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Research on the Application of Digital Modeling Technology in Nixing Pottery from the Perspective of Maker Education Theory

Jiaqing Lyu, Xue Bai, Zhi Liao

Guangxi Vocational and Technical College, Nanning 530226, China

Abstract: In the context of global digital transformation and the rising prominence of maker education, this study explores the innovative integration of digital modeling technologies with traditional Nixing Pottery craftsmanship. By constructing a teaching framework under maker education theory, the research investigates how 3D modeling, CAD design, and 3D printing technologies can empower learners to address challenges in cultural heritage preservation and artistic innovation. Through experimental teaching and case analysis, the study verifies that this integrated approach significantly enhances learners' digital literacy, creative thinking, and cultural identity while optimizing Nixing Pottery's production processes and design possibilities. The findings contribute to theoretical models of technology-enhanced craft education and provide practical pathways for the digital transformation of intangible cultural heritage.

Keywords: Maker education theory; Digital modeling technology; Nixing Pottery; Educational innovation; Cultural heritage digitization; 3D printing; Cross-disciplinary education; Artisan revitalization

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1. Introduction

1.1. Research background and significance

The global maker movement, characterized by its emphasis on hands-on practice, collaborative innovation, and cross-disciplinary integration, has profoundly impacted educational paradigms [1]. Simultaneously, digital modeling technologies represented by 3D scanning, parametric design, and additive manufacturing are reshaping traditional craft industries [2]. As a national-level intangible cultural heritage, Nixing Pottery faces dual challenges: the aging of artisans and the rigidity of design paradigms [3]. This study posits that the fusion of maker education's core tenets with digital tools can create a regenerative mechanism for traditional crafts, balancing cultural preservation with contemporary innovation.

The research significance lies in three dimensions: (1) Theoretical contribution to craft education by bridging maker pedagogy with heritage contexts; (2) Practical value in revitalizing Nixing Pottery through technology-enabled design innovation; (3) Cultural importance in exploring sustainable models for intangible heritage preservation in the digital age.

1.2. Problem statement and research objectives

While prior research has separately explored digital applications in craft education [4] or cultural heritage protection [5], the intersection of these domains remains underexamined. This study specifically addresses: (1) How to construct a pedagogical framework integrating maker education principles with Nixing Pottery's craft characteristics? (2) What are the optimal pathways for digital modeling technologies to enhance design innovation and production efficiency? (3) How does this integration affect learners' comprehensive competencies and cultural perceptions?

1.3. Research content and method overview

Adopting a design-based research methodology, the study implements a three-phase experimental program: (1) Development of a digital-craft integrated curriculum; (2) Implementation of teaching interventions in vocational education contexts; (3) Multi-dimensional evaluation through quantitative surveys, qualitative interviews, and artifact analysis. The research involves 48 participants from a vocational college's art department, utilizing professional-grade 3D scanners and ceramic printers.

2. Literature review and theoretical foundation

2.1. Maker education theory and its application

Maker education, rooted in constructionist learning theory, advocates learning-through-doing and open-ended exploration [6]. Studies indicate its effectiveness in fostering problem-solving skills and technological fluency [7]. In craft education, maker-oriented approaches have demonstrated improved student engagement and creative outcomes when applied to textile arts and woodworking [8]. However, limited research exists on its application to ceramic crafts with strong cultural heritage attributes.

2.2. Digital modeling in traditional crafts

3D scanning technologies enable precise documentation of craft techniques, while parametric design tools facilitate exploration of complex geometries [9]. Research on ceramic 3D printing shows significant reductions in prototyping time and material waste [2]. However, challenges persist in maintaining tactile authenticity during digital-analog transitions, particularly in clay's material behavior during firing processes.

2.3. Nixing Pottery research status

Current scholarship focuses on material science and aesthetic evolution, with limited exploration of pedagogical innovations [3]. Existing digital initiatives primarily involve basic 3D scanning without systemic integration into educational frameworks [10]. This research gap necessitates a holistic approach combining technical, educational, and cultural perspectives.

2.4. Theoretical framework construction

This study synthesizes maker education's "5C" competencies (Critical Thinking, Collaboration, Communication, Creativity, Cultural Awareness) with digital modeling workflows to create a tetrahedral model connecting technology, education, craft, and culture (**Figure 1**). The framework emphasizes iterative cycles of virtual modeling and physical crafting, supported by collaborative digital platforms.

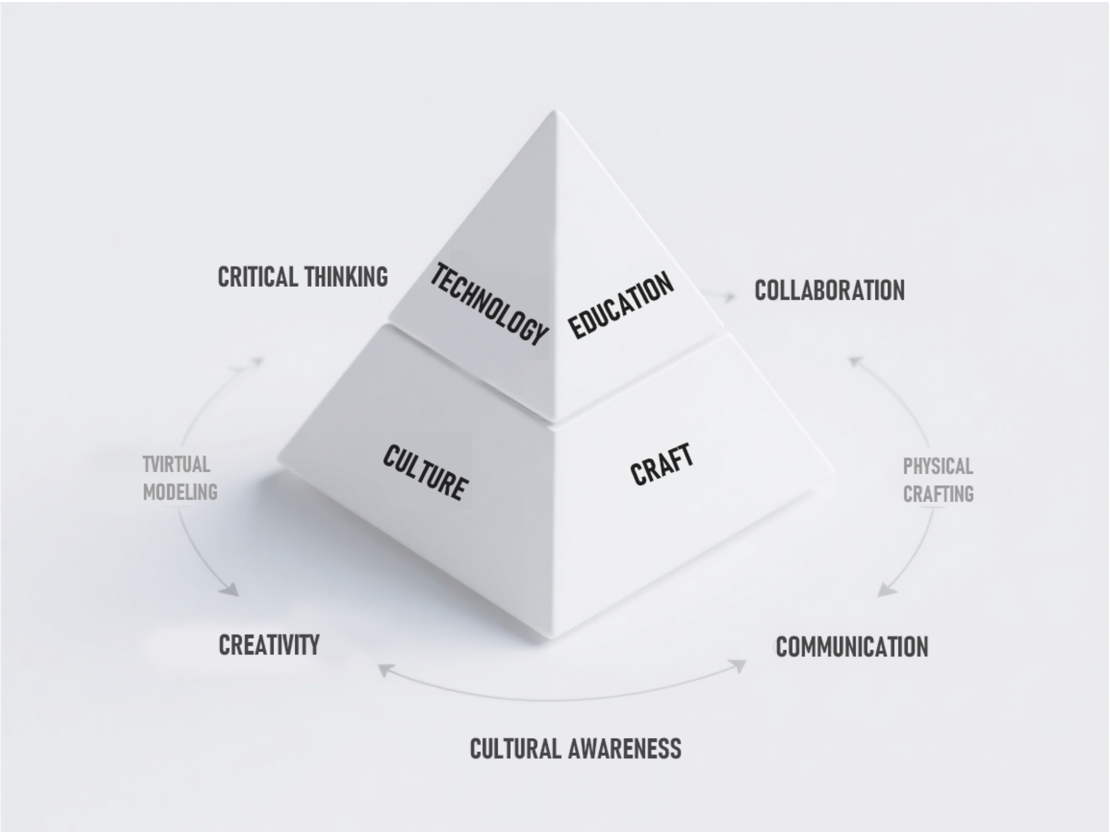

Figure 1. "5C" competencies (Critical Thinking, Collaboration, Communication, Creativity, Cultural Awareness)

3. Digital modeling application framework

3.1. Core integration principles

The framework emphasizes: (1) Learner-driven project initiation through cultural context analysis; (2) Iterative design cycles combining virtual modeling and physical crafting; (3) Collaborative knowledge construction through digital platforms; (4) Cultural narratives embedded in technical processes; (5) Ethical considerations in digital heritage representation.

3.2. Layered framework design

(1) Goal layer: Cultivate "T-shaped" talents with deep craft knowledge and broad digital competencies, emphasizing a balance between technical proficiency and cultural interpretation.

(2) Content layer:

Core modules: Nixing Clay Rheology, 3D Modeling Fundamentals (Blender/Rhino), Multi-material 3D Printing.

Integration units: Digital Restoration of Ancient Pottery, Parametric Tea Set Design, 3D-Printed Mold Making.

Cultural modules: Iconography Interpretation, Historical Context Analysis, Contemporary Cultural Adaptation.

(3) Activity layer:

Phase 1: Digital Documentation of Craft Processes (3D scanning of master artisans' techniques)

Phase 2: Computational Design Explorations (Generative algorithms for pattern creation)

Phase 3: Hybrid Prototyping (3D Printed Elements + Traditional Firing)

Phase 4: Cultural Narrative Integration (Storytelling through form and surface treatment)

(4) Environment layer:

Physical: Makerspace with ceramic kilns, 3D printers, and CNC mills, configured for cross-disciplinary access.

Digital: Cloud-based pattern library with AR annotations, collaborative design platform supporting version control.

4. Research methodology

4.1. Research design

Adopting a mixed-methods approach, the study combines:

(1) Pre-post experimental design measuring skill acquisition through rubric-based assessments

(2) Case studies of exemplary student projects using design thinking protocols

(3) Thematic analysis of interview transcripts coded for cultural perception shifts

4.2. Experimental implementation

Conducted at a vocational college's art department, the 16-week program included:

(1) Weekly 4-hour sessions combining technical training and creative projects

(2) Access to professional-grade 3D scanners (EinScan Pro 2X) and ceramic 3D printers (Delta WASP 2040)

(3) Collaborative projects with local Nixing Pottery studios, including joint exhibitions

4.3. Data collection

(1) Quantitative: Skill assessments (n = 48), cultural identity scale (pre/post), design complexity ratings

(2) Qualitative: Semi-structured interviews (n = 12), design journals, expert evaluations

(3) Artifacts: 3D models, physical prototypes, process documentation, digital design iterations

5. Research results

5.1. Technical application outcomes

Participants achieved:

(1) 85% reduction in prototyping time for complex forms (average 3.2 vs. 21.5 hours)

(2) 62% improvement in geometric precision compared to manual modeling (measured through 3D scan comparison)

(3) Successful fabrication of hybrid pieces combining 3D-printed elements with traditional hand-building (e.g., lattice structures in teapot bodies)

5.2. Educational effects

Statistical analysis revealed:

(1) Significant increase in spatial reasoning scores ($P < 0.01$, Cohen's d = 1.32)

(2) 78% of students reported enhanced cultural pride through digital storytelling capabilities

(3) 64% developed hybrid workflows combining digital and analog techniques, with 23% continuing

independent projects post-course

5.3. Cultural innovation impact

Digital archives now include 128 high-precision models of rare pottery forms, accessible through an online platform with multilingual metadata. Student-designed contemporary pieces won awards at national craft exhibitions, with 14% achieving commercial sales. Notably, a parametrically designed tea set incorporating traditional cloud patterns sold 287 units within six months.

6. Discussion

6.1. Theoretical contributions

The study advances maker education theory by demonstrating its applicability to material-based crafts, expanding beyond digital fabrication contexts [6]. The framework provides a replicable model for technology integration in vocational craft education, addressing calls for context-specific pedagogical innovations [8].

6.2. Practical implications

Recommended strategies include:

(1) Developing industry-specific CAD plugins for ceramic modeling with clay shrinkage compensation algorithms

(2) Establishing digital craft repositories with open-access licenses under Creative Commons frameworks

(3) Training programs for master artisans in 3D documentation techniques, incorporating AR for procedural knowledge capture

6.3. Challenges and limitations

Key issues include:

(1) High initial equipment costs (average $12,500 per workstation)

(2) Digital-material mismatch in clay shrinkage compensation requiring iterative calibration

(3) Ongoing debates about "authenticity" in hybrid pieces, addressed through transparent documentation protocols

7. Conclusion

This research validates the transformative potential of integrating maker education with digital modeling in traditional craft contexts. The framework not only preserves Nixing Pottery's heritage through digital documentation but also revitalizes its creative potential through computational design. Future work should address scalability challenges through modular equipment packages and explore blockchain-based certification for digital craft innovations. The study underscores the importance of balancing technological innovation with cultural integrity in heritage education, offering a model for sustainable craft revitalization in the digital era.

Disclosure statement

The authors declare no conflict of interest.

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