Design and Development of a Mobile Application System for Yangjiang Lacquerware Craftsmanship and Cultural Preservation: Integrating AR/VR Learning, Blockchain Authentication, and Community Engagement

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ABSTRACT

The preservation of intangible cultural heritage has become increasingly challenging due to declining numbers of skilled practitioners, limited opportunities for intergenerational knowledge transmission, market competition, and the rapid transformation of cultural consumption patterns. Yangjiang lacquerware, one of China's recognized forms of intangible cultural heritage, faces significant threats related to artisan succession, loss of tacit knowledge, counterfeit products, and decreasing engagement among younger generations. To address these challenges, this study designed, developed, implemented, and evaluated a mobile application system that supports the preservation and promotion of Yangjiang lacquerware through the integration of emerging digital technologies. The study employed Design and Development Research (DDR) as its methodological framework and utilized the ADDIE Model (Analysis, Design, Development, Implementation, and Evaluation) to guide the development process. The application incorporated six major functional components: an AR/VR Learning Module, Knowledge Graph Module, Blockchain Authentication and NFT Certification Module, Creative Workshop Module, Community Interaction Module, and Gamification Module. Data were collected through interviews, observations, usability reviews, system testing, questionnaires, learning assessments, and system analytics. Formal implementation and evaluation involved fifty-seven participants representing artisans, learners, and cultural consumers. Findings indicated that the developed application enhanced cultural learning, improved user engagement, facilitated knowledge transmission, and strengthened authenticity verification mechanisms. Participants reported positive perceptions regarding usability, learning support, and cultural relevance. The integration of immersive technologies, knowledge management systems, and blockchain authentication contributed to a comprehensive digital ecosystem capable of supporting both cultural preservation and sustainable cultural development. The study demonstrates the potential of mobile technologies to serve as effective tools for safeguarding intangible cultural heritage while fostering community participation and cultural innovation.

Keywords: Intangible Cultural Heritage, Yangjiang Lacquerware, Mobile Application, AR/VR Learning, Blockchain Authentication, Cultural Preservation, Design and Development Research

INTRODUCTION

Intangible cultural heritage (ICH) constitutes a vital component of cultural identity, social memory, and community continuity. It encompasses traditional knowledge, craftsmanship, performing arts, oral traditions, rituals, and cultural practices transmitted across generations through participation and lived experience. According to UNESCO (2023), safeguarding intangible cultural heritage is essential for maintaining cultural diversity, strengthening social cohesion, and preserving the collective knowledge of communities. However, many traditional cultural practices are increasingly threatened by globalization, urbanization, demographic changes, and the rapid evolution of digital societies.

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Among China's rich cultural traditions, Yangjiang lacquerware represents one of the most distinctive forms of traditional craftsmanship. Originating during the Ming Dynasty and flourishing throughout subsequent historical periods, Yangjiang lacquerware is renowned for its intricate production techniques, artistic value, and cultural significance. The craft combines hundreds of specialized procedures involving water buffalo hide processing, lacquer application, carving, decoration, and finishing techniques that have been transmitted through generations of master artisans. As a result of its historical and cultural importance, Yangjiang lacquerware has been recognized as part of China's National Intangible Cultural Heritage List.

Despite its significance, Yangjiang lacquerware faces substantial preservation challenges. One major concern is the declining number of skilled artisans capable of transmitting traditional knowledge to future generations. Many recognized inheritors are aging, while fewer young individuals are pursuing long-term apprenticeship opportunities. The resulting interruption in intergenerational knowledge transfer threatens the survival of specialized craftsmanship techniques and cultural practices. Furthermore, much of the expertise associated with lacquerware production exists as tacit knowledge acquired through years of observation, practice, and mentorship, making preservation particularly difficult through conventional documentation approaches.

In addition to succession-related challenges, Yangjiang lacquerware faces increasing pressures within contemporary markets. Counterfeit products, unauthorized reproductions, and limited consumer awareness have affected public confidence in authentic lacquerware products. These conditions reduce economic incentives for artisans and contribute to declining participation in traditional craftsmanship industries. Consequently, preserving Yangjiang lacquerware requires strategies that address both cultural transmission and economic sustainability.

Recent advances in digital technology have created new opportunities for cultural heritage preservation. Technologies such as mobile applications, augmented reality (AR), virtual reality (VR), artificial intelligence (AI), blockchain systems, and digital knowledge management platforms have demonstrated significant potential for supporting cultural documentation, learning, community engagement, and authenticity verification. Studies have shown that immersive technologies can facilitate experiential learning and improve the transmission of procedural knowledge, while blockchain systems can enhance transparency, provenance tracking, and trust in cultural products. Similarly, mobile applications provide accessible platforms for integrating multiple preservation functions within a single digital ecosystem.

Although numerous digital heritage initiatives have emerged in recent years, many remain fragmented in scope. Existing projects often focus on isolated technologies such as digital archives, virtual exhibitions, or blockchain certification systems without integrating educational, cultural, technological, and community-oriented functions into a unified platform. Furthermore, limited research has examined how these technologies can be adapted specifically to support traditional craftsmanship preservation within culturally sensitive contexts. Existing studies also provide insufficient evidence regarding the long-term effectiveness of integrated digital preservation systems in supporting cultural transmission, user engagement, and sustainable heritage development.

To address these gaps, this study designed and developed a comprehensive mobile application system for Yangjiang lacquerware craftsmanship and cultural preservation. The proposed platform integrates immersive learning technologies, knowledge management systems, blockchain-based authentication mechanisms, community participation features, and gamification strategies within a single mobile environment. Guided by Design and Development Research (DDR) and operationalized through the ADDIE Model, the study sought to create a sustainable digital ecosystem capable of supporting cultural learning, authenticity verification, stakeholder engagement, and cultural promotion.

Specifically, the study aimed to: (1) analyze the current preservation challenges and stakeholder needs associated with Yangjiang lacquerware; (2) design an integrated mobile application architecture supporting cultural preservation and learning; (3) develop a functional cross-platform application prototype incorporating advanced digital technologies; (4) implement the application among representative stakeholder groups; and (5) evaluate its effectiveness in terms of usability, learning support, cultural engagement, and user acceptance.

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The significance of this study extends beyond the preservation of Yangjiang lacquerware. By integrating educational technologies, digital governance mechanisms, immersive learning environments, and community participation strategies, the study contributes to the growing field of digital heritage preservation. The resulting framework provides a potential model for safeguarding other endangered forms of intangible cultural heritage while demonstrating how emerging technologies can support cultural continuity, innovation, and sustainable development in the digital age.

LITERATURE REVIEW

Digital Preservation of Intangible Cultural Heritage

The rapid advancement of digital technologies has transformed approaches to the preservation and promotion of intangible cultural heritage (ICH). Traditionally, cultural preservation relied heavily on physical documentation, apprenticeship systems, oral transmission, and institutional archiving. While these approaches remain important, contemporary researchers have increasingly emphasized the role of digital technologies in addressing challenges associated with cultural loss, declining practitioner populations, and changing patterns of cultural participation (UNESCO, 2023).

Recent studies have demonstrated that digital preservation extends beyond simple documentation and archiving. Instead, it involves the creation of dynamic and interactive systems that facilitate cultural learning, community engagement, and long-term sustainability. Zhang et al. (2023) argued that digital heritage platforms provide opportunities to preserve both explicit cultural knowledge and tacit knowledge that would otherwise be difficult to transmit through conventional methods. Similarly, Li and Huang (2024) reported that mobile and web-based cultural heritage systems significantly improve accessibility and public engagement by allowing users to interact with cultural resources regardless of geographic location.

The preservation of traditional craftsmanship presents unique challenges because much of the knowledge involved is procedural, experiential, and context-dependent. Craftsmanship skills are often acquired through observation, imitation, and repeated practice under the supervision of experienced artisans. Consequently, preserving intangible cultural heritage requires digital solutions capable of supporting experiential learning rather than merely providing static information (Wang et al., 2023).

Recent developments in digital heritage research have therefore emphasized the integration of immersive technologies, knowledge management systems, artificial intelligence, and community participation mechanisms. According to Chen and Zhao (2024), successful digital preservation initiatives increasingly combine technological innovation with cultural authenticity to create sustainable heritage ecosystems that support both preservation and cultural transmission.

Despite these advances, many digital heritage projects continue to focus primarily on documentation and archival functions. Limited attention has been devoted to integrating preservation, learning, authentication, creativity, and community engagement within a single platform. This limitation highlights the need for comprehensive digital preservation systems capable of addressing the multiple dimensions of intangible cultural heritage conservation.

Mobile Applications for Cultural Heritage Education

Mobile applications have emerged as important tools for cultural heritage education due to their accessibility, flexibility, and capacity to support interactive learning experiences. The widespread adoption of smartphones has enabled cultural institutions, educators, and heritage organizations to deliver learning resources directly to users through mobile platforms.

Research conducted by García-Crespo et al. (2022) found that mobile heritage applications enhance user engagement by providing location-independent access to cultural content. Through multimedia resources, interactive interfaces, and personalized learning pathways, mobile applications support self-directed exploration and knowledge acquisition. Similarly, Luo et al. (2023) reported that mobile learning environments

increase learners' motivation and willingness to engage with cultural heritage topics, particularly among younger generations.

The educational effectiveness of mobile applications is closely associated with constructivist learning principles. Mobile technologies enable users to actively interact with content, construct personal understanding, and engage in contextual learning experiences. Studies have shown that mobile applications incorporating multimedia content, simulations, and collaborative learning functions produce significantly higher levels of engagement and knowledge retention than traditional information delivery methods (Zheng & Xu, 2024).

In cultural heritage contexts, mobile applications have been successfully utilized to support museum education, heritage tourism, language preservation, traditional craft learning, and cultural storytelling. However, many existing applications remain limited in scope, focusing on information dissemination rather than comprehensive preservation and learning ecosystems. Furthermore, few applications integrate educational technologies with authenticity verification, community participation, and cultural production functions.

These limitations suggest the need for mobile applications that combine learning support, cultural communication, authenticity verification, and community engagement within a unified digital environment.

Augmented Reality and Virtual Reality in Cultural Learning

Augmented Reality (AR) and Virtual Reality (VR) technologies have become increasingly important in cultural heritage education because of their ability to provide immersive and experiential learning experiences. AR overlays digital information onto physical environments, while VR creates fully immersive virtual spaces that allow users to interact with simulated cultural contexts.

Recent research has demonstrated that immersive technologies significantly improve learning outcomes in heritage education. According to Alkhafaji et al. (2023), AR-based educational systems increase learner engagement, curiosity, and knowledge retention by enabling users to visualize complex cultural processes and artifacts. Similarly, Kim and Park (2024) found that VR environments effectively support procedural learning by allowing learners to practice cultural skills within simulated environments before engaging in real-world activities.

The relevance of AR and VR technologies is particularly evident in traditional craftsmanship education. Craft production processes often involve sequential procedures, tacit knowledge, and physical techniques that are difficult to convey through text or static images. Immersive environments enable learners to observe expert demonstrations, practice procedural skills, and receive immediate feedback on performance.

Studies focusing on craft heritage preservation have reported positive outcomes associated with AR and VR integration. For example, Yang et al. (2024) developed an immersive cultural heritage learning system that improved participant understanding of traditional ceramic production techniques. Their findings indicated significant improvements in learner motivation, cultural appreciation, and procedural knowledge acquisition.

Despite these benefits, researchers have noted that many existing AR and VR heritage applications function as isolated educational tools rather than components of broader preservation ecosystems. Greater integration with knowledge management systems, community participation features, and authenticity verification mechanisms remains necessary to maximize their preservation impact.

Knowledge Graph Technology in Cultural Heritage Management

Knowledge graph technology has emerged as a powerful tool for organizing, connecting, and retrieving complex cultural information. A knowledge graph represents information through interconnected entities and relationships, allowing users to explore cultural knowledge in a semantic and contextually meaningful manner.

Recent applications of knowledge graphs in cultural heritage have focused on integrating archival records, historical documents, museum collections, and expert knowledge into unified information systems (Liu et al.,

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2023). Through semantic relationships, knowledge graphs facilitate advanced search functions, knowledge discovery, and personalized learning experiences.

Researchers have highlighted the value of knowledge graphs for preserving traditional craftsmanship knowledge. According to Zhao and Sun (2024), knowledge graph systems can capture relationships among materials, tools, techniques, historical events, artisans, and cultural symbols, thereby preserving complex cultural knowledge structures that are difficult to represent through conventional databases.

The integration of knowledge graph technology with mobile applications further enhances accessibility and user engagement. Users can explore interconnected cultural concepts, retrieve relevant information, and visualize relationships among cultural elements through intuitive interfaces.

Although knowledge graph applications in cultural heritage continue to expand, relatively few studies have integrated knowledge graphs with immersive learning environments, community participation systems, and blockchain-based preservation mechanisms. This limitation presents opportunities for developing more comprehensive digital heritage platforms.

Blockchain Technology and Cultural Heritage Authentication

Blockchain technology has received increasing attention within cultural heritage research because of its capacity to support authenticity verification, provenance tracking, intellectual property protection, and decentralized record management. Blockchain systems maintain immutable transaction records that cannot easily be altered, thereby increasing transparency and trust.

In the context of traditional craftsmanship, blockchain technology offers mechanisms for documenting production processes, verifying authenticity, and protecting artisans' intellectual property rights. According to Xu et al. (2023), blockchain-based certification systems improve consumer confidence by enabling transparent verification of product origins and ownership histories.

The emergence of non-fungible tokens (NFTs) has further expanded opportunities for cultural heritage preservation. NFTs allow digital representations of cultural assets to be authenticated, traded, and preserved within blockchain ecosystems. Recent studies have explored the use of NFTs for preserving cultural artifacts, promoting artisan-created works, and generating sustainable economic opportunities for heritage communities (Martins & Oliveira, 2024).

Despite growing interest in blockchain applications, existing studies frequently examine authentication systems independently of educational and cultural learning functions. There remains a need for integrated platforms that combine blockchain authentication with heritage education, community engagement, and cultural preservation activities.

Research Gap and Conceptual Foundation

The reviewed literature demonstrates significant progress in digital heritage preservation, mobile learning, immersive technologies, knowledge management, and blockchain-based authentication. Previous studies have established the effectiveness of AR/VR technologies in cultural education, knowledge graph systems in information management, blockchain mechanisms in authenticity verification, and mobile applications in heritage dissemination.

However, several gaps remain evident. First, most existing systems focus on a single technological solution rather than integrating multiple preservation technologies into a unified platform. Second, relatively few studies have addressed the preservation of traditional craftsmanship through comprehensive digital ecosystems that simultaneously support learning, authentication, community participation, and cultural innovation. Third, limited research has examined the application of integrated digital preservation systems within the context of Yangjiang lacquerware, despite its recognized cultural significance and documented preservation challenges.

To address these gaps, the present study developed a mobile application system that integrates AR/VR learning

environments, knowledge graph technology, blockchain authentication, NFT certification, community participation functions, and gamification mechanisms within a single platform. Guided by Design and Development Research and operationalized through the ADDIE Model, the study contributes both a practical preservation solution and an interdisciplinary framework for supporting the sustainable preservation and promotion of intangible cultural heritage in the digital era.

METHODOLOGY

Research Design

This study employed Design and Development Research (DDR) as the overall methodological framework and utilized the ADDIE Model as the operational process for the design, development, implementation, and evaluation of the Yangjiang Lacquer Art Inheritance Mobile Application System. DDR was selected because it provides a systematic approach for creating innovative technological solutions while generating practical and theoretical knowledge applicable to real-world contexts. The ADDIE Model, consisting of the Analysis, Design, Development, Implementation, and Evaluation phases, guided the iterative development and refinement of the application.

The methodological process was further informed by Constructivist Learning Theory, Contextual Learning Theory, the Technology Acceptance Model (TAM), Cultural Communication Theory, and Digital Heritage Governance Theory. These frameworks guided the design of learning environments, user interactions, cultural preservation functions, and evaluation criteria throughout the development process.

Participants

Purposive sampling was employed to recruit participants who possessed relevant knowledge and experience related to Yangjiang lacquerware preservation, learning, and cultural participation. Participant involvement varied across the stages of the study.

During the Analysis Phase, seven Yangjiang lacquerware inheritors and artisans participated in interviews and consultations to identify preservation challenges, stakeholder needs, and system requirements. During the Design Phase, five usability experts and thirty representative users participated in heuristic evaluations and interface reviews. The formal implementation and evaluation involved fifty-seven participants consisting of seven artisans and inheritors, thirty learners and apprentices, and twenty cultural consumers and collectors. These participants represented the primary stakeholder groups expected to utilize and benefit from the developed application.

Research Procedure

The study was conducted from September 2025 to February 2026 in Yangjiang City, Guangdong Province, China. The research process followed the five phases of the ADDIE Model.

During the Analysis Phase, field observations, interviews, documentary analysis, and literature reviews were conducted to identify preservation challenges, stakeholder needs, and technological opportunities. Interview data were analyzed using thematic analysis to generate functional requirements and system specifications.

During the Design Phase, findings from the analysis were translated into system architecture diagrams, interface prototypes, database structures, workflow models, and module specifications. The proposed system architecture integrated six major components: an AR/VR Learning Module, Knowledge Graph Module, Blockchain Authentication and NFT Certification Module, Creative Workshop Module, Community Interaction Module, and Gamification Module. Design validation was conducted through heuristic evaluation and usability review activities involving experts and representative users.

During the Development Phase, the approved designs were transformed into a functional mobile application prototype. React Native was used for cross-platform development, while Node.js and Express.js supported backend services. MySQL and Neo4j databases were utilized for structured and graph-based cultural

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knowledge management. Blockchain services, AR/VR learning functions, community participation features, and gamification mechanisms were integrated into the system. Continuous testing, debugging, and refinement were performed throughout development.

The Implementation Phase involved deploying the application among selected participants and providing orientation regarding system usage. Participants interacted with the application's learning, authentication, creative, and community functions within authentic cultural learning environments. User activities, system logs, and feedback were collected throughout the implementation period.

The Evaluation Phase assessed the effectiveness of the application in terms of usability, learning outcomes, cultural engagement, technical performance, and preservation contributions. Data were collected through interviews, questionnaires, learning assessments, practical evaluations, system logs, and usability assessments. Evaluation findings informed recommendations for future enhancement and sustainability.

Instruments and Data Collection

Multiple instruments were utilized throughout the study. Semi-structured interview guides were used during the analysis and evaluation phases to collect detailed qualitative information from stakeholders. Evaluation questionnaires consisting of closed-ended and open-ended items were administered to assess user perceptions regarding usability, learning support, engagement, and overall satisfaction.

Learning outcome assessments consisting of theoretical and practical components were employed to evaluate knowledge acquisition and skill development. The System Usability Scale (SUS) was used to assess the usability of the application. In addition, Firebase Analytics and custom backend monitoring tools were utilized to collect objective system data, including user activity, feature utilization, application performance, and engagement indicators.

Data collection was conducted across all phases of the ADDIE process. Interviews, observations, and documentary analysis were conducted during the Analysis Phase. Usability reviews and design consultations were conducted during the Design Phase. Technical testing and monitoring occurred during the Development Phase. User interactions, observations, and system-generated records were collected during the Implementation Phase. Finally, questionnaires, assessments, interviews, and system analytics were utilized during the Evaluation Phase.

Data Analysis

Qualitative data obtained from interviews, observations, field notes, and open-ended responses were analyzed using thematic analysis following the six-step framework of Braun and Clarke (2022). The analysis involved familiarization with the data, generation of initial codes, identification of themes, theme review, theme definition, and interpretation of findings. NVivo 12 software was used to facilitate coding and data management.

Quantitative data obtained from questionnaires, learning assessments, usability evaluations, and system analytics were analyzed using descriptive statistical techniques. Frequencies, percentages, means, and standard deviations were calculated to summarize participant responses and evaluation results.

To enhance validity and credibility, methodological triangulation was employed by comparing qualitative findings with quantitative results and system-generated data. Learning outcomes were evaluated through assessment scores and operational performance indicators. Cultural engagement was assessed through community participation activities, user-generated content submissions, and interaction frequencies. Technical performance was evaluated using application response times, crash rates, and feature utilization statistics. Economic and preservation-related indicators were examined through authentication records, blockchain transactions, and user participation metrics.

The integration of qualitative and quantitative analyses provided comprehensive evidence regarding the effectiveness, usability, educational value, cultural relevance, and preservation potential of the Yangjiang

Lacquer Art Inheritance Mobile Application System.

RESULTS AND DISCUSSION

User Needs Analysis Findings

The analysis phase revealed several critical challenges affecting the preservation, transmission, and promotion of Yangjiang lacquerware. Through interviews with artisans and inheritors, field observations, and documentary analysis, five major themes emerged: (1) declining intergenerational transmission of craftsmanship knowledge, (2) difficulty in preserving tacit knowledge and practical skills, (3) limited engagement among younger generations, (4) concerns regarding product authenticity and counterfeit products, and (5) insufficient digital platforms for cultural promotion and market expansion.

Participants consistently emphasized that traditional apprenticeship models alone were no longer sufficient to support sustainable cultural transmission. Experienced artisans reported difficulties attracting younger learners due to the lengthy training process and limited economic incentives associated with traditional craftsmanship. In addition, many critical aspects of lacquerware production relied on tacit knowledge acquired through observation and repeated practice, making documentation through conventional methods challenging.

Young learners identified barriers related to limited access to learning resources, insufficient opportunities for practical demonstration, and difficulties understanding complex production procedures. Cultural consumers and collectors expressed concerns regarding authenticity verification and the lack of accessible information about the cultural significance and production history of lacquerware products. These findings confirmed the need for a comprehensive digital solution capable of supporting cultural learning, preservation, authentication, and community participation.

The results of the needs analysis directly informed the design requirements of the mobile application system. Specifically, stakeholders expressed the need for immersive learning tools, digital knowledge repositories, authenticity verification mechanisms, interactive community features, and opportunities for creative participation. These requirements served as the foundation for the subsequent design and development phases.

System Design and Developed Features

Based on the identified requirements, the Yangjiang Lacquer Art Inheritance Mobile Application System was developed as an integrated digital preservation ecosystem. The system combined educational technologies, knowledge management tools, blockchain-based authentication mechanisms, and community engagement functions within a unified mobile platform.

The AR/VR Learning Module was designed to support experiential learning through immersive simulations of traditional lacquerware production processes. Users could observe demonstrations, explore virtual workshop environments, and receive interactive guidance while learning craftsmanship techniques. This feature operationalized constructivist learning principles by allowing users to actively engage with cultural content rather than passively consuming information.

The Knowledge Graph Module organized cultural knowledge into interconnected semantic relationships linking materials, tools, techniques, artisans, symbols, historical events, and production processes. This structure enabled users to retrieve cultural information through both keyword searches and visual exploration of knowledge relationships. The integration of knowledge graph technology enhanced knowledge accessibility and supported contextual learning experiences.

To address concerns regarding authenticity and intellectual property protection, the application incorporated a Blockchain Authentication and NFT Certification Module. This feature enabled artisans to register cultural products, generate blockchain-based certificates, and establish transparent provenance records. Consumers could verify product authenticity through digital verification functions, thereby increasing trust and reducing the risk of counterfeit products.

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The Creative Workshop Module encouraged user-generated content and cultural innovation. Users could access traditional design resources, create original works inspired by lacquerware culture, and participate in collaborative design activities. Community voting and expert evaluation mechanisms supported the recognition and dissemination of outstanding contributions.

Gamification features including points, badges, achievement systems, and leaderboards were integrated throughout the platform to encourage sustained participation and engagement. These features aligned with previous findings indicating that gamified learning environments can increase motivation and retention among younger users.

The resulting system established a closed-loop preservation framework that connected cultural documentation, learning, authentication, creation, dissemination, and evaluation activities within a single digital environment.

Usability and User Experience Results

The formal evaluation involved fifty-seven participants representing artisans, learners, and cultural consumers. Evaluation findings indicated positive perceptions regarding the usability and overall user experience of the developed application.

Participants reported that the application interface was intuitive, visually appealing, and easy to navigate. The integration of multimedia resources, interactive functions, and clearly organized learning pathways contributed to positive user experiences. The AR/VR Learning Module was frequently identified as one of the most valuable features because it enabled users to visualize and practice cultural processes that are typically difficult to learn through text-based materials alone.

Users also expressed positive perceptions regarding the Knowledge Graph Module. Participants reported that the interconnected presentation of cultural knowledge enhanced their understanding of relationships among materials, techniques, historical developments, and cultural meanings. This finding supports previous studies suggesting that semantic knowledge structures can improve information retrieval and contextual understanding.

The System Usability Scale (SUS) evaluation further indicated satisfactory usability performance. Participants generally agreed that the application was easy to learn, straightforward to use, and capable of supporting their learning and cultural engagement needs. Feedback collected through interviews and open-ended questionnaire responses also highlighted the importance of mobile accessibility in enabling continuous learning and participation.

Nevertheless, some participants identified areas for future improvement, including the expansion of cultural content, increased personalization options, additional language support, and enhanced social networking features. These suggestions provide valuable directions for future development and refinement.

Learning Outcomes and Cultural Engagement

Evaluation findings suggested that the developed application positively influenced cultural learning and engagement. Participants demonstrated improvements in their understanding of Yangjiang lacquerware history, production techniques, cultural symbolism, and preservation practices. Learners particularly benefited from the immersive learning features, which enabled them to observe and interact with complex craftsmanship procedures in a more accessible manner.

The practical assessment results indicated improved procedural understanding and increased familiarity with traditional production processes. Participants reported greater confidence in their ability to recognize materials, identify craftsmanship stages, and understand the cultural significance of specific design elements. These findings support previous research demonstrating the effectiveness of immersive technologies for procedural and experiential learning.

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The application also contributed to increased cultural engagement. Community participation features encouraged users to share experiences, discuss cultural topics, and contribute creative content. User-generated submissions demonstrated active participation in cultural reinterpretation and innovation while maintaining connections to traditional heritage elements.

The gamification mechanisms further supported engagement by encouraging users to complete learning activities, participate in community discussions, and explore cultural resources. Consistent with previous studies, achievement systems and reward structures appeared to increase motivation and sustained platform usage.

The integration of educational content, immersive technologies, creative participation opportunities, and social interaction functions contributed to the development of an active digital cultural community. This outcome aligns with contemporary approaches to heritage preservation that emphasize participation, collaboration, and community-based cultural transmission.

Implications for Intangible Cultural Heritage Preservation

The findings of this study demonstrate the potential of integrated digital platforms to support the preservation and promotion of intangible cultural heritage. Unlike many existing heritage applications that focus primarily on documentation or information dissemination, the developed system combined learning, authentication, creativity, governance, and community participation within a unified framework.

From an educational perspective, the integration of AR/VR technologies and knowledge graph systems provided effective mechanisms for supporting experiential learning and preserving tacit cultural knowledge. These findings reinforce the relevance of Constructivist Learning Theory and Contextual Learning Theory in digital heritage education.

From a technological perspective, the incorporation of blockchain authentication and NFT certification introduced new opportunities for protecting cultural products, enhancing consumer trust, and supporting sustainable cultural economies. The results suggest that digital governance mechanisms can play an important role in addressing authenticity and intellectual property challenges affecting traditional craftsmanship industries.

From a cultural perspective, the application facilitated active participation among multiple stakeholder groups and supported the transformation of users from passive consumers to active contributors within the preservation ecosystem. The Creative Workshop Module and community participation features encouraged cultural co-creation and strengthened connections between heritage traditions and contemporary digital culture.

The study therefore contributes both a practical preservation solution and a replicable framework for other forms of endangered intangible cultural heritage. By integrating educational technologies, knowledge management systems, blockchain authentication, and community participation mechanisms, the proposed model demonstrates how digital innovation can support cultural continuity while promoting sustainable cultural development in the digital era.

Theoretical and Practical Implications

Theoretical Implications

This study contributes to the growing body of knowledge in digital heritage preservation, educational technology, and cultural informatics by demonstrating how multiple theoretical perspectives can be integrated into a unified digital preservation framework. The findings support the applicability of Constructivist Learning Theory and Contextual Learning Theory in the design of technology-enhanced cultural learning environments. The AR/VR Learning Module provided opportunities for experiential learning, allowing users to actively construct knowledge through interaction with simulated cultural processes rather than relying solely on passive information consumption. The positive responses from learners and artisans suggest that immersive

technologies can facilitate the transmission of tacit knowledge, which is often difficult to document through conventional preservation methods.

The study also extends the application of the Technology Acceptance Model (TAM) within the context of intangible cultural heritage preservation. User feedback indicated that perceived usefulness and ease of use significantly influenced participants' willingness to engage with the mobile application. The integration of intuitive interfaces, immersive learning tools, and accessible cultural resources contributed to positive user experiences and acceptance of the system. These findings reinforce previous research emphasizing the importance of user-centered design in cultural technology applications.

Furthermore, the study contributes to Cultural Communication Theory by illustrating how digital platforms can facilitate intergenerational knowledge exchange and cultural dissemination. The Community Interaction Module and Creative Workshop Module transformed users from passive consumers of cultural information into active participants and contributors. This shift supports contemporary perspectives that view cultural preservation as a collaborative and participatory process rather than a solely institutional responsibility.

The incorporation of Blockchain Authentication and NFT Certification functions also extends Digital Heritage Governance Theory by demonstrating how decentralized technologies can support authenticity verification, provenance tracking, and intellectual property protection. The study provides evidence that blockchain technologies may serve as valuable governance mechanisms within cultural heritage ecosystems by enhancing transparency, trust, and accountability.

Finally, the integration of DDR and the ADDIE Model offers a methodological contribution by providing a replicable framework for the design, development, and evaluation of digital heritage applications. The study demonstrates how iterative development processes can be aligned with educational, cultural, technological, and governance objectives to create sustainable preservation solutions.

Practical Implications

The findings of this study have practical implications for cultural institutions, policymakers, educators, artisans, and technology developers involved in intangible cultural heritage preservation.

For cultural heritage institutions, the developed application demonstrates how mobile technologies can be utilized to expand access to cultural resources and support broader public engagement. Museums, heritage centers, and cultural organizations may adopt similar approaches to create interactive learning environments and digital preservation platforms capable of reaching audiences beyond traditional physical settings.

For artisans and cultural practitioners, the application provides a mechanism for documenting, preserving, and disseminating craftsmanship knowledge. The integration of immersive learning technologies offers opportunities to supplement traditional apprenticeship systems and attract younger generations to cultural heritage learning. In addition, blockchain-based authentication functions provide practical tools for protecting intellectual property rights and enhancing consumer confidence in authentic cultural products.

For educators, the study highlights the potential of AR/VR technologies and knowledge graph systems to support experiential and contextualized learning. Educational institutions may utilize similar approaches to enhance the teaching of traditional arts, craftsmanship, and cultural heritage topics. The findings suggest that immersive and interactive learning environments can improve engagement, knowledge retention, and appreciation of cultural traditions.

For policymakers, the results demonstrate the value of integrating digital technologies into cultural preservation strategies. Digital preservation platforms can complement existing heritage conservation programs by supporting documentation, education, community participation, and economic sustainability. The study provides evidence that technology-driven initiatives can contribute to the long-term safeguarding of endangered cultural practices.

For technology developers, the research offers a framework for designing integrated heritage applications that

combine learning technologies, knowledge management systems, authentication mechanisms, and community engagement features. The proposed architecture may serve as a reference model for future digital heritage projects involving other forms of intangible cultural heritage.

CONCLUSION AND FUTURE RESEARCH

This study addressed the challenges associated with the preservation, transmission, and promotion of Yangjiang lacquerware by designing, developing, implementing, and evaluating a mobile application system that integrates AR/VR learning technologies, knowledge graph systems, blockchain authentication, NFT certification, community participation functions, and gamification mechanisms. Guided by Design and Development Research and operationalized through the ADDIE Model, the study developed a comprehensive digital ecosystem capable of supporting cultural learning, authenticity verification, stakeholder engagement, and cultural innovation.

The findings revealed that the developed application effectively addressed several key preservation challenges identified during the needs analysis phase. The integration of immersive learning technologies supported experiential learning and facilitated the transmission of procedural and tacit knowledge. The Knowledge Graph Module enhanced access to interconnected cultural information, while blockchain-based authentication mechanisms strengthened transparency and consumer trust. Community participation features and gamification elements encouraged active engagement and cultural co-creation among users.

Evaluation results indicated positive user perceptions regarding usability, learning support, cultural relevance, and overall system effectiveness. The participation of artisans, learners, and cultural consumers demonstrated the application's potential to serve diverse stakeholder groups and contribute to both cultural preservation and cultural promotion objectives. The findings further suggest that integrated digital heritage platforms can provide sustainable solutions for safeguarding endangered forms of intangible cultural heritage in contemporary digital environments.

Despite these contributions, several limitations should be acknowledged. First, the formal evaluation was conducted within a specific geographic and cultural context involving a limited number of participants. Future studies may expand the participant base and examine application performance across broader demographic groups. Second, the evaluation period was relatively short and therefore did not fully capture long-term user engagement and learning outcomes. Longitudinal studies are recommended to examine sustained adoption and preservation impacts over time. Third, while the application incorporated multiple advanced technologies, additional features such as artificial intelligence–based personalization, multilingual support, advanced analytics, and cross-cultural collaboration functions may further enhance system effectiveness.

Future research should explore the application of the proposed framework to other forms of intangible cultural heritage, including traditional crafts, performing arts, indigenous knowledge systems, and cultural practices. Comparative studies across different cultural contexts may provide additional insights regarding the adaptability and scalability of integrated digital preservation ecosystems. Researchers may also investigate the role of emerging technologies such as generative artificial intelligence, digital twins, extended reality, and decentralized cultural governance systems in supporting future heritage preservation initiatives.

In conclusion, this study demonstrates that the integration of educational technologies, immersive learning environments, blockchain authentication mechanisms, knowledge management systems, and community participation strategies can contribute significantly to the preservation and promotion of intangible cultural heritage. The Yangjiang Lacquer Art Inheritance Mobile Application System provides both a practical preservation solution and a replicable framework for future digital heritage initiatives, thereby contributing to the sustainable safeguarding of cultural knowledge and traditions in the digital age.

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