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Research on Digital Experience Game Design for Intangible Cultural Heritage Communication

-- Starting from the "Digital Scripture Cave" of Dunhuang Academy

Binwen Yan

Beijing Forestry University, Beijing 100080, China

Abstract: This study takes Donald Norman's three-level theory of experience design as the theoretical foundation, deeply deconstructs the design strategies of the "Digital Scripture Cave" project by the Dunhuang Academy. Through exploring the advantages and disadvantages of digital intangible cultural heritage (ICH) communication, it proposes a virtual space construction strategy centered on "artistic conception reconstruction". By integrating high-precision digital asset acquisition, embodied interaction design, and the application of symbolic cognition theory, this research provides a systematic design path for digital ICH communication, contributing to the effective inheritance and innovative expression of traditional culture in the digital era. The study shows that "Digital Scripture Cave" has achieved remarkable results in enhancing users' perceptual depth of Dunhuang culture, enhancing the fun of interactive experience, and guiding cultural reflection by breaking through traditional communication models. It provides a reference design paradigm and practical experience for the innovative development of digital ICH communication.

Keywords: Intangible Cultural Heritage Communication; Digital Experience Design; Donald Norman's Theory; Digital Scripture Cave; Perception-Interaction-Reflection Model.

1. Introduction

1.1. Research Background

As a treasure of human civilization, intangible cultural heritage (ICH) carries rich historical memories and cultural connotations. However, under the impact of rapid modern social development and the digital wave, ICH faces challenges such as inheritance disruption, limited communication scope, and loss of young audiences. Meanwhile, the vigorous development of digital technologies has brought new opportunities for ICH communication. More and more cultural institutions are exploring the use of digital technologies to innovate ICH communication methods. As an important force in China's ICH protection and communication, the Dunhuang Academy has launched the "Digital Scripture Cave" project, which reproduces the historical and cultural features of the Scripture Cave through digital means, arousing widespread attention in the field of digital ICH communication and becoming a typical case of great research value [1].

Digital ICH communication needs to clarify its strategic positioning, integrating cultural inheritance with modern experience needs. The core lies in constructing an immersive cultural scene, awakening users' emotional resonance with traditional culture through the "artistic conception" reconstruction of virtual spaces. Taking the Dunhuang Academy's "Digital Scripture Cave" as an example, the project breaks through the static display mode of traditional cultural relics[5]. With the narrative main line of "traveling through thousands of years to dialogue with history", it transforms the historical profoundness of the Scripture Cave into a perceptible and participatory digital experience through scene restoration, character interaction, and plot deduction, establishing a strategic model for digital ICH communication.

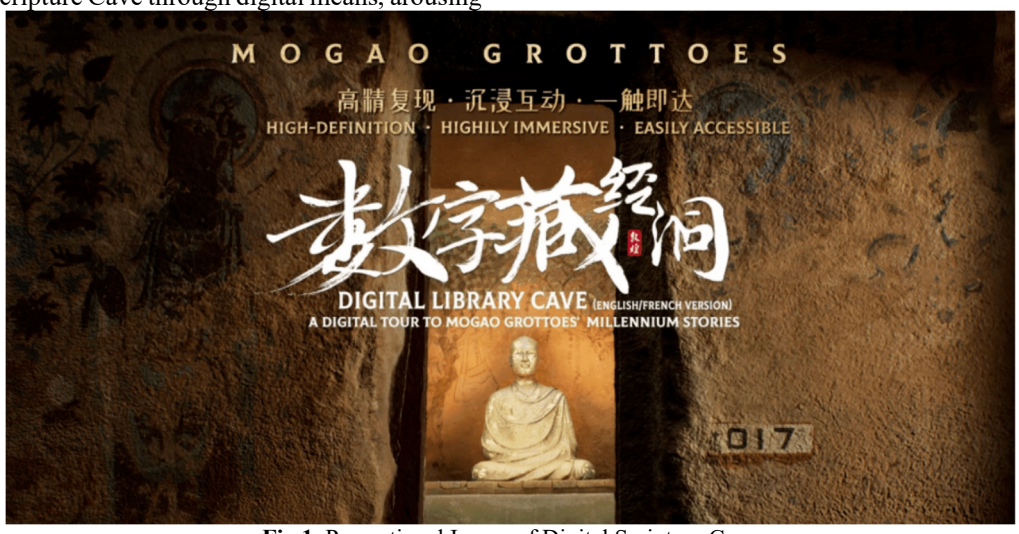

Fig 1. Promotional Image of Digital Scripture Cave
(Image Source: Dunhuang Academy)

1.2. Research Purpose and Significance

This study aims to deeply analyze the design strategies and practical experience of the "Digital Scripture Cave" project, reveal its innovations and success factors in digital ICH communication, construct a theoretical model applicable to digital ICH communication, and provide theoretical guidance and practical references for the digital communication of other ICH projects. Theoretically, it helps enrich the research achievements of digital experience design in the field of ICH communication and expand the application boundaries of related theories. Practically, it can provide operable design methods and ideas for ICH cultural institutions and design teams, promote the innovative development of digital ICH communication[6], enhance the influence and communication power of ICH culture, and facilitate the inheritance and protection of ICH.

1.3. Research Status

Scholars at home and abroad have carried out extensive research in the fields of ICH protection and communication, as well as digital experience design. In terms of ICH protection and communication, foreign studies focus on protection through legislation, establishing cultural heritage databases, etc., and use new media, virtual reality, and other technologies to enhance cultural experiences in communication. Domestic scholars have also actively explored paths for combining ICH with modern technologies, such as using short videos, live broadcasts, and other platforms to promote ICH culture. In the field of digital experience design, Donald Norman's three-level theory of experience design (instinct level, behavior level, reflection level) has been widely applied in product design, interaction design, and other fields, but systematic application in digital ICH communication research remains relatively limited.

In foreign studies, digital experience design in game development is a multi-dimensional research field integrating narrative construction, user interaction, emotional resonance, and educational potential. Jantke (2009) was the first to emphasize the core role of dramaturgical design in non-linear game spaces, proposing that systematic story integration can significantly enhance the immersion of digital games through artificial intelligence planning for engaging narrative architectures[4]. On this basis, Jantke et al. (2012) further pointed out that the application of storyboarding and taxonomic concepts is crucial for narrative construction in educational games, and an orderly narrative framework is the key to ensuring the effective delivery of educational goals. Emotional drive and educational value constitute important dimensions of digital experience design. Li (2010) found through empirical research that primary school students' emotional investment in game construction and experience can promote the formation of participatory culture, indicating that emotional resonance is the core driving force for constructing deep digital experiences[5]. Navarrete's (2013) study on middle school students' game creation showed that despite technical challenges[6], the sense of satisfaction and interactive experience brought by the creative process remain decisive factors in shaping positive learning effects[7].

In the context of lifelong learning, Romero et al. (2017) proposed a full-cycle design framework integrating learning theories, narrative construction, game mechanics, and user experience, highlighting the need to integrate educational and experiential aspects[8]. Aguiar et al. (2018) laid a theoretical foundation for constructing efficient educational digital games by systematically sorting out existing design models and learning theories[9].

Research on emotional and cultural dimensions has further deepened the understanding of digital game experiences. Bednorz (2020), taking *Emily Is Away* as an example, revealed how emotional design conveys complex emotions such as love and loss through digital media[10]. Wilhelmsson et al. (2021) confirmed through mixed-media game research that the integration of physical and digital activities can create special experiential fields, triggering players' in-depth thinking on social and personal levels.

Most existing studies focus on technical applications or discussions of single communication models, lacking in-depth and systematic research on digital ICH communication from the perspective of the entire experience design process, leaving room for theoretical innovation and practical exploration for this study. In summary, existing research collectively shows that digital experience game design is essentially a dynamic balancing process of narrative architecture, emotional interaction, interface optimization, educational integration, and cultural adaptation. Future research needs to further explore how to construct a systematic design framework from the multi-dimensional perspectives of cognition, emotion, and social interaction to create more in-depth and lasting digital experiences.

2. Theoretical Foundation: Donald Norman's Three-Level Theory of Experience Design

Donald Norman's three-level theory of experience design, proposed in his work “The Design of Everyday Things”, divides user experience into three levels: instinct, behavior, and reflection. The instinct level is the user's first impression of a product or service, mainly based on direct reactions to sensory stimuli such as vision, hearing, and touch, involving aspects like appearance modeling, color matching, and material texture. The behavior level focuses on the operational convenience, functional practicality, and interaction fluency during user use, emphasizing whether the product or service can meet users' actual needs. The reflection level focuses on users' emotional resonance, cultural identity, and value thinking after use, involving the cultural connotations and emotional meanings conveyed by the product, as well as the self-cognition and social identity generated by users. These three levels are interrelated and progressive, jointly constituting a complete user experience system[11].

Applying Donald Norman's three-level theory of experience design to the field of digital ICH communication helps systematically analyze and optimize digital ICH communication projects from the perspective of user experience. At the instinct level, exquisite visual design and realistic sound effects can quickly attract users' attention and stimulate their interest in ICH culture. Design at the behavior level ensures convenient operation, clear functions, and smooth interaction during users' digital experience, enhancing user participation and experience satisfaction. The reflection level can guide users to deeply understand the connotations and values of ICH culture, strengthen users' sense of identity and inheritance responsibility for ICH culture, thereby

achieving effective communication and inheritance of ICH culture. This theory provides a scientific theoretical framework and analytical perspective for the design, evaluation, and improvement of digital ICH communication projects [12].

3. Overview of the "Digital Scripture Cave" Project by Dunhuang Academy

3.1. Project Background and Objectives

As an important heritage of human civilization, the Dunhuang Scripture Cave preserves Buddhist scriptures, social documents, and artworks from the 4th to the 11th century, witnessing the multicultural integration of the Silk Road. Due to historical reasons, the cultural relics in the cave are scattered worldwide, restricting physical protection and display, making it difficult for the public to have close contact and hindering academic research due to resource dispersion. Nowadays[13], with the development of information technology and the advancement of Digital China construction, the digital protection of the Scripture Cave has obtained technical support.

Since the proposal of the "Digital Dunhuang" concept in the 1980s, a large amount of experience and resources have been accumulated, and significant achievements have been made in Dunhuang studies. However, Su Bomin, Director of the Dunhuang Academy, pointed out based on more than 30 years of work experience that the thousand-year-old civilization is enough to make every Chinese son and daughter proud, but many people have limited depth and breadth of understanding of national cultural heritage. How to optimize the presentation and interpretation of achievements and resources to communicate with a broader audience has become an important issue urgently to be solved by the Dunhuang Academy[14].

The "Digital Scripture Cave" project is a trans-temporal participatory museum jointly created by the National Cultural Heritage Administration, the Dunhuang Academy, and Tencent. It aims to construct a virtual cultural heritage space through digital technologies, allowing the cultural relics of the Scripture Cave to "come alive" in a new way. It establishes a high-precision and systematic digital archive of Scripture Cave cultural relics, providing permanent data support for cultural relic protection and research. It also requires presenting traditional cultural values in high definition within a short time, enabling the thousand-year-old Dunhuang culture to cross time and space restrictions and return to modern life in a more vivid and friendly way through "immersive" and "participatory" interactive experiences, entering the vision of more people. This exploration is not only an upgrade of the Dunhuang cultural heritage protection model but also an innovative practice of the inheritance and communication path of ICH culture in the digital era.

Fig 2. Project Interface Design
(Image Source: Tencent Games Official Account)

3.2. Core Content and Technical Applications of the Project

The "Digital Scripture Cave" project has achieved high-precision digital reconstruction and immersive communication of the Dunhuang Scripture Cave through multi-technology integration, providing a typical paradigm for the digital activation of cultural heritage. At the content construction level, the project is based on millimeter-level 3D modeling technology, carrying out panoramic reproduction of Mogao Caves 16 and 17 and the surrounding cliff faces. It has processed more than 30,000 high-resolution images in total, generating a digital model containing 900 million triangular meshes, accurately restoring the color of murals, texture of painted sculptures, and architectural structure details. Through the "Cloud Tour Dunhuang" mini-program, users can enter the virtual cave, zoom in to view the brushstrokes of the flying Apsaras' ribbons and the text details of sutra inscriptions from a "dynamic perspective," and even simulate the light and shadow changes of the real visit scene by "turning on the lights" to light up the corridor and inscriptions layer by layer[15]. At the same time, the project embeds a "time travel" narrative module, allowing users to choose four historical nodes (such as the late Tang and Northern Song dynasties), interact with eight historical figures such as Monk Hongbian in a role-playing way, gradually unlock the historical context behind documents like the *Guiyijun Yafu Jiu Poli* by completing mini-game tasks such as cultural relic sorting and document deciphering, and finally enter the cross-

regional digital exhibition hall to browse the Scripture Cave cultural relics collected by the Dunhuang Academy and overseas institutions in France, Britain, etc., constructing a trinity cultural cognition path of "spatial immersion - temporal narrative - knowledge system".

In the dimension of technological innovation, the project breaks through the technical bottlenecks of traditional cultural relic digitization: First, it introduces photogrammetry technology from game development. Through multi-view image acquisition and computer vision algorithms, it achieves millimeter-level precision in 3D modeling of cultural relics, increasing efficiency by more than 70% compared with traditional manual surveying and mapping, providing a reusable technical process for large-scale cultural relic digitization. Second, it adopts a technical chain of "digital scanning + virtual restoration + physical rendering", restores the color of faded murals through spectral analysis and algorithm optimization, and uses PBR (Physically Based Rendering) technology and 4K texture mapping to make the virtual materials maintain optical consistency under different lighting conditions[16]. The visual realism of the main Scripture Cave model (20 million triangular meshes) and the Hongbian Statue (10 million triangular meshes) reaches film and television standards. Third, it develops a dynamic global lighting system, combining Precomputed Radiance Transfer (PRT) with adaptive sparse probe technology to achieve real-time switching between outdoor natural light and indoor artificial light on mobile terminals. It not only ensures the physical accuracy of light and shadow effects but also compresses 36GB of digital assets through cloud rendering technology, increasing the mini-program loading speed by 40%, breaking through the compatibility problem of "high-precision models and low-end devices".

The practical value of this project is reflected in the dual dimensions of technological cross-border and communication model innovation: On the one hand, it deeply integrates digital technologies such as game engines and cloud rendering with cultural relic protection, creating an inheritance activation path of "technological restoration - narrative reconstruction - experience innovation". On the other hand, through the design framework of "multimodal interaction + trans-temporal narrative + knowledge graph", it transforms static cultural relics into dynamic cultural narrative carriers. Users complete the identity transformation from "bystanders" to "participants" in role-playing and task-driven processes, effectively improving the modern communication efficiency of cultural heritage. Its technical experience and narrative strategies provide replicable methodologies for digital ICH communication, especially with broad reference significance in fields such as cross-regional cultural resource integration and immersive educational scene construction.

3.3. Analysis of Design Strategies of the "Digital Scripture Cave" Project

3.3.1. Instinct Level: Multisensory Immersive Visual and Auditory Design

Cultural relic display in the digital era has shifted from the linear display of "centering on objects" to the perceptual experience construction of "centering on users". As Shao Lingyan pointed out in “Research on Interactive Display Design of the Medicine Master Sūtra Transformation Painting in Mogao Caves Based on Embodied Phenomenology”, simple image reproduction cannot restore the viewer's physical perception and cultural experience of cultural relics. The "Digital Scripture Cave" achieves a breakthrough in the display paradigm through dual design in spatial and temporal dimensions: In the spatial dimension, it constructs a 1:1 digital panoramic cave, allowing users to freely zoom in on the perspective through mouse interaction and feel the spatial depth of the cave. In the temporal dimension[17], it designs the plot from the perspective of a "time traveler", and users advance the story by interacting with virtual characters (such as the celestial bird Garuda), breaking the passive viewing mode of traditional displays and establishing an emotional connection.

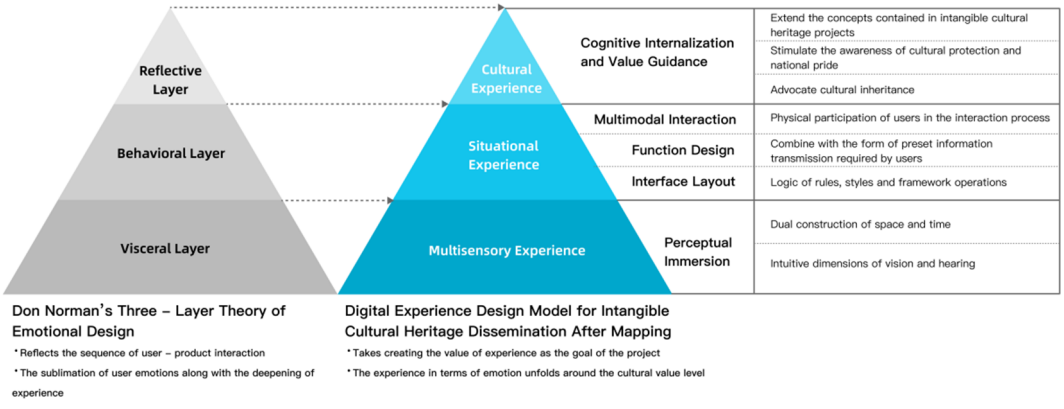

Fig 3. Digital Experience Design Model for the Dissemination of Intangible Cultural Heritage

At the instinct level, the "Digital Scripture Cave" project quickly captures users' attention and stimulates their exploration desire through multisensory immersive design. In visual design, it uses high-precision image acquisition and 3D modeling technologies to realistically restore the color, texture, and details of the murals in the Scripture Cave, making the figures and story scenes on the murals come alive. At the same time, it uses dynamic light and shadow effects to simulate the natural light changes in the cave, creating a mysterious and realistic atmosphere. In terms of cave space design, it constructs a 3D model according to a 1:1 scale. After users enter the virtual cave, they can feel the depth and hierarchy of the space, as if they are in the real historical scene. In auditory design, the project team deeply studied the historical culture and musical characteristics of the Dunhuang region and created exclusive background music. The music integrates the unique timbres of Western Regions instruments such as the pipa and konghou, with a melodious and gentle

melody, which not only reflects the exotic customs of Dunhuang culture but also matches the quiet atmosphere of the cave. In addition, it adds rich environmental sound effects, such as the wind sound, dripping sound in the cave, and the subtle sound of flipping through scriptures, further enhancing the realism and immersion of the scene, allowing users to obtain a shocking first impression from multiple dimensions of vision and hearing [18].

3.3.2. Behavior Level: Multimodal Interaction and Functional Optimization Design

The theory of embodied cognition emphasizes the importance of physical perception in cognitive formation. In digital ICH communication, multimodal interaction technology can enhance users' physical participation. In terms of touch, “DreamAbion” is inspired by the Tang Dynasty “Zhenzhongji”, and simulates the tactile changes in dreams through a pressure-sensitive device. In terms of smell, the 2025 Central Academy of Fine Arts graduation project *Miracle* takes Dunhuang incense culture as the carrier and develops a customized fragrance system, making smell a new medium for cultural narrative. The "Digital Scripture Cave" project reduces the "dizziness" in digital experience through low-latency rendering technology and high-resolution image output, achieving the deep integration of operation logic and cultural experience.

At the behavior level, the "Digital Scripture Cave" project focuses on multimodal interaction design and functional optimization to ensure convenient operation and smooth interaction during users' experience. In terms of multimodal interaction, in addition to traditional mouse and keyboard operation methods, it also introduces new interaction methods such as gesture recognition and voice interaction. Users can achieve operations such as scene switching and cultural relic zooming through simple gesture actions like waving and nodding; they can query cultural relic-related information and listen to explanations using voice commands, which reduces the operation threshold and improves the naturalness and fun of interaction. In functional design, the project fully considers users' needs and provides a variety of functional modules. For example, it sets up a "Cultural Relic Details" module, where users can obtain detailed text introductions, high-definition pictures, and expert interpretation videos by clicking on interested cultural relics; the "Story Mode" module interprets historical stories and legends related to the Scripture Cave in the form of animations, enhancing the vividness of cultural communication; the "Personalized Collection" function allows users to add favorite cultural relics and scenes to the collection, facilitating review and sharing at any time. In addition, it optimizes the interface layout, adopts a simple and clear design style, highlights important function buttons, and the operation process is clear and easy to understand, ensuring that users can easily get started and enjoy a smooth digital experience.

3.3.3. Reflection Level: Cultural Cognition Mapping and Value Guidance Design

At the reflection level, the "Digital Scripture Cave" project helps users deeply understand the connotations and values of Dunhuang culture, triggering emotional resonance and cultural reflection through cultural cognition mapping and value guidance design.

In terms of cultural cognition mapping, the project correlates and interprets the cultural relics in the Scripture Cave with relevant historical and cultural knowledge, as well as artistic achievements. For example, when displaying murals, it not only presents their artistic beauty but also deeply analyzes their painting techniques, theme sources, historical backgrounds, etc., allowing users to understand the profound cultural heritage contained in the murals. Meanwhile, by comparing and displaying similar cultural relics from different periods and regions, it guides users to recognize the important status and role of Dunhuang culture in cultural exchanges between China and foreign countries.

In value guidance design, the project stimulates users' cultural protection awareness and national pride by telling the story of the discovery, loss, and protection of the Scripture Cave cultural relics. During the experience, interactive links such as the "Cultural Relic Restoration Challenge" game are set up, enabling users to personally experience the hardships of cultural relic restoration and enhance their understanding and respect for cultural relic protection work. In the process of time-traveling stories and cave exploration, the Dunhuang Notes in the control panel at the upper right corner of the interface are updated, integrating scattered information into a thematic whole for users to review. Under such connection, the fragments collected by users seem to piece together an epic, which can more effectively stimulate users' emotions, leave a deep impression, and achieve the goal of value transmission.

In addition, the "Cultural Inheritance Initiative" activity is launched to encourage users to share their experience feelings and understanding of Dunhuang culture on social platforms, forming a diffusion effect of cultural communication, and guiding users to transform from passive cultural receivers to active cultural disseminators and inheritors.

4. Design Insights of the "Digital Scripture Cave" Project for Digital ICH Communication

4.1. Focus on Multisensory Experience Design to Enhance Cultural Attraction

The core of digital ICH communication is to construct an immersive experience through multisensory collaborative design, transforming abstract cultural connotations into perceivable concrete experiences to address the dilemmas of obscure cultural connotations, scattered and obsolete objects, and the difficulty of effective connection in traditional display methods in ICH communication. Digital technology can create multisensory collaborative immersive experiences, centrally presenting core cultural elements and forming a strong sensory impact, which not only breaks through the limitations of ICH cultural display but also meets the communication needs of the information age. At the visual level, high-fidelity digital acquisition technology can be used to record the physical form characteristics of ICH, and dynamic visual narrative techniques such as light and shadow changes and particle special effects can be used to reproduce dynamic processes; auditory design needs to break through the simple background music mode, restore the original soundscape through spatial audio technology, and use voiceprint analysis technology to deconstruct the melodic characteristics of musical ICH to generate interactive experiences; emerging cross-modal perception technologies such as tactile feedback devices and olfactory simulation technologies provide more possibilities for ICH experiences. Touch can simulate the texture of traditional handicraft materials, and smell can restore the atmosphere of cultural

scenes or design fragrances based on ICH concepts. Multisensory collaborative stimulation can activate users' synesthetic associations and form deeper cultural memories.

4.2. Innovate Interaction Methods to Enhance User Participation

Digital ICH communication urgently needs to break through the traditional one-way display mode and construct a cultural experience system centered on user participation. Interaction design should follow the logic of "progressive cognition" and build a three-level information architecture of "macro-meso-micro": the macro level presents the overall context and ecological system of ICH culture from a panoramic perspective, such as outlining the cultural panorama through digital maps or timelines; the meso level focuses on specific entities, decomposing ICH projects into perceivable element modules. For example, in the Digital Scripture Cave project, the content is divided into two modules: cultural relic display and time-traveling historical narrative, achieving a structured presentation of core cultural elements; the micro level goes deep into the details and textures, adopting a "two-level interface" design - when users engage in entity interaction, they first obtain an overall cognition through the first-level interface (such as perspective zooming and locking with a brief introduction), and then can independently trigger the second-level interface, focusing on local details such as gilded key words in murals and the dynamic unfolding of scriptures through perspective rotation, object lighting/enlargement special effects, or action guidance, supplemented by multi-dimensional interpretations.

In the innovation of interaction forms, digital technology injects multiple possibilities into ICH communication: first, body interaction allows users to imitate the movements of ICH skills such as calligraphy and traditional dance through motion capture technology, and the system provides real-time feedback and correction suggestions simultaneously, constructing an embodied cognitive experience; second, social collaboration creates a virtual identity system of "ICH guardians", combined with check-in mechanisms, digital poster generation, and knowledge achievement sharing functions, transforming individual experiences into shareable social currency, and realizing cultural diffusion and knowledge exchange among users through the Internet ecology; third, gamified exploration deeply integrates game elements such as role-playing, combat puzzle-solving, and card collection with ICH narratives, wrapping cultural cores in lightweight and entertaining carriers, allowing users to naturally unlock ICH knowledge and its historical origins in immersive storylines, achieving the communication goal of "learning through fun". This multi-level interaction system not only conforms to the human cognitive law but also activates the contemporary communication vitality of ICH culture through technological empowerment.

4.3. Deepen the Excavation of Cultural Connotations and Guide Cultural Reflection

The deep value of digital ICH communication lies in constructing cultural cognition that can be internalized, which requires building a complete interpretation system: analyzing the composition of traditional patterns and extract visual symbols at the formal level, deconstructing the technological processes of materials and tools at the technical level, and interpreting abstract connotations such as ecological ethics in the thought of creation at the cultural level; the "comparative interpretation" strategy can be adopted, showing the modern transformation of traditional wisdom through vertical ancient-modern evolution comparison, and revealing the traces of civilization exchange through horizontal cross-cultural comparison, helping users establish a systematic cultural cognitive framework. In terms of value guidance, taking participatory inheritance as the design direction, endow users the identity recognition of "cultural guardians" through interactions such as virtual cultural relic restoration and digital preservation of skills, establishing a user contribution system to encourage uploading ICH clues, sharing oral history, and supplementing data visualization, transforming one-way communication into joint creation, and strengthening the sense of responsibility for cultural inheritance.

5. Conclusion and Prospects

Based on Donald Norman's three-level theory of experience design, this study analyzes the "Digital Scripture Cave" project and finds that it constructs three mechanisms of immersive narrative, multimodal interaction, and cultural cognition mapping through multisensory immersion at the instinct level, multimodal interaction and functional optimization at the behavior level, and cultural cognition mapping and value guidance at the reflection level, providing a design paradigm for digital ICH communication. Future research can expand the types of ICH projects, explore the innovative applications of technologies such as artificial intelligence and the metaverse in digital ICH communication, and strengthen the long-term tracking and evaluation of communication effects to promote the sustainable development of ICH culture in the digital era.

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