present two-dimensional images but not a full range of images. In this topic, a new method of 3D high-definition scanner scanning will be used. Three-dimensional high-definition scanner scanning is a new digital collection technology. By scanning with a scanner, the patterns, colors, textures and

other information of intangible cultural heritage can be converted into digital signals for digital storage and digital display. The advantage of scanning with a 3D high-definition scanner is that it can achieve high-precision and high-definition digital collection, which greatly improves the efficiency of photography and hand-drawing. This topic will use cloud storage method. Cloud storage is an emerging digital storage method. By storing digitally collected intangible cultural data in a cloud server, data sharing and access can be achieved globally. Digital storage solves the incomplete database of Henan cultural heritage and plays a role in mutual communication and interaction and resource sharing among various cities.



Figure 1. 3D Digital collection and storage

Data recommendation

This topic plans to use a method based on deep learning to make personalized recommendations. Deep learning is a research direction in machine learning and has attracted widespread attention in fields such as computer vision, speech recognition, and image processing. In recent years, the explosive research and application of deep learning has led to further development of artificial intelligence. Deep learning has relatively mature applications in image, voice, NLP and other fields. In recent years, deep learning has begun to be applied in recommendation systems. It plays a very significant role in recommendation systems and can extract features directly from content. It has strong ability to express features; it can learn user and product features more accurately; a large number of studies have shown that compared with traditional methods, deep learning can effectively improve the recommendation effect. In recent years, methods based on deep learning have also been applied in recommendation systems. Since Henan non-heritage cultural resources may contain a large number of documents and pictures, deep learning-based methods can be used to recommend users. The application of this new technology in digital museums has greatly improved the reading efficiency of visitors.



Figure 2. Data recommendation visualization

Digital display

Digital display is the most critical step in transforming digital collection and digital storage into practical applications. In the digital display, the inheritor's production process can be digitally edited to form an intelligent voice system. Using AIGC technology, AIGC (AI Generated Content) refers to artificial intelligence generated content, that is, technology that uses artificial intelligence algorithms to quickly generate text, images, audio and other content. AIGC is a new content production method after UGC (User Generated Content) and PGC (Professionally Generated Content). It uses a model trained with a large amount of data to generate content, which can solve content generation problems for users, thereby saving time and resources and improving efficiency. Work efficiency. For example, chatbots (virtual assistants) are the application results of AIGC technology. AIGC undertakes basic and mechanical labor such as information mining, material calling, copying, and editing to meet massive personalized needs with low marginal cost and high efficiency. However, the application of AI, VR, and AIGC technologies in digital museums should also consider implementation costs, technical maintenance requirements, and accessibility for elderly users or digitally disadvantaged groups. Therefore, these technologies are proposed as supportive tools rather than replacements for traditional cultural interpretation and human-centered museum experiences.



Figure 3. Utilize AIGC technology to establish a virtual-real interaction relationship

Digital original design

This topic will be based on AIGC technology for digital original design. Using traditional computer-aided design tools, such as AutoCAD, 3ds Max, etc., some software operations are complex, time-consuming and labor-intensive, and cannot adapt to the rapidly changing and developing design needs of the outside world. The ability to prepare and apply new technologies, new tools and software is insufficient, and the technical literacy fails to meet the requirements of innovative design teaching. AIGC technology has penetrated into various fields of design, such as digital media design, clothing design, product design and other majors, providing creative ideas and inspiration for creators and improving design production efficiency. In the digital original work, this project will use AIGC technology to transform Henan's non-heritage culture into AI Hanfu costumes, AI-generated paper-cuts, AI-generated woodblock New Year paintings, and AI-generated "lion awakening" image designs, etc. Providing cultural and creative digital works for visitors to experience, better bringing the public closer to intangible cultural heritage, allowing visitors to better participate in the design of Henan cultural heritage, and using intelligent AIGC technology for digital communication.



Figure 4. Utilize AIGC technology to establish a virtual-real interaction relationship

DISCUSSION

The findings of this study provide clear and consistent empirical evidence that digital technology significantly enhances user experience, learning effectiveness, and cultural engagement within the context of the Henan Intangible Cultural Heritage Digital Museum. The survey results indicate that users demonstrate strong interest in intangible cultural heritage, with over 80% expressing active or moderate engagement intentions. At the same time, users show clear preferences for digital, interactive, and immersive forms of cultural dissemination, such as digital exhibitions, live-streaming interactions, and cultural creative products. However, similar to patterns observed in digital capability studies, a gap emerges between user expectations and current platform performance. While users express high demand for interactive functions, personalized learning, and diversified activities, existing digital museum platforms still exhibit limitations in interaction depth, content richness, and activity design, indicating that current digital applications remain insufficiently aligned with user-centered needs.

The results further reinforce that usability, interaction quality, and learnability are core determinants of user satisfaction. In particular, the strong demand for VR/AR interaction, AI-guided navigation, and personalized recommendation systems reflects the transition of museums from static information providers to dynamic, experience-oriented platforms. At the same time, the high preference for traditional visual styles and warm color systems suggests that digital innovation must remain culturally grounded, balancing technological advancement with cultural authenticity. This aligns with the perspective that digital museums should not only enhance accessibility but also strengthen cultural identity and emotional resonance. Moreover, the digitization of intangible cultural heritage may introduce risks of cultural misinterpretation, symbolic simplification, or excessive commercialization. Therefore, digital content development should involve heritage inheritors, cultural experts, and local communities to ensure authenticity, ethical representation, and cultural continuity throughout the digitization process.

From a theoretical perspective, this study extends existing research on digital museums by integrating eight key dimensions (usability, self-efficacy, learnability, interaction quality, interface design, visual guidance, philosophical sociality, and economic value) into a comprehensive analytical framework. This multidimensional structure confirms that digital museum experience is not determined by a single technological factor but by the coordinated interaction of functional, experiential, cultural, and economic elements. Furthermore, the findings support the view that digital platforms can enhance user's self-efficacy and learning motivation by providing intuitive interfaces, interactive environments, and personalized content pathways, thereby improving knowledge acquisition and cultural understanding.

From a practical perspective, several implications emerge. First, digital museums should prioritize user-centered design by strengthening interactive functions, expanding activity diversity, and improving personalized services through technologies such as deep learning and data recommendation. Second, platform design should integrate regional cultural characteristics, ensuring that interface aesthetics, visual guidance, and content presentation reflect Henan cultural identity. Third, the integration of AIGC technology can significantly improve content production efficiency and enable scalable, personalized cultural experiences; however, its application should remain supportive rather than dominant, ensuring authenticity and accuracy of cultural representation. Finally, the economic dimension (NFT transactions, membership systems, and digital cultural products) demonstrates strong user acceptance, indicating that digital museums can achieve sustainable development by combining cultural dissemination with innovative business models.

CONCLUSION

This study systematically explored the design and development of a Henan Local Intangible Cultural Heritage Digital Museum from the perspective of digital technology integration and user experience optimization. By combining literature review, questionnaire survey, and quantitative data analysis, the research demonstrates that digital technologies, particularly 3D scanning, cloud storage, deep learning recommendation systems, VR/AR interaction, and AIGC, play a critical role in enhancing the accessibility, interactivity, and dissemination efficiency of intangible cultural heritage. The findings confirm that digital museums are not only an effective tool for cultural preservation but also a key platform for promoting cultural innovation, education, and economic transformation.

The study further reveals that user demand is highly concentrated in three aspects: interactive experience, learning functionality, and cultural authenticity. While users show strong acceptance of digital formats and emerging technologies, they also emphasize the importance of maintaining traditional cultural characteristics in visual design and content presentation. This highlights a fundamental principle in digital museum construction: technological advancement must be balanced with cultural continuity. In addition, the integration

of personalized recommendation systems and AIGC-based content generation provides new pathways for improving user engagement and operational efficiency, although challenges related to content accuracy, ethical considerations, and long-term sustainability remain.

Theoretically, this research enriches the academic understanding of digital museums by proposing a comprehensive, multidimensional framework that integrates functional, experiential, cultural, and economic factors. It also extends the application of digital technology theories in the field of cultural heritage preservation, demonstrating how emerging technologies can reshape traditional cultural transmission models. Practically, the findings provide actionable guidance for designers, museum practitioners, and policymakers, including the need to strengthen user-centered design, enhance technological integration, promote culture collaboration, and develop sustainable digital business models.

Despite its contributions, this study has several limitations. First, the sample is relatively concentrated among young, highly educated users, which may limit the generalizability of the findings to broader populations. Second, the research adopts a cross-sectional design, which restricts the ability to examine long-term user behavior and platform effectiveness. Third, although AIGC technology is discussed as an emerging tool, its practical implementation and impact require further empirical validation. In addition, the economic cost, technical accessibility, and operational sustainability of advanced technologies such as AI and VR were not comprehensively evaluated in this study and require deeper investigation in future research. Future research can expand the sample scope to include more diverse demographic groups and conduct longitudinal studies to explore the long-term effects of digital museum usage on cultural learning and identity formation. In addition, further investigation into the integration of advanced technologies, such as artificial intelligence ethics, digital cultural copyright protection, and immersive metaverse environments. It will be essential to support the sustainable development of digital museums. As digital transformation continues to accelerate, building an intelligent, interactive, and culturally grounded digital museum system will be crucial for preserving and revitalizing intangible cultural heritage in the modern era.

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