

A Study on the Interactive Communication Path of the Dunhuang Manuscript Heritage Diamond Sutra Based on Serious-Game Narratives

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Abstract. This article takes the Dunhuang manuscript heritage Diamond Sutra as a focal case to examine pathways for re-narrating Dunhuang heritage within the discourse of digital humanities. It finds that existing digital applications for Dunhuang manuscripts largely concentrate on image scanning and bibliographic archiving. While such practices realize a form of “formal preservation” in the digital sense, they remain limited in terms of interactive communication—particularly for adolescent audiences. To address this constraint, the study begins with the Diamond Sutra’s historical conditions of emergence, approaching the topic through the lens of craftsmanship and production. It proposes translating the scroll-making process into a participatory digital experience so that users can learn about Dunhuang manuscript culture through embodied engagement. The proposed experience follows a framework of “narrative transposition plus gamified mechanisms,” integrating narrative design, serious games, and mixed-reality technologies (AR/MR). The results suggest that this design paradigm can help convert Dunhuang manuscript heritage from “cold data” into a “warm experience,” injecting new vitality into youth education and offering a viable practical route for the contemporary articulation of Dunhuang manuscript culture.

Keywords: Dunhuang manuscripts, Diamond Sutra, cultural heritage communication, youth education, narrative translation + gamification mechanisms

1. Introduction

With the continuous development of the digital humanities, the digital preservation of Dunhuang heritage has been steadily advancing. Initiatives such as “Digital Dunhuang” and the “International Dunhuang Project (IDP)” have achieved high-resolution scanning, image archiving, and online presentation of Dunhuang manuscript artefacts, laying a solid foundation for document preservation and scholarly research [1].

However, existing achievements largely remain at the level of technical documentation, with limited cultural engagement and educational outreach in terms of audience experience and interaction. As a crucial link in understanding and communicating the significance of cultural heritage, it is essential to employ innovative media and narrative approaches to strengthen public—

especially youth—cognition of and emotional connection to Dunhuang culture, thereby creating digital heritage experiences that are more compelling and participatory [2].

This study takes the Dunhuang manuscript Diamond Sutra as its point of departure to explore dynamic narrative and experiential communication pathways for cultural heritage within the context of the digital humanities [3]. Unlike previous studies that focus primarily on technological reconstruction and scholarly display, this paper emphasizes how digital media can animate the craft value of Dunhuang manuscripts and foster emotional engagement among young audiences [4]. Through narrative and gamification strategies, the study aims to build a digital communication model that integrates educational value with cultural experience, and to investigate mechanisms for the regeneration of cultural heritage in virtual environments. The significance of this research lies in promoting a shift in cultural heritage communication—from “preservation” to “experience” and from “technical presentation” to “cultural regeneration.” It offers new perspectives and methodological insights for the contemporary reinterpretation of Dunhuang art, the presentation of digital heritage, and youth education in cultural heritage.

2. The cultural value of the Dunhuang manuscript Diamond Sutra and its contemporary digital context

2.1. Historical significance and technological innovation

The Dunhuang manuscript Diamond Sutra (Figure 1), currently housed in the British Museum, was unearthed from the Library Cave of the Mogao Grottoes and printed in the ninth year of the Xiantong reign (868 CE) of the Tang dynasty. As the world’s earliest extant printed book with a verified date, it stands as a milestone in the history of printing technology and exemplifies the deep integration of Tang-dynasty craftsmanship, aesthetic sensibilities, and Dunhuang culture [5].

From the perspective of craft value, this manuscript artifact signifies the maturation and refinement of Tang-dynasty woodblock printing. An examination of the scroll itself reveals a layout that is orderly and well-proportioned, with images and text integrated in a natural, balanced manner and with a clear, harmonious visual hierarchy. Such a polished mode of presentation fully demonstrates the exceptional technical mastery of Tang artisans in woodblock printing. At the same time, the wider diffusion of woodblock printing markedly increased the efficiency with which such scrolls could circulate, thereby facilitating the formation and development of the Dunhuang cultural system.



Figure 1. Woodblock-printed Dunhuang Diamond Sutra (source: British Museum)

2.2. The Diamond Sutra as Dunhuang manuscript heritage in the contemporary digital context

As a representative work within the Dunhuang manuscript corpus, the Diamond Sutra has been systematically preserved and disseminated through various international digitization projects and open-access platforms. Its digital construction has primarily taken shape at the level of scholarly databases and image repositories.

The International Dunhuang Project (Figure 2) is the most authoritative digital database for Dunhuang studies, jointly initiated by the British Library and partner institutions in China, France, Japan, Russia, and other countries. The platform provides comprehensive cataloging data, provenance records, and material descriptions for the Diamond Sutra, establishing its status as a digital primary source in international scholarly research [6]. The Digital Dunhuang Resource Platform (Figure 3) uses high-precision photography and panoramic imaging to construct systematic digital models of the Mogao Grottoes and their murals. It includes visual materials related to the Diamond Sutra, such as Diamond Sutra Transformation Scenes and Buddhist ritual depictions. Although the printed scroll itself is not directly exhibited, the platform contextualizes the manuscript by reconstructing its visual connections with grotto spaces and mural imagery, forming a “text–image–space” pathway for research [7]. The Digital Library Cave Project (Figure 4), centered on the manuscripts from Mogao Cave 17, adopts digital acquisition and image processing to provide global access to manuscript materials, thus expanding avenues for Dunhuang research and public education [8]. Projects such as the “Digital Dunhuang Immersive Exhibition” (Figure 5) attempt to integrate spatial narrative with Dunhuang manuscripts. Nevertheless, they remain primarily image-oriented and lack mechanisms for game-based storytelling and interactive engagement. As a result, the craft logic and cultural depth of the Diamond Sutra are still difficult to fully perceive or reconstruct in digital environments [9].

Overall, these initiatives have made major advances in document preservation and the standardization of scholarly data. However, their focus remains largely on technical documentation. Existing platforms are structured around archival materials and image presentation, emphasizing knowledge storage and academic utility, but they provide limited opportunities for immersive experience or audience participation—an issue particularly evident in youth education. At present, education on Dunhuang manuscripts relies mainly on classroom instruction, thematic exhibitions, and digital platforms. Schools use image materials and textual explanations; museums and cultural institutions offer exhibitions and study programs for direct engagement; and online projects such as “Digital Dunhuang” extend learning through virtual exhibitions and 3D modeling [10]. Yet these formats remain centered on information transmission and lack mechanisms that foster emotional resonance and active participation. They rarely inspire young people to develop creative, self-motivated interest in Dunhuang culture. Therefore, the key issue addressed in this study is how to break away from a “data-display” model of digital heritage for Dunhuang manuscripts and explore pathways of cultural communication that transform “cold data” into “lived experience.”

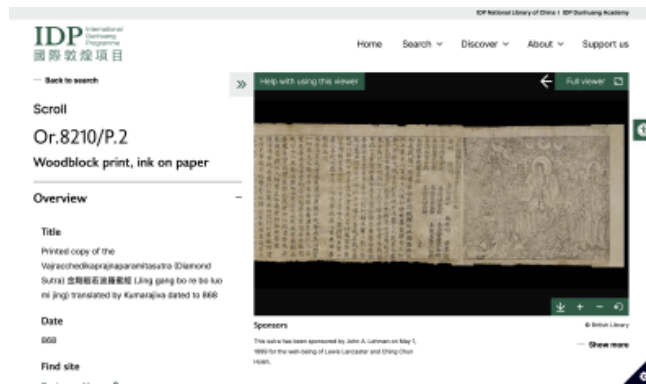


Figure 2. Screenshot of the International Dunhuang Project (IDP) platform (source: IDP)



Figure 3. Screenshot of the digital Dunhuang resource platform (source: digital Dunhuang)



Figure 4. Screenshot of the digital library cave project (source: Dunhuang academy)



Figure 5. “Digital Dunhuang Immersive Exhibition” (source: Xinhua News Agency)

3. Narrative translation and the integration of serious games: a new pathway for interactive communication

3.1. The logic of “serious games” and “narrative translation”

Within the broader field of digital humanities, the presentation of cultural heritage has been shifting from static display toward experiential participation [11]. The combined use of serious games and narrative translation provides new pedagogical and narrative approaches for cultural dissemination.

Relevant studies indicate that serious games differ from entertainment-oriented games, as their core lies in the achievement of specific objectives such as education, training, and cognitive development. As defined by Michael and Chen: “Serious games are games that do not have entertainment, enjoyment, or fun as their primary purpose” but are instead “designed to educate, train, and inform players through game-based systems” [12]. Concurrently, the structured design of gamification mechanisms can enhance learning motivation and engagement. Deterding et al. conceptualize gamification as “the use of game design elements in non-game contexts” and note that components such as points, levels, feedback, and challenges can “increase motivation and engagement” [13].

In recent years, numerous practical projects have validated the effectiveness of serious games in cultural heritage education. For example, a VR serious game developed from the color system of Dunhuang murals [14] (Figure 6) showed that players significantly outperformed traditional virtual exhibition users in knowledge comprehension and memory retention. A gamified virtual museum featuring Chinese bronzes (Figure 7) used tiered missions and curatorial experience design [15], resulting in clear improvements in learning outcomes. Similarly, In the study by Ali, a VR serious-game designed for Saudi architectural heritage ‘immerses players in cultural scenes, fostering a lasting appreciation for art history,’ and participants reported ‘increased interest in Saudi cultural heritage and appreciation for VR technology’ after gameplay [16]. Moreover, as shown in Huang & Lin’s meta-analysis, game-based interventions in museums typically yield small-to-moderate gains (0.20–0.50 effect sizes), equivalent to roughly 10%–30% improvements in knowledge acquisition, engagement duration, and motivation [17]. These examples underline the capacity of serious games to transform cultural heritage from “passive information” into “participatory scenarios,” enhancing young audiences’ understanding of historical craftsmanship and deepening emotional identification. This provides both practical grounding and theoretical support for designing a serious game centered on the Dunhuang Diamond Sutra.



Figure 6. VR serious game based on Dunhuang mural color systems [14]



Figure 7. Gamified virtual museum of Chinese bronzes [15]



Figure 8. VR experience of Saudi architectural heritage (UNESCO)

3.2. Practical insights for digital cultural heritage presentation: integrating AI guidance with AR/MR narrative systems

At the level of concrete technological implementation (Figure 9), this study integrates an AI-based digital guide, AR/MR spatial construction, user-interaction tracking, and an affective feedback system, among other technical approaches [18], to build a virtual, immersive experiential environment centered on the craft-based production process of the Diamond Sutra. The AI digital guidance system, enabled by speech recognition and goal-oriented prompting, functions as a “facilitator” within the space, providing audiences with interactive guidance that conveys

informational content with an affective, human-like warmth. AR/MR technologies, through the fusion of virtual and physical elements, establish an immersive contextual setting for the Diamond Sutra’s production process, allowing users to explore the craft environment behind the Dunhuang Diamond Sutra within the immersive space. The user-interaction tracking system, supported by gesture tracking and spatial positioning, enables audiences to participate in a simulated manuscript-making workflow, thereby deepening their understanding of the production procedure and its historical context. In parallel, an affective feedback system—comprising perceptual interfaces and personalized response mechanisms—effectively strengthens users’ cognitive engagement and behavioral coherence, enhancing the overall continuity of the immersive experience.

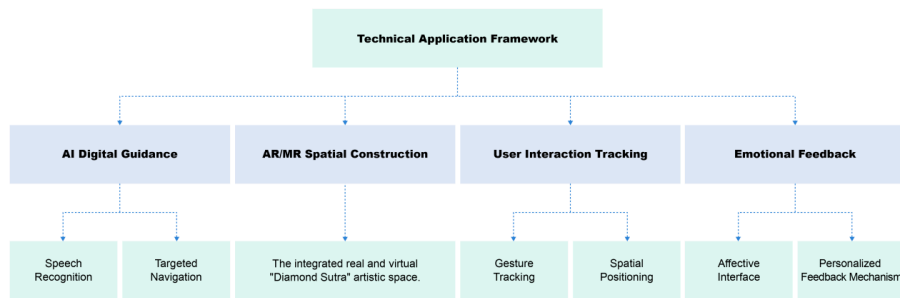


Figure 9. Technical framework of the system

International and domestic cultural heritage exhibitions offer important precedents. The French immersive exhibition *Eternal Notre-Dame* [19] (Figure 10) uses gamified narrative techniques to reconstruct the architectural and spiritual space of Notre-Dame Cathedral. Through MR headsets and AI-guided systems, visitors explore virtual restoration scenes, gaining an immersive experience that merges learning with emotional resonance. In China, *In Search of Dunhuang: The Digital Dunhuang Immersive Exhibition* (Figure 11) employs panoramic projection, motion capture, and voice-guided narration to recreate Mogao Grotto mural spaces and Buddhist ritual settings, enabling visitors to sense the atmosphere of “entering a cave” and understand mural narratives and religious symbolism. Similarly, the Henan Museum’s XR project *Night Banquet in the Tang Palace* [20] (Figures 12 and 13) combines mixed reality with AI motion capture to merge artifact display with digital performance. Guided by virtual characters, visitors participate in festive interactions and experience the elegance and artistic charm of Tang court culture. Collectively, these cases demonstrate the strong potential of AI-guided narration, immersive storytelling, and mixed reality in cultural heritage presentation. They also provide methodological inspiration for this study’s design of a serious game and narrative translation framework for digitally reinterpreting the Dunhuang Diamond Sutra.



Figure 10. Eternal Notre-Dame immersive exhibition (design aesthetics)



Figure 11. In search of Dunhuang: digital Dunhuang immersive exhibition (Xinhua News Agency)

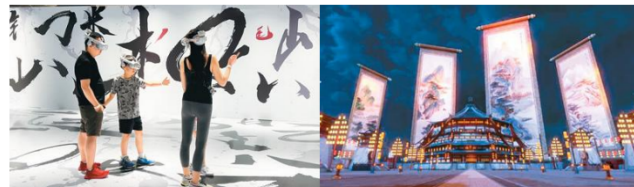


Figure 12 -13. Night Banquet in the Tang Palace immersive experience (People's Daily)

4. Narrative design of a serious game based on the Dunhuang Diamond Sutra manuscript

The narrative design of the serious game centered on the Dunhuang Diamond Sutra manuscript adopts serious-game methodology and takes the printing and binding craftsmanship of Dunhuang manuscripts—represented by the Diamond Sutra—as its narrative backbone. The design constructs an interactive experience composed of three chapters: Prelude to Craftsmanship – Woodblock Carving and Printing – Binding and Sealing. Following the actual production sequence of Dunhuang manuscripts, each stage translates traditional techniques and historical knowledge into experiential digital narrative units through narrative translation and AR/MR interaction. The aim is to introduce young users to traditional craftsmanship and cultural knowledge through hands-on participation and guided discovery.

Building on this foundation, the design incorporates serious-game mechanisms and an AI-driven guidance system. Task prompts, progress indicators, puzzle solving, behavioral feedback, and emotional reinforcement together create a transition pathway from “watching” to “participating.” The AI-based virtual character serves both as narrator and guide. With semantic recognition and

context-specific instructions, it enables dynamic interaction and knowledge scaffolding, allowing young players to understand the logic and cultural meaning behind Dunhuang printing and binding through immersive experience.

This design framework can be applied not only to virtual exhibition systems related to Dunhuang manuscripts, but also to museums, traveling exhibitions, and educational experience spaces. Through AI-guided navigation and AR/MR immersion, young users can learn about the history and stories behind the Dunhuang manuscripts—especially the Diamond Sutra—while breaking free from the limitations of archival or static display. The result is an affective connection with cultural heritage. Such serious-game design introduces new social dimensions for the contemporary dissemination of Dunhuang manuscripts and allows digital-humanities research to manifest in perceptible, interactive, and extensible forms within youth education and cultural communication.

4.1. Framework for the serious-game narrative design of the Dunhuang Diamond Sutra (Figure 14)

Grounded in the theoretical integration of “serious games + narrative translation,” the framework establishes a six-stage narrative loop: knowledge introduction – craft engagement – cultural understanding – ritual sealing – digital dissemination – emotional return. This structure translates the printing and binding techniques of the Dunhuang Diamond Sutra into an interactive learning pathway, forming an educational model that cycles through “cognition – experience – dissemination – re-cognition.”

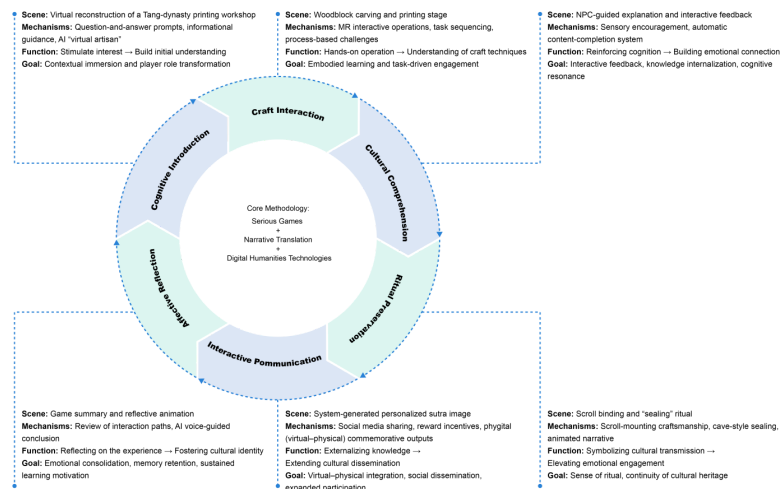


Figure 14. Narrative design framework for the serious game based on the Dunhuang Diamond Sutra

4.2. Prelude to craftsmanship: introducing the production context

The narrative segment titled “Origins of the Scripture” is designed to help young users understand the historical background and cultural significance of Dunhuang manuscript production, exemplified by the Diamond Sutra. This stage uses guided questions and informational prompts to activate the explanatory sequence of the game, preparing users cognitively for the subsequent hands-on craft stages.

Once players put on the headset, their physical surroundings gradually transform into a Tang-dynasty printing workshop constructed through AR/MR technology. Within this wooden workshop setting, artisans carve woodblocks, apply ink, lay paper, and make impressions; the rhythmic sounds

of mallets and paper create an atmosphere of focused manual labor. At this moment, the AI-powered guide appears in the form of a non-player character—a “virtual artisan.” Interface elements and task prompts are presented as the NPC poses a series of puzzles: “What printing technique was used to produce the Dunhuang Diamond Sutra manuscript you are about to recreate?” “In which dynasty did this printed manuscript originate?” “Where is the artifact currently held?” During the puzzle-solving process, the NPC “artisan” provides positive or corrective cues through visual glows or bell-like audio prompts, gradually drawing the young user into the emotional atmosphere of the immersive game.

After the puzzle sequence concludes, the player’s virtual attire automatically transforms into that of a traditional artisan. The system then activates an NPC interaction video that further explains the historical context of Dunhuang manuscript production and introduces the woodblock printing procedures that follow. Through sequential stages of information retrieval, guided questioning, voice interaction, and knowledge activation, the system forms a coherent narrative chain. It avoids overly complicated task structures while still achieving cognitive stimulation and cultural learning, preparing users—both intellectually and emotionally—for the main gameplay centered on woodblock printing. In this way, young users undergo a narrative transition from “learner” to “artisan” within the immersive environment.

4.3. Woodblocks and printing: an interactive presentation of the woodblock engraving and printing craft of the Dunhuang Diamond Sutra

4.3.1. Constructing cognitive understanding of craft logic

This segment moves the gameplay into the manuscript-production phase. The overall design strictly follows the procedural sequence of Tang-dynasty woodblock engraving and printing. Before any hands-on operations begin, the system builds players’ cognitive understanding of the underlying craft logic through guided questions and informational prompts. After the player is granted the identity of “artisan,” they arrive at the woodblock workbench in a virtual timber-framed workshop space. At this point, the NPC “virtual craftsman” appears, provides a task-progress prompt, and presents a sequencing puzzle based on the Tang woodblock printing workflow. Players must arrange the key terms from the printing process—“material selection, tracing, block carving, inking, paper laying, and rubbing/printing”—in the correct order before they can enter the first interactive stage, “material selection and tracing.” During the puzzle-solving process, the NPC supports the player through guiding cues and an affective feedback mechanism, helping them grasp the logic of manuscript production and laying the foundation for the subsequent craft-operation interactions.

4.3.2. Craft operation experience

In the “Material Selection and Outlining” stage, players pick up a brush and printing block and trace the opening lines of the Diamond Sutra onto a pearwood or jujube-wood block using the reverse-writing technique. Before the operation begins, the system displays a knowledge prompt—“Why must the characters be written in reverse?”—and explains the principle that reverse carving yields upright characters in print, reflecting the ingenuity and technical wisdom of ancient artisans. During tracing, MR tracking assists players in following brushstrokes. When the system detects improved proficiency, the NPC provides verbal encouragement, and the system auto-completes part of the reverse text to maintain rhythm. Through repeated cycles of questioning, explanation, and feedback,

this design transforms “cold knowledge” into a “heated experience,” facilitating internalization of technical concepts.

In the subsequent “Carving and Inking” stage, players pick up a carving knife to engrave the reverse text. Using MR hand-tracking and physical simulation, the system captures the player’s pace and pressure variations, providing sound, vibration, and lighting feedback to simulate the tactile sensation of “the blade entering the wood.” When the player’s operation becomes stable, the NPC again offers positive feedback and the system auto-completes remaining portions of the carving. Afterward, the player applies ink evenly with a brush, overlays xuan paper, and rubs gently with a palm brush to transfer the ink clearly onto the paper. Once finished, the NPC issues a reward prompt and displays the printed Diamond Sutra text.

Through these interactive operations, adolescents engage with Tang woodblock printing as embodied artisans, “learning by playing.” After completing all stages, the system automatically triggers an NPC video that narrates the historical development of woodblock printing as represented by the Diamond Sutra, guiding players toward renewed conceptual understanding and completing the shift from perceptual engagement to rational cognition.

4.4. Binding and sealing: from craft practice to digital commemoration

As the final stage of the game, after completing the woodblock printing operations, players enter the phase in which the printed text is assembled and bound into a scroll. Before the binding process begins, the NPC “virtual craftsman” poses a riddle in the form of a guiding question: “What binding method will be used to produce the scroll?” The study finds that Dunhuang manuscript artifacts—represented by the Diamond Sutra—most commonly adopt the scroll format. This prompt is designed to guide players toward a preliminary grasp of the basic knowledge of scroll binding, thereby establishing the cognitive foundation for the subsequent binding operations.

Next, under the NPC’s guidance, players proceed into the binding workflow. First, they connect the printed virtual text panels end to end in the correct sequence. They then apply a silk backing to the reverse side of the joined sheets. Finally, they attach a wooden roller at the tail end to enable rolling and storage, completing the fundamental structure of scroll binding. Throughout the process, gesture tracking and visual guidance support the player in executing actions such as paper joining and rolling, ensuring that the binding workflow is experienced as smooth and continuous. Through this immersive experience, players can directly appreciate, through virtual practice, the sophistication of Dunhuang scroll-binding craftsmanship.

Once binding is successfully completed, the NPC guides the player to place the scroll into a virtual Mogao “Library Cave” (Cave 17) constructed through AR/MR technologies, thereby completing a “sealing” ritual that symbolizes the preservation and transmission of Dunhuang manuscripts. At this moment, the system automatically triggers an NPC interactive video: in animated form, it presents the historical trajectory through which Dunhuang scrolls—exemplified by the Diamond Sutra—move from binding to sealing, helping players deepen understanding and memory through visual narrative.

4.5. Dissemination and reward mechanisms: share-based generation of digital scrolls and cultural communication

Upon successful completion, the system generates a personalized digital scroll image of the player’s Diamond Sutra. This image can be shared on social media to extend cultural dissemination. A sharing incentive allows players to redeem physical rewards, such as turning their digital scroll into

printed postcards—creating a dual commemorative form in both the virtual and physical worlds. This mechanism enhances interactivity and ritual engagement, stimulates emotional involvement and the desire to share, and enables cultural learning to extend from experience to dissemination, and from virtual space to real life [21].

5. Conclusion

This study takes the Diamond Sutra manuscript from Dunhuang as a core case to explore approaches to narrative translation and interactive communication of cultural heritage within the context of digital humanities. By integrating the method of “serious games + narrative design” with AI-guided interaction, AR/MR spatial construction, and multimodal interactive technologies, the research develops an immersive experiential structure consisting of “Craft Prelude – Carving and Printing – Binding and Sealing.” Through this structure, the printing and binding craftsmanship of Dunhuang manuscripts is reconstructed and made experiential within a virtual environment. The findings indicate that serious game mechanisms can effectively enhance adolescents’ cognitive understanding and emotional engagement in cultural learning. The design supports a transition in user identity from “learner” to “artisan,” forming an experience-driven pathway for cultural education. This model breaks through the static limitations of traditional digital exhibitions and provides new directions for the contemporary communication of Dunhuang manuscript culture. It also offers methodological insights and sustainable development pathways for applying digital humanities research to practical initiatives in cultural heritage education and dissemination.

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