ASI Asia Social Issues
ASIA SOCIAL ISSUES 2026; 19(2): 285257
https://doi.org/10.48048/asi.2026.285257
DJMP Center for Digital Journal Management & Multidisciplinary Academic Platform
RESEARCH ARTICLE

Narrative Review on Application of Digital Popular Science Design for the Protection and Dissemination of Chinese Intangible Cultural Heritage

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Received: 27 May 2025, Revised: 16 September 2025, Accepted: 19 September 2025, Published: 30 September 2025

Abstract

With the rapid advancement of digital technology, digital popular science design has shown considerable potential in preserving and disseminating China's Intangible Cultural Heritage (ICH). This research conducts a systematic review of relevant domestic and international literature from 2021 to 2025, supplemented by expert interviews, to examine the current applications and representative cases of digital popular science design in the preservation, restoration, display, and dissemination of ICH. The analysis identifies several challenges, including issues related to information integrity, technological updates, the maintenance of cultural authenticity, and multi-stakeholder collaboration. Employing Heeks's design–reality gap model, the research systematically investigates the implementation gaps between design and practice, and proposes optimization strategies involving technological standardization, deepened cultural integration, expanded dissemination channels, and improved training and management mechanisms. This research aims to provide theoretical and practical insights for the digital popular science design of ICH, ultimately fostering its revitalization in the digital era.

Keywords: Digital popular science design, Intangible cultural heritage, Digital preservation, Cultural dissemination, Technology integration

Introduction

Intangible cultural heritage represents a vital manifestation of national cultural identity and spiritual heritage. Relying on local communities, it embodies profound cultural, ethnic, and regional characteristics. Intangible cultural heritage has become a positive driving force for economic, social, and environmental development (Heritage, U.I.C., 2024). China, with its profound cultural heritage and harmonious multi-ethnic coexistence, has nurtured a rich, diverse, and unique intangible cultural heritage. As a key component of cultural heritage, China's intangible cultural heritage (hereinafter referred to as "ICH") plays a vital role in the prosperity of Chinese culture. Protecting ICH is of great significance for enhancing the nation's cultural confidence, promoting cultural prosperity and development, and promoting Chinese culture (Jin, 2019).

The rapid advancement of modernization and deepening globalization pose significant challenges to the inheritance and dissemination of China's ICH. Many ICH items are constrained by geographical and temporal constraints, making them difficult to disseminate and effectively transcend geographical boundaries. This is particularly difficult for young people living far from their places of origin to access, experience, and gain a deeper understanding of these items. These ICH treasures, such as traditional handicrafts and performing arts, often exhibited with local characteristics, can often only be seen at specific community celebrations or festivals, significantly reducing their dissemination and influence (Liao, 2021). The transmission of traditional intangible cultural heritage often relies on face-to-face instruction between master and apprentice, a cumbersome process that consumes significant time and effort. The quality of intangible cultural heritage

dissemination needs improvement, and young people lack access to and opportunities for exposure to ICH, leading to its gradual decline (Han, 2025). With no successors to ICH, a significant gap in transmission is emerging. Some young people lack a deep understanding of the profound cultural connotations and irreplaceable social and historical value of ICH, leading to a lack of motivation to actively inherit and promote it (Liao, 2021).

Safeguarding and disseminating ICH while preserving its authenticity has therefore become a critical concern for both academics and practitioners. The research will focus on the application of digital popular science design in the protection and dissemination of ICH. By integrating cutting-edge technologies such as virtual reality (VR), augmented reality (AR), and big data analysis, it will provide innovative approaches for the protection and dissemination of ICH. The application of digital popular science design in the preservation of ICH stems from the urgent need to bridge the gap between traditional culture and modern society (Alpatova, 2021). As a medium that transforms complex professional knowledge into accessible and engaging content, digital science design not only enhances public awareness and appreciation of ICH but also inspires cultural pride and identity among younger generations. Of course, the rapid development of digital technology requires continuous innovation in the concepts and practices of science design. While maintaining its appeal and effectiveness, it must also ensure that the unique characteristics and cultural values of ICH are faithfully presented.

This research aims to systematically explore the role of digital popular science design in preserving and disseminating ICH. It seeks to reveal the potential and challenges of digital technology in the digital preservation of ICH. Based on a comprehensive review of relevant domestic and international literature and in-depth interviews, this article will evaluate the practical applications, advantages, and challenges of digital science design and propose optimization strategies. The research will provide theoretical guidance and practical references for the digital preservation and innovative development of ICH, thereby promoting the continued prosperity of ICH and the sustainable development of cultural diversity in contemporary society.

Methodology

To systematically examine the current application and research developments of digital popular science design in the protection and dissemination of ICH, this research adopts a systematic narrative review methodology, supplemented by qualitative interviews to enhance empirical support.

In order to systematically analyze the application status and research progress of digital popular science design in the protection and dissemination of ICH, a systematic search was conducted across four major databases — Science Direct, Springer Link, China National Knowledge Infrastructure (CNKI), and Web of Science —for studies published between 2021 and July 2025. The search keywords included " Intangible Cultural Heritage", "digital popular science design", and "digital protection". After deduplication, a total of 451 documents were obtained, including 19 from Science Direct, 158 from Springer Link, 89 from Web of Science, and 185 from CNKI. To ensure literature quality, the following inclusion criteria were applied: (1) peer-reviewed academic papers or research reports published by authoritative institutions; (2) research topics clearly focusing on the digital protection, dissemination, or popular science application of ICH; (3) studies that provide empirical data, typical cases, or have a systematic analytical framework. Exclusion criteria include: (1) informal publications, such as news reports and interview briefs; (2) commentary and essay articles that lack specific data or method descriptions.

During the data collection and analysis process, the literature content was analyzed using a thematic synthesis approach (Thomas & Harden, 2008). This rigorous process involved three stages: 1) Line-by-line coding of key findings and conclusions from the included literature; 2) Grouping these codes into descriptive themes that summarized prominent patterns and phenomena across the studies; 3) Developing analytical themes by interpreting and synthesizing the descriptive themes to answer the research questions. This process culminated in the generation of four core analytical themes: current applications, challenges, stakeholder responsibilities, and optimization strategies, which structure the Results and Discussion sections

To enhance the comprehensiveness and empirical support of the research, semi-structured in-depth interviews were conducted in July 2025 with three experts in ICH and three managers of ICH centers. The

interview outline focused on the application, effectiveness, and challenges of digital science popularization design. All interviews were recorded and transcribed, and encoded and analyzed using thematic analysis methods. The interview results were used for triangulation to supplement and validate the findings from the literature review, ensuring the depth and reliability of the research findings. Although the research mainly focuses on literature review, clear retrieval strategies, rigorous quality assessment, and systematic comprehensive methods ensure the systematicity, representativeness, and reliability of the research results.

Results

1. Current status of intangible cultural heritage protection and dissemination in China

1.1 Definition of intangible cultural heritage

The Law of the People's Republic of China on Intangible Cultural Heritage (2011) provides a clear definition, stating: "Intangible Cultural Heritage recognized by Chinese law refers to various traditional cultural expressions passed down through generations by people of all ethnic groups and regarded as components of their cultural heritage, as well as the material objects and spaces related to these expressions." Endowed with unique and profound connotations, ICH embodies the essence of human creativity and cultural diversity, characterized by intangibility, vitality, heritability, and sociality (Zhao, 2016). ICH is further categorized into ten major types: folk literature, traditional music, traditional dance, traditional theater, quyi (a genre of Chinese storytelling and ballad singing), traditional sports, acrobatics, and recreations, traditional fine arts, traditional craftsmanship, traditional medicine, and folklore. In China, ICH is classified into four hierarchical levels—national, provincial, municipal, and county—forming a comprehensive and systematic protection framework that encompasses diverse domains of traditional culture.

1.2 Significance of ICH protection and dissemination

ICH is a vital component of human civilization, embodying the unique wisdom and aesthetic values of each ethnic group and a crucial expression of global cultural diversity and human creativity. Protecting and disseminating ICH is not only a respect for historical traditions but also crucial for the construction of contemporary cultural identity and the sustainable development of future societies. Carrying with collective memory and spiritual values, intangible cultural heritage serves as a crucial vehicle for strengthening national identity and enhancing cultural confidence. In the context of globalization, the protection of ICH contributes to maintaining cultural diversity and the uniqueness of local cultures. Furthermore, intangible cultural heritage is a living entity, requiring integration into contemporary society through educational outreach, digital representation, and industrial transformation, enabling creative transformation and innovative development. The protection of ICH also has significant economic and social value, promoting the upgrading of cultural industries, rural revitalization, and the development of cultural tourism. Therefore, the protection and dissemination of ICH is a shared mission for all of society, crucial to national cultural security, harmonious social development, and global cultural coexistence.

2. Applications of digital popular science design in intangible cultural heritage preservation and dissemination

Digital popular science utilizes digital technology to process and store popular science resources, creating works that combine text, graphics, and audiovisual content, and then widely disseminate them through digital technology. Audio, video, animation, virtual reality, simulation, 3D, and 4D imaging technologies are utilized to make the presentation of popular science content more vivid and intuitive (Peng et al., 2024). Digital popular science design can generally be understood as the process of using digital technology to process and store popular science resources and present them to the public in an artistic manner. Digital popular science design focuses not only on the digital presentation of popular science content but also on the interactivity, participation, and experience of popular science activities to satisfy the public's desire to explore scientific knowledge and their need to learn.

To further explore the practical application of digital popular science design in the protection and dissemination of ICH, the research conducted in-depth

interviews with three experts in the field of ICH and three managers of ICH centers. The results showed that the interviewees unanimously believed that digital popular science plays a vital role in the protection and dissemination of ICH. Compared with traditional science popularization methods, digital popular science has the advantages of large information capacity, strong interactivity, fast dissemination speed, and wide coverage. It can break through geographical and time limitations, attract more young audiences, and significantly improve the preservation, restoration, and dissemination efficiency of ICH. At present, the application of digital popular science in the protection and dissemination of ICH is mainly reflected in the following three aspects:

2.1 Digital documentation and preservation

Digital technologies have become instrumental in recording and preserving ICH. Techniques such as 3D scanning, high-resolution photography, and panoramic imaging enable comprehensive, high-precision documentation of ICH artifacts, craftsmanship processes, and performance contexts, generating detailed digital archives. For instance, the Palace Museum in Beijing employs advanced scanning technologies to digitize ancient calligraphy and paintings, preserving their original aesthetic while enabling global accessibility through online platforms. This approach mitigates issues like fading or deterioration associated with traditional paper-based records, ensuring long-term cultural preservation. Similarly, in Suzhou, high-precision 3D scanning of Huqiu clay figurines has produced digital models for virtual exhibitions and cultural heritage education, with 3D printing technology facilitating replicas for exhibitions and educational activities, thereby minimizing handling of fragile originals, as Figure 1. It illustrates the 3D modeling process of Huqiu clay figurines, showcasing how digital technology can capture intricate details for preservation and educational purposes (Li, 2024).

2.2 digital restoration and Reconstruction

With the support of big data analytics and artificial intelligence (AI) technologies, some endangered or lost ICH (ICH) projects have been enabled to undergo intelligent restoration and virtual reconstruction. By systematically integrating multi-source information such as historical documents, audiovisual materials, and oral accounts from practitioners, computer algorithms can achieve high-precision modeling and restoration of the core techniques and artistic forms of traditional crafts. Taking traditional Chinese opera as an example, the application of motion capture technology and artificial intelligence allows not only for the accurate acquisition and digital preservation of performers' movements, but also for the construction of reusable digital asset repositories. These resources ultimately facilitate the activation of traditional opera's contemporary value in multiple scenarios such as education, dissemination, and creative practice. As shown in Figure 2, the AR Peking Opera short film "The Real and Fake Monkey King" demonstrates an innovative representation of traditional opera elements through the deep integration of AR technology and digital opera assets (Li, 2025). AI technology has also shown significant promise in the field of digital conservation of cultural relics. For instance, in the mural restoration practices at the Dunhuang Academy, computer algorithms have been employed to achieve millimeter-level virtual restoration of murals. Furthermore, digital technologies such as virtual reality (VR) and augmented reality (AR) have been utilized to establish an iterative "online + offline" exhibition model, offering new pathways for promoting Dunhuang culture. As illustrated in Figure 3, the effect of AI-assisted restoration of a Dunhuang mural clearly demonstrates notable recovery in pattern details and color gradation (Lu & Zhao, 2025).

2.3. Digital Exhibition and Dissemination

Digital exhibition and dissemination platforms offer innovative avenues for promoting ICH. Technologies such as VR, AR, and multimedia presentations can create immersive experiences with ICH. For example, AR should allow visitors to scan exhibits with their mobile devices, triggering supplementary information and animated presentations to enhance engagement. Web GIS tools can map ICH data (such as shadow puppet performances and artisan profiles), enabling spatial navigation and attribute search (He & Peng, 2025). Regarding social media dissemination, Peking Opera artist Wang Peiyu's short videos on the Douyin platform, which explain vocal

techniques, have garnered 2. 61 billion views and significantly increased public awareness of Peking Opera. Furthermore, digital museums powered by AR technology, such as the digital batik exhibition hall, not only expand educational functions but also significantly broaden their audience reach (Zeng & Li, 2025) . Examples show in Figure 4 and Figure 5. It demonstrates the massive outreach potential of short-video platforms, as evidenced by Wang Peiyu's successful Douyin channel, which has significantly revitalized public interest in Peking Opera.

Figure 1 3D digital model of Huqiu Clay Figurines and its data visualization process
Source Li（2024）. Digital design exploration of Suzhou Huqiu clay figurines from the perspective of ICH protection. New Media Research.

Figure 2 Deep integration of AR technology and traditional opera: The AR Peking opera short film the true and false Monkey King

Source: Li (2025). Practical application of motion capture technology empowering the inheritance and innovation of traditional opera. Shanghai Art Review

Figure 3 Comparative effect of applying digital image processing technology for virtual restoration of Dunhuang murals

Source: Lu & Zhao (2025). "Digital Immortality" of Dunhuang Murals: a Study on the International Dissemination Path of Chinese Culture. New Media and Society.

Figure 4 Comprehensive visualization and interactive experience design of Wuhu iron painting craft based on AIGC technology

Source: Lou (2025). Research on the living inheritance of Anhui ICH handicrafts based on AIGC. Tiangong, 1.

Figure 5 Wang Peiyu's Douyin Channel: A typical case of using short video platforms to achieve mass dissemination of Peking Opera

Source: Douyin App Peiyu Wang

2.4 International experience

Internationally, South Korea, Japan, and Italy each have their own unique approaches to the preservation and dissemination of ICH, supported by digital technology. The "3D Digital Database Project," led by the Cultural Heritage Administration of South Korea, uses high-precision 3D scanning and multi-perspective imaging to establish an authoritative database covering traditional dance, court rituals, and folk crafts. This project emphasizes data standardization and cross-platform sharing, balancing academic research with public outreach (Korea Cultural Heritage Administration, 2023). Dai Nippon Printing (DNP) of Japan collaborates with museums on the "DNP Museum Lab" and "DNP Cultural Promotion Fund Archive Project," utilizing high-resolution imaging, virtual reality, and tactile interaction technologies to achieve precise digital reproduction and long-term preservation of ICH, such as kabuki, ukiyo-e, and washi paper, with an emphasis on enhancing the visitor's immersive experience (DNP, 2025). Italy's "Venice Time Machine" project recreates a millennia-old "virtual Venice" through high-speed document scanning, AI text recognition, and 3D city modeling. Combining digital storytelling to recreate historical and cultural scenes, it achieves a fusion of tangible and intangible heritage restoration (EPFL, 2023).

3. Challenges for digital Popular Science Design

The introduction of digital technology has brought unprecedented opportunities for the protection and dissemination of ICH, but it is also accompanied by multiple challenges such as cultural inheritance, management coordination, and economic benefits. This study will introduce Heeks's application design-reality gap model (Heeks, 2002) to systematically analyze the challenges of digital popular science design in the protection and dissemination of ICH. This model analyzes the gap between digital project design and actual implementation from seven dimensions: information, technology, process, goals, skills, management systems, and other resources. It provides a powerful theoretical tool for us to discover and deeply understand its root causes. The following combines the seven dimensions of the model to explore the specific challenges of digital science popularization design in the protection of ICH:

3.1 Information dimension: Data integrity, cultural authenticity, and privacy protection

Digital popular science relies on high-quality data to record and present ICH content. However, ICH data is often fragmented and unstructured, distributed across diverse communities, archives, or oral records, making it difficult to integrate (Wang & Li, 2022). The interview results of this study are highly consistent with this. An Lizhe, an expert in Chinese intangible cultural heritage, pointed out that "the skills of many old artists only exist in their memory. Once they are not systematically recorded in a timely manner, they will be permanently lost, and digitization is also impossible to talk about." For example, oral histories or details of traditional weaving techniques may be lost due to the aging of inheritors or insufficient documentation, compromising the cultural authenticity of digital archives. Furthermore, the public may misunderstand intangible cultural heritage content due to a lack of context, such as a lack of understanding of the cultural symbolism of Peking Opera singing. As Judijanto (2024) emphasizes, when digitization proceeds without thick contextual annotation, the symbolic meanings of ICH risk being "flattened," resulting in a levelling of cultural understanding. Therefore, digitized archives contain the personal information and sensitive cultural data of inheritors, posing challenges to data leakage and privacy protection. Encryption technologies or access controls are essential to ensure data security and privacy protection (Li, 2023). Improving data collection standards and privacy protection measures to integrate dispersed data and ensure cultural authenticity are key challenges in the information dimension.

3.2 Technical dimension: Technological upgrades, data security, and user access

Digital popular science design must continuously adopt new technologies, such as 3D scanning, virtual reality VR), and augmented reality (AR), to enhance presentation and dissemination efficiency. However, the rapid evolution of technology places high demands on ICH preservation institutions. Many institutions face difficulties upgrading equipment due to funding and

technical constraints. Mao Yan, director of the Intangible Cultural Heritage Center of Hebei Province, admitted in an interview, "We really hope to introduce high- precision VR experience equipment, but its procurement and maintenance costs far exceed our annual budget." Director Mao's statement corroborates the funding challenges identified by Li (2023), suggesting that technological barriers often stem from resource allocation issues rather than technical limitations. Furthermore, users (especially in rural communities or among elderly inheritors) may lack the skills to operate compatible devices or AR/VR interfaces, limiting the widespread adoption of this technology. For example, audiences in remote areas may not be able to use VR devices to experience digital intangible cultural heritage exhibitions. Data security issues further exacerbate this challenge. Cyberattacks and data leaks threaten the security of ICH digital resources. For example, digitized shadow puppetry archives can be tampered with due to network vulnerabilities. Blockchain technology offers a robust solution for ensuring authenticity and traceability. By creating an immutable digital ledger, each ICH work can be assigned a unique digital fingerprint (hash). This record can include "timestamps" to certify the date of digitization and "inheritor seals" (digital signatures) to authenticate the source, making any unauthorized alteration easily detectable (Li, 2023). As predicted by the Heeks model, the challenge in the technological dimension is not only about owning technology, but also about its sustainability, accessibility, and safety, which is a systems engineering that requires continuous investment.

3.3 Process dimension: Compatibility of digital processes with traditional crafts and the innovative balance

Digital popular science design requires integrating traditional intangible cultural heritage crafts with modern digital processes, but there are differences in operational habits and pace between the two. For example, Suzhou Tiger Hill clay figurine production relies on the flexibility of manual techniques, while 3D scanning and modeling require standardized processes, which can result in loss of detail or digital representations that deviate from traditional craftsmanship (Li, 2024). According to observations, the contradiction between "standardization" and "flexibility" is a common challenge in the digitalization process of many manual skills. Digital popular science design also needs to strike a balance between cultural preservation and innovation. When designing digital processes, the uniqueness and authenticity of traditional crafts should be respected, avoiding excessive commercialization or entertainment that dilutes cultural connotations. At the same time, modern aesthetics and technological innovations should be incorporated to attract contemporary audiences (UNESCO, 2003). In an interview, Chinese intangible cultural heritage expert Xiang Zhaolun warned, "Deviations in process design can lead to cultural distortion. We cannot make digital 'Peking Opera' look less like Peking Opera just to pursue cool effects." Therefore, designing digital processes that adapt to the characteristics of intangible cultural heritage and are compatible with both traditional dissemination and innovation is the core challenge of the process dimension.

3.4 Objective dimension: Balancing cultural heritage preservation with commercialization and innovation

The objectives of digital popular science design encompass cultural preservation, market promotion, and cultural innovation, but these goals often conflict. Design may prioritize commercial aesthetics over cultural authenticity. For example, digital museums or AR applications, catering to public entertainment needs, may simplify traditional opera into animated images, diminishing its historical value (UNESCO, 2003). Excessive commercialization can cause ICH to stray from its cultural roots, while innovation that ignores tradition can undermine its authenticity. Literature research has found that this is a common concern. Wang and Li (2022) study also documented the public controversy caused by a digital exhibition's overemphasis on interactivity and neglect of cultural context, which resonates with our findings. Clearly prioritizing cultural heritage preservation as the core goal, while using commercialization and innovation as supporting means, can mitigate these conflicts (Wang & Li, 2022).

3.5 Skills dimension: The skill gap between technicians and inheritors

Digital popular science design requires close collaboration between technicians and intangible cultural heritage inheritors, but differences in their skill sets can make collaboration difficult. For example, technicians may be skilled in VR/AR development but may not understand the cultural context of ICH. while inheritors may be familiar with traditional crafts, they often lack digital skills, making it difficult to adopt or maintain digital systems. This skills gap can lead to low-quality digital content or distorted cultural connotations (Wang & Li, 2022). The representative inheritor of the national ICH project Jingxing La Hua, Wu Xinquan, once said, "I know my skills, but if I were to pass them on through a computer, I would have no idea where to start, and I wouldn't know if what they made was right." This vividly reflects the gap between the "personnel" ability and the "design" requirements emphasized by the Heeks model.

3.6 Management system dimension: Community engagement and organizational coordination

The success of digital popular science design relies on effective organizational management and community engagement, but many ICH preservation projects lack systematic management mechanisms. Community-based ICH management structures (such as local festival organizations) are often overlooked in digital design, resulting in insufficient community engagement. For example, one intangible cultural heritage digital project failed to incorporate community input, resulting in content that was out of touch with local culture (General Office of the State Council, 2022). Chinese intangible cultural heritage expert Dong Xiaolong mentioned in an interview that a digital archive project caused resource waste due to insufficient communication with the community in the early stages, resulting in no one using it after completion. Furthermore, insufficient cross-departmental coordination can lead to wasted resources and project delays. For example, a provincial and municipal intangible cultural heritage digital archive, lacking a unified plan, resulted in duplicated development. Establishing a multi-stakeholder collaborative mechanism, integrating community governance, and clarifying the responsibilities of the government, businesses, and communities are key areas of focus within the management system.

3.7 other resource dimensions: Funding, infrastructure, and Long-Term Maintenance

The implementation of digital popular science design requires significant capital investment and infrastructure support, but many intangible cultural heritage preservation institutions face funding shortages and insufficient technical infrastructure. For example, ICH projects in remote areas may lack high-speed internet or advanced equipment, limiting the promotion of digital science popularization design (Tencent Cloud, 2021). Ongoing technical maintenance and updates require long-term funding, and sustainable funding plans are often lacking. This is not only a problem pointed out by previous researchers, but also the biggest pain point mentioned by all interviewees. Governments, businesses, and social organizations need to jointly invest and provide financial and technical support to ensure the long-term maintenance and sustainable development of digital popular science design.

4. Balancing digital technology with intangible cultural heritage protection and multi-party responsibilities

In supporting the preservation and dissemination of intangible cultural heritage, digital technology must scientifically balance multiple relationships, including technological application and cultural preservation, innovation and traditional inheritance, and economic and cultural benefits. Furthermore, it is necessary to clarify the responsibilities of multiple stakeholders, including the government, inheritors, businesses, and social organizations, to forge a synergistic force and promote the sustainable development and innovative transformation of ICH.

4.1 Balance multiple relationships

4.1.1 Balance between technology and culture

When applying digital technology to protect and disseminate ICH, we must uphold the core importance of cultural connotation. Technological applications should serve as tools to enhance cultural experience, rather than hindering cultural inheritance. For example, when using virtual reality technology to restore traditional opera performances, it is not only necessary

to reproduce the visual effects of the performance, but also to use explanations, background introductions, and other methods to help the audience understand the cultural significance and social value behind the opera. Meanwhile, the application of technology should avoid excessive commercialization and ensure that the cultural value of ICH is not weakened (UNESCO, 2003).

4.1.2 Balance between innovation and tradition

Innovation cannot be separated from tradition, and should be carried out on the basis of respecting and inheriting the cultural traditions of ICH. Digital popular science design can combine modern aesthetics and market demand to creatively design ICH elements, but it cannot change the core skills and cultural connotations of ICH. Meanwhile, traditional ICH can also provide inspiration for digital technology innovation and promote the deep integration of digital technology and ICH. Through this balance, it is necessary to attract young audiences while ensuring the inheritance of the traditional essence of ICH.

4.1.3 Balance between economic and cultural benefits

The primary goal of protecting and disseminating ICH is to achieve cultural benefits, that is, to protect and inherit ICH. When pursuing economic benefits, cultural benefits should not be sacrificed. To transform ICH into products and services with market competitiveness through reasonable commercial operations, obtain economic benefits, and invest these economic benefits into the protection, inheritance, and innovation of ICH, forming a virtuous cycle of cultural and economic benefits.

4.2 Clarify the responsibilities of multiple parties involved

In order to achieve a balanced and sustainable development between digital technology and the protection of ICH, multiple parties need to clarify their responsibilities and work together.

4.2.1 Government's main responsibility

The government should play a leading role in continuously improving the policy and regulatory system for the digital protection of ICH, and provide sufficient resource guarantees for the digitization of ICH through special funds, policy support, and other means (General Office of the State Council, 2022). We need to strengthen the supervision and evaluation of digital ICH projects, establish a scientific evaluation system, regularly evaluate the dissemination effect and cultural heritage value of projects, and ensure that projects comply with cultural protection principles and digital technology standards. In addition, the government should actively promote international cooperation, strengthen exchanges and cooperation with other countries in the digital protection of ICH, learn from advanced experience, and jointly promote the global dissemination of ICH.

4.2.2 Main responsibility of inheritors of intangible cultural heritage

As the core carrier of intangible cultural heritage, inheritors of ICH should actively participate in digital protection work. To establish a sound mechanism for safeguarding the rights and interests of inheritors, clarify their intellectual property rights, economic benefits, and other rights in the digital protection of ICH, and stimulate the enthusiasm of inheritors to participate in the digital protection of ICH (Wang & Li, 2022). At the same time, inheritors should deeply explore the cultural connotations of ICH projects, accurately interpret the value and significance of ICH in the process of digital dissemination, avoid misinterpreting or weakening the cultural connotations of ICH due to digital presentation, and ensure that the authenticity of ICH is reflected in digital dissemination (Ministry of Culture and Tourism, 2019).

4.2.3 Corporate and social organization main responsibility

Enterprises and social organizations should leverage their technological advantages, continuously invest in research and development resources, and explore the application of new technologies in the digital protection of ICH, such as artificial intelligence, virtual reality, blockchain, etc. (Lu et al., 2020), to improve the quality and efficiency of digital protection of ICH. Meanwhile, enterprises and social organizations should utilize their own resources to promote digital products and services of ICH, continuously enhancing the influence of Chinese ICH. In addition, enterprises and social organizations should actively promote the deep integration of ICH with tourism, education, cultural and

creative industries, and develop ICH products with market competitiveness.

Suggestion

Based on the systematic review and field interviews of the application of digital popular science design in the protection and dissemination of ICH, in order to effectively promote its effective application, it is necessary to make systematic efforts from multiple dimensions such as technology, culture, dissemination, talent training and management, to achieve the coordinated development of digital technology and cultural protection, implement the responsibilities of multiple parties, and promote the sustainable prosperity of ICH.

1. Technical aspect: Strengthen research and development and standardize application

Strengthen technological research and innovation, promote interdisciplinary cooperation, encourage universities, research institutions, ICH protection units, and enterprises to establish industry university research cooperation mechanisms, jointly tackle technical bottlenecks in digital protection of ICH, and introduce cutting-edge technologies such as artificial intelligence, big data, blockchain, etc. to explore their application scenarios in ICH protection and dissemination. Establish technical standards and specifications, develop technical standards and specifications for the digital protection and dissemination of ICH, covering various aspects such as digital recording, storage, display, and dissemination, to ensure the quality and compatibility of ICH digital resources. Simultaneously carry out digital technology training activities for ICH inheritors, protection workers, and related technical personnel, promote advanced digital technology achievements and application cases, and promote the widespread application of digital technology in the field of ICH protection and dissemination.

2. Cultural aspect: Deepening connotation and promoting integration

Deep cultural engagement is fundamental to the effective transmission of the value of intangible cultural heritage through digital popular science design. Cultural scholars, ICH inheritors, and related experts should be systematically organized to conduct in-depth research on the historical origins, cultural symbols, and social significance of ICH items, providing a solid theoretical and material foundation for digital content creation. Furthermore, we should encourage the close integration of cultural and creative industries with ICH protection, integrating traditional techniques with modern design concepts to develop cultural and creative products that both embody traditional charm and meet contemporary aesthetics, thereby promoting the innovative development of ICH. During this innovation process, we must strictly adhere to cultural principles, prevent cultural alienation caused by excessive commercialization or entertainment, and ensure that the core values and authenticity of ICH are respected and preserved.

3. Communication level: Expand channels and optimize content

Building a multi- channel, precision- focused digital communication system is key to enhancing the influence of ICH. Online digital platforms and social media should be integrated with offline cultural venues and community resources to achieve cross- sector integration and collaborative promotion, expanding the reach and depth of engagement of ICH. Customized digital science popularization content and communication strategies should be designed and developed for different audience groups, taking into account differences in age, region, cultural background, and interests, to enhance the relevance and effectiveness of communication. Furthermore, we should actively expand international communication channels and promote the production and dissemination of multilingual ICH digital content, thereby enhancing the influence of Chinese intangible cultural heritage in the global cultural market and demonstrating its soft power.

4. The level of talent cultivation: improving the system and incentivizing participation

Universities should offer relevant majors or courses to cultivate composite talents who understand ICH and master digital technology. Simultaneously carrying out vocational training and continuing education activities, setting personalized courses for the

actual needs of ICH inheritors, protection workers, and technical personnel to enhance their professional competence and skill level. In addition, a talent incentive mechanism should be established, and the government and social organizations should set up reward funds to recognize and reward individuals and teams who have made outstanding contributions. And provide broad career development opportunities and promotion channels for digital talents in ICH, such as establishing digital positions in ICH to enable them to showcase their talents.

5. Management and resource assurance: Collaborative governance to ensure sustainability

The successful implementation of digital popular science design projects relies on multi- stakeholder collaboration and systematic management. A governance system involving governments, communities, businesses, and social organizations should be established to clarify the responsibilities and collaborative mechanisms of each party and promote resource integration and efficient utilization. As the core carriers of ICH, communities should be deeply involved in the design and implementation of digitization projects to ensure that digital content aligns with local cultural needs. Furthermore, a sustainable and stable funding mechanism should be established to guarantee the long-term operation and maintenance of digital science design projects, avoid idle resources and project stagnation due to funding gaps, and ensure the continuity and effectiveness of ICH digital preservation efforts.

Conclusion

As an integral part of China' s fine traditional culture, intangible cultural heritage carries rich historical memories, national spirit, and cultural values, and is of great significance for enhancing national cultural confidence and maintaining cultural diversity. The research systematically reviews research on the application of digital popular science design in the preservation and dissemination of ICH between 2021 and 2025. Combined with field interviews and international comparisons, it reveals the enormous potential and multiple challenges of integrating digital technology with ICH preservation. It also proposes optimization strategies, including standardizing technology research and development, deepening the integration of cultural connotations, expanding and personalizing dissemination channels, improving talent training systems, and coordinating management resources. Nevertheless, this research has several limitations. While the literature review covers a wide range, it remains limited by a lack of open data and the geographical concentration of the research sample. The lack of systematic public data on the digitalization practices of some ICH projects limits the depth of the research. Future research should focus on the ethical norms, copyright protection, and community participation mechanisms of digital technology in intangible cultural heritage preservation, explore governance models for interdisciplinary and multi-stakeholder collaborative innovation, further promote the in-depth integration of digital popular science design and ICH preservation, and achieve the creative transformation and innovative development of ICH.

In summary, digital popular science design has opened up a new path for the protection and dissemination of intangible cultural heritage, not only empowering cultural inheritance but also promoting its modern transformation and the realization of its social value. We hope that through the deep integration of technology and culture, China' s intangible cultural heritage will be revitalized in the digital age, contributing further to the protection of cultural diversity and the sustainable development of human civilization.

Acknowledgements

This research project was financially supported by Faculty of Informatics, Mahasarakham University, Year 2026.

Declaration of generative AI in scientific writing

This research uses Generative AI to check grammar and improve key content for readability and better understanding for readers**.**

CRediT author statement

Erjuan Ji: Conceptualization, Methodology, Investigation, Resources, Writing **-** Original Draft**. Worawith Sangkatip:** Software, Validation**. Suwich Tirakoat:** Conceptualization, Writing**-** Reviewing and Editing, Supervision**.**

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