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Research on Visualization Education Strategies for Traditional Craftsmanship in the Metaverse Perspective: A Case Study of Kaogong Ji

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Abstract: In the wave of the digital age, the inheritance and innovation of traditional crafts are facing unprecedented challenges and opportunities. With the rapid development of technology, the Metaverse—a digital space integrating advanced technologies such as Virtual Reality (VR), Augmented Reality (AR), and 3D printing—has opened up new perspectives and platforms for the visualization of traditional craft education. This emerging field not only provides a more intuitive and vivid way to learn and disseminate traditional crafts but also stimulates unlimited possibilities for the inheritance of skills and cultural innovation. This study focuses on the metalworking techniques recorded in the Kaogong Ji (Classic of Crafts), such as bronze casting and gold and silver engraving, and explores how Metaverse technology can empower the visualization of ancient goldsmithing education. By constructing immersive virtual workshops, restoring cultural contexts, and employing user-driven educational strategies, the study aims to promote the digital inheritance and innovative application of goldsmithing crafts. Drawing on the methodology of digital media art design, the research proposes an educational approach that blends the virtual and the real, while balancing technological practice with cultural authenticity to analyze the potential and challenges of the Metaverse in traditional craft education.

Keywords: metaverse, visualization, traditional craftsmanship, education

1. Limitations of Traditional Craft Education

The limited availability of teaching resources and the singularity of presentation formats constitute a major bottleneck in traditional craft education. Printed textbooks, due to their abstract and concise content, struggle to fully convey the complexity and cultural significance of traditional craftsmanship. Physical demonstrations are constrained by spatial and temporal conditions, while on-site teaching is often limited by geographical factors and the availability of skilled instructors, making it difficult to achieve widespread dissemination. These limitations prevent learners from accessing comprehensive, in-depth, and diverse educational resources, thereby hindering their ability to gain a thorough understanding and deeper mastery of traditional crafts.

Another significant challenge in traditional craft education lies in its rigid transmission methods, low efficiency, and shallow exploration of cultural connotations. Master-apprentice training and oral transmission, while ensuring the authenticity of the craft, often lead to insularity and a lack of innovation (Li, 2022). This form of transmission is not only inefficient and unable to meet the demands of a broad learner base but also tends to present cultural connotations superficially and singularly. Learners often acquire only surface-level technical skills without gaining a profound understanding of the historical background, cultural meaning, and social value embedded in these crafts. This limitation restricts their comprehensive perception and deep experience of traditional craftsmanship. Therefore, it

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is crucial to innovate transmission methods while enhancing the in-depth exploration and diversified presentation of cultural connotations to improve the quality of education and the learning outcomes for students.

2. Constructing an Educational Scene for Metalworking in the Metaverse Context

With the rapid advancement of Metaverse technology, the field of education is undergoing a profound transformation, offering unprecedented opportunities for traditional craft education. The Metaverse—a virtual world meticulously constructed through digital technology—provides an immersive, time-transcending platform for learners to explore and study traditional crafts. This novel learning model not only breaks through the physical boundaries of conventional education but also greatly enriches teaching methods and content, injecting new vitality into the preservation and dissemination of ancient skills such as metalworking(Ma & Zhang, 2023).

As a treasured ancient Chinese craft classic, Kaogong Ji meticulously records the "Six Qi" principle of alloy composition, which involves adjusting the copper-tin ratio based on the specific functions of bronze artifacts. However, in traditional teaching methods, these intricate and detailed processes are typically conveyed through textual descriptions and static images, making it difficult to present the complete workflow and fine details intuitively. The integration of Metaverse technologies offers an innovative solution to this challenge.

Through the deep integration of digital twin technology, virtual reality (VR), and mixed reality (MR), a hybrid virtual-physical educational environment can be constructed. This approach allows learners to engage with and experience craftsmanship in an immersive setting, achieving the dual goals of skill transmission and cultural identity reinforcement.

2.1 Virtual metalworking workshop: A bridge between craft reproduction and cognitive innovation

The virtual workshop serves as the core platform for integrating Metaverse technology into metalworking education. It is designed to balance the precision of craft reproduction with the interactive experience of learners, allowing them to operate metalworking tools firsthand in a virtual environment, observe the microscopic changes in metal flow and cooling, and thereby gain a profound understanding of the essence of metal craftsmanship.

In terms of 3D modeling and dynamic process chain reproduction, high-precision scanning data from archaeological artifacts, such as Shang and Zhou dynasty bronzes and Warring States gold and silver objects, combined with textual records from Kaogong Ji, enable the use of digital twin technology to achieve millimeter-level replication of metalworking tools and processes. Taking bronze casting as an example, a physics engine can simulate the entire workflow—from mold-making to casting and polishing—dynamically showcasing phenomena such as the turbulence of molten metal flow and the microscopic deformation caused by cooling contraction. Learners can freely switch viewpoints to observe the distribution of air holes inside ceramic molds and even use slow-motion playback to study the impact of casting speed on artifact integrity. This intuitive and detailed presentation significantly enhances the effectiveness and immersive quality of the learning experience (Yang, 2023).

For gold and silver engraving, hyperspectral imaging technology can extract the depth information of surface patterns on cultural relics, which, when combined with parametric design tools, generates engraving path algorithms. In the virtual environment, learners use a haptic stylus to simulate engraving on metal surfaces, enabling them to perceive real-time variations in pattern depth corresponding to different levels of applied pressure. The system concurrently generates a heat map of engraving precision, providing quantitative feedback to guide skill improvement. This virtual practice method not only reduces material consumption and safety risks associated with traditional teaching but also allows learners to refine their craftsmanship through

repeated practice (Lu, 2023).

2.2 Immersive cultural reconstruction: A bridge for craft transmission and value recognition

In the reconstruction of craft application scenarios, Metaverse technology can dynamically restore the cultural spaces recorded in Kaogong Ji. Through digital twin technology, it is possible to create virtual environments that closely resemble ancient societies, allowing learners to experience firsthand the historical context and social functions of metalworking (Chen, 2021).For example, in a virtual scene set within a "Shang and Zhou Ancestral Temple Sacrificial Ceremony," learners must first complete the task of casting a bronze cauldron before gaining access to the core ceremonial area. When the virtual cauldron is placed at the center of the temple, the environmental engine synchronously triggers visual effects such as the playing of bronze chimes and swirling incense smoke, creating a solemn and mysterious atmosphere. An NPC priest, utilizing AI voice interaction, explains the symbolic relationship between the cauldron's patterns and the authority of the sacrificial ritual. This approach allows learners to engage in hands-on craft practice while gaining a deeper understanding of the cultural significance and social values embedded in craftsmanship.

The application of digital human technology further breaks down the temporal and spatial barriers between ancient and modern times. By capturing the movements of intangible cultural heritage (ICH) inheritors through motion capture systems and using AI voice synthesis technology to replicate regional dialects, it is possible to create interactive virtual artisans. These virtual artisans can not only demonstrate precise techniques but also engage in real-time interactions to answer learners' questions. Additionally, an AI-assisted learning system can analyze learner behavior data and dynamically push supplementary content and learning resources, transforming cultural understanding from passive reception to active exploration.

2.3 In-depth exploration and diversified presentation of cultural connotations

In Metaverse-supported visual education, the objective should go beyond the mere transmission of technical skills to deeply explore and present the cultural connotations of metalworking techniques recorded in Kaogong Ji. This exploration encompasses but is not limited to, the scientific principles behind alloy composition, the social status and functions of bronze artifacts in ancient societies, and their connections to historical events, religious beliefs, and artistic styles.

To enhance learners' cultural awareness and understanding, a comprehensive and multi-dimensional cultural knowledge base can be constructed using various formats such as text, images, videos, audio, interactive Q&A, and virtual tours. These diverse presentation methods not only stimulate learners' interest and engagement but also provide them with a holistic and profound understanding of metalworking techniques.

Furthermore, AI technology can be utilized to enable personalized recommendations and learning path planning. By analyzing learners' interests and needs, the system can intelligently deliver relevant learning resources and activities. This approach allows learners to enjoy the benefits of advanced technology while gaining a deeper appreciation of the cultural connotations and social significance of metalworking techniques. Personalized learning not only enhances learning efficiency and quality but also promotes learners' self-growth and development (Yin & Huang, 2024).

2.4 Virtual-real integration practice path: A closed loop of technological rmpowerment and real-world feedback

The ultimate vision of Metaverse-based educational scenarios is to dissolve the boundaries between the virtual and the real, establishing a comprehensive and in-depth integration system that spans from "digital creativity incubation – physical form transformation – industrial chain extension." Particularly in the critical stage of transforming digital assets into physical forms, the practice path driven by virtual prototypes to facilitate physical creation has demonstrated significant vitality and vast development potential.

This approach is vividly exemplified in real-world applications. For instance, during the restoration of a Spring and Autumn Period Jin State Bronze Square Hu from the Shanxi Museum collection, restorers utilized laser scanners to capture three-dimensional information about the bronze artifact from multiple angles. By combining point cloud registration with 3D modeling technology, they created a high-precision digital model, which was refined through preprocessing to ensure accuracy.

To enhance the model's detail, texture mapping technology was applied. By aligning corresponding points, texture coordinates were generated, accurately restoring the damaged areas' surface patterns. For the missing sections, researchers analyzed similar samples and gradually reconstructed the lost parts using mirror symmetry and computer-aided design (CAD). Ultimately, the integration of digital scanning and texture mapping technologies enabled the restoration model to achieve a high degree of fidelity in both texture and form, closely replicating the original artifact (Economic Observer, 2025).

2.5 Dual empowerment: from technological cycles to civilizational evolution

The deep interaction between virtual-real integration and the sustainable development framework fundamentally represents the dialectical unity of technological instrumental rationality and cultural value rationality (Jia & Zhang, 2018). In Metaverse-based educational scenarios, pathways such as digital asset transformation and cultural-tourism integration unlock economic value, providing robust support for the inheritance and development of traditional crafts. Meanwhile, the sustainable development framework ensures the preservation of cultural authenticity through ethical constraints, offering a solid foundation for the transmission of craftsmanship.

Together, these elements form a "double-helix structure" in traditional craft education. On one hand, the market revenue from digital assets—such as 3D-printed bronze artifacts—can be reinvested into building intangible cultural heritage (ICH) databases and advancing technical research. On the other hand, blockchain-based intellectual property protection generates revenue that supports the dissemination and adoption of lightweight educational terminals. This positive feedback loop—linking technological application, commercial return, cultural preservation, and technological iteration—not only facilitates the inheritance and innovation of traditional crafts but also drives the prosperity and advancement of related industries.

At the level of civilizational evolution, this cycle holds even deeper significance. When learners engage in immersive experiences—such as "participating" in bronze casting at the Yin Ruins of the Shang Dynasty while using smart contracts to protect original pattern designs—they are, in effect, traversing the complete cultural lifecycle of "historical cognition – contemporary creation – future preservation." In this way, the Metaverse becomes a temporal hub connecting the past and the future. It revives the Kaogong Ji philosophy of "exquisite materials and skillful craftsmanship" within virtual workshops, transforming ancient Shang and Zhou artisans' wisdom into contemporary artistic expression through parametric design tools (Fu & Feng, 2021).

Conclusion

The Metaverse presents both new opportunities and challenges for the visualization of traditional craft education. Through strategies such as digital simulation and reconstruction, the design of interactive experiences, and the in-depth exploration and presentation of cultural connotations, the Metaverse enables the intuitive and vivid display of traditional crafts like the metalworking techniques recorded in the Kaogong Ji (Records of Examination of Crafts) (Luo, 2021). This innovative learning approach not only breaks the boundaries of conventional education but also greatly enriches teaching methods and content. Moreover, the immersive and interactive nature of the Metaverse stimulates learners' curiosity and creativity, injecting new vitality into the inheritance and innovation of

traditional crafts.

Looking ahead, as technology continues to advance and educational models evolve, the visualization of traditional craft education within the Metaverse is expected to become even more diverse and dynamic. On one hand, the ongoing development and widespread adoption of technologies such as 3D printing and virtual reality will further enhance the quality and effectiveness of visualized education. On the other hand, the continuous innovation and expansion of educational models will place greater emphasis on meeting the personalized and differentiated needs of learners, offering more precise and effective learning support.

Through the Metaverse's capacity for display and dissemination, traditional crafts will no longer be confined to specific geographic and cultural contexts. Instead, they can transcend spatial and temporal limitations to become shared cultural resources on a global scale. This not only facilitates the preservation and development of traditional culture but also fosters intercultural exchange and integration, contributing wisdom and strength to the construction of a shared future for humanity.

Conflict of Interest

The author declares that she has no conflicts of interest to this work.

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