

APPLYING JIN DYNASTY AESTHETICS IN DIGITAL DESIGN FOR TONGXIANG BLUE CALICO: A MIXED-METHODS STUDY IN ZHEJIANG PROVINCE, CHINA

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ABSTRACT

This study investigates how Jin Dynasty aesthetics can be translated into digital design for Tongxiang blue calico in Zhejiang Province, China. The research addresses three gaps in the current literature: the lack of a systematic framework for translating Jin aesthetic principles into digital design language, the limited development of empirically evaluated design prototypes, and the insufficient integration of heritage aesthetics with contemporary user demand. A mixed-methods design was employed. Qualitative data were collected through literature review, field investigation in Tongxiang, and in-depth interviews with experts, blue calico inheritors, and design-related participants in order to identify the historical, artistic, and cultural characteristics of Tongxiang blue calico and to extract key aesthetic dimensions of Jin Dynasty aesthetics, particularly nature, simplicity, and harmony. Quantitative data were then collected from potential users to examine aesthetic preference, cultural perception, and design expectations. Based on these findings, digital design prototypes were developed and subsequently evaluated by users and experts in terms of aesthetic coherence, cultural appropriateness, and user response. The study proposes a design-oriented framework for integrating traditional Chinese aesthetics with contemporary digital practice and demonstrates how heritage-based design can be adapted to present-day cultural and market contexts. The findings contribute to design research, digital heritage practice, and the innovation of traditional crafts through culturally grounded design development.

Keywords: Jin Dynasty Aesthetics, Tongxiang Blue Calico, Digital Design, Cultural Heritage Innovation, Mixed-Methods Research, Prototype Evaluation

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INTRODUCTION

Cultural heritage serves as both a repository of collective memory and a resource for contemporary creative practice in the digital age. Among China's intangible cultural assets, Tongxiang blue calico a hand-printed indigo fabric with distinctive white patterns exemplifies a folk craft with over a millennium of history. Concurrently, the Jin Dynasty (265-420 CE) aesthetic legacy, noted for its philosophical depth and artistic refinement, represents a pivotal epoch in Chinese aesthetic consciousness (Ye, 2014). Despite the individual significance of these domains, their intersection Jin aesthetic principles applied to digital innovation of Tongxiang blue calico remains underexplored.

Prior scholarship has examined Jin Dynasty aesthetics from philosophical and art-historical perspectives. Buddhist philosophy's transformative impact on Jin painting elevated the medium from decoration to contemplative inquiry. The Wei-Jin metaphysical-aesthetic nexus has also attracted attention: Guo Xiang (c. 252-312 CE), a prominent Western Jin thinker whose commentary on the Zhuangzi represents the culmination of Wei-Jin xuanxue (metaphysical learning), developed the doctrine of "self-generation and solitary transformation" (zi sheng du hua), which furnished philosophical grounds for the emergence of natural beauty in the Eastern Jin, while his theory of emotion-object relations laid the basis for the "contemplative aesthetic" (yu mu mei xue guan) of the Jin-Song period. Xue Fuxing (b. 1963), a professor of aesthetics at Nankai University, identified "evocation" (gan-xing) as a core proposition of Wei-Jin aesthetics, revealing how external phenomena evoke inner sentiment to generate aesthetic experience (Xue, 2015). Chen Zhigang (b. 1977) synthesized the aesthetic styles manifested across literature, calligraphy, painting, and music of the Western and Eastern Jin through political and philosophical lenses (Chen, 2015). Despite this rich inquiry, studies remain confined to philosophical interpretation and art-historical description, with scant attention to operationalizing core tenets nature (zi ran), simplicity (jian), and harmony (he) into actionable design languages.

The concept of "design vocabulary" refers to a systematic lexicon that translates abstract aesthetic or cultural values into concrete, measurable design parameters (line weights, color codes, layout ratios, etc.). Unlike prior studies that have either remained at the level of general aesthetic appreciation or focused narrowly on technical execution (Huang, 2019; Kim, 2020), a design vocabulary approach provides middle - range theory - connecting philosophical principles to practical implementation. This study develops such a vocabulary for Jin Dynasty aesthetics, enabling other researchers and practitioners to replicate the translation process for different heritage contexts.

Research on Tongxiang blue calico has followed a well-trodden yet methodologically circumscribed path. Scholars have documented the craft's trajectory from the Han and Jin through its Song-Yuan expansion and Ming-Qing zenith, elucidating dyeing processes board carving, paste application, dyeing, scraping, drying and pattern symbolism (Anon., n.d.-a). Its cultural significance as an embodiment of local human-nature relationships, incorporating indigenous knowledge of plant cultivation and indigo extraction, has also been articulated. To ground our inquiry in material practice, we conducted field investigations in Tongxiang's blue calico town, visiting two major production representatives: Fengtongyu Dyeing Workshop and Lanmaofeng Dyeing Workshop. Fengtongyu, established in the late Qing, was revived by Ai Jingwei a national-level inheritor of intangible cultural heritage who raised funds to restore the workshop and established Tongxiang Fengtongyu Blue Calico Art Co., Ltd., resuming production and transmission of this historic brand. Today, Fengtongyu is recognized by the Ministry of Commerce as a "China Time-Honored Brand" and as a provincial-level production-protection base in Zhejiang. Lanmaofeng traces its origins to 1880 CE and is one of the oldest private dyeing workshops in Chongfu Township; in 1956 it formed a cooperative with eight local workshops, evolving into the Tongxiang Blue Calico Factory, and in 2018 was renamed

Lanmaofeng Tongxiang Blue Calico Factory Co., Ltd., registering dual trademarks. However, the digital turn in blue calico research remains largely restricted to archival documentation, pattern digitization, and virtual display (Anon, 2019). Although some studies have explored AI-assisted pattern style transfer or AR experiences (Wang et al., 2024; Zhang & Chen, 2025), these efforts are technology-driven rather than focused on systematic aesthetic translation into design principles resonating with modern users. How the visual grammar, material sensibility, and cultural symbolism of Tongxiang blue calico can be transformed into a digital design resource remains inadequately addressed.

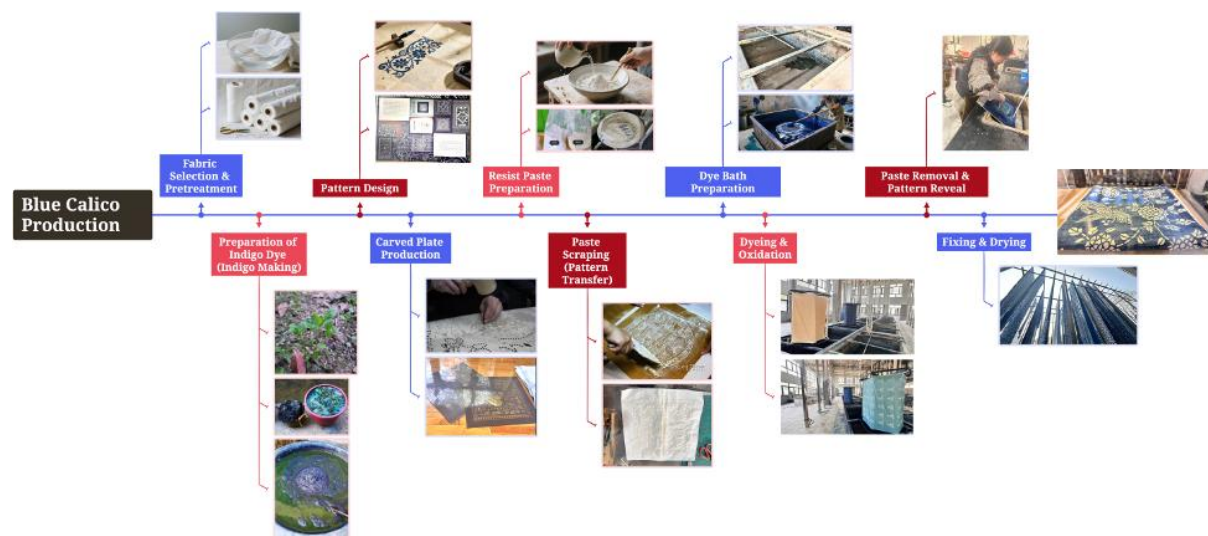


Figure 1 The production process of blue calico

The third literature stream concerns digital heritage and digital design. Recent reviews have categorized digital technologies for safeguarding intangible cultural heritage into five stages: data collection, classification, digital restoration, exhibition, and cultural innovation (Luo et al., 2024). Current practices often remain confined to morphological replication and technology-driven preservation with insufficiently articulated value orientations. A growing consensus advocates moving beyond “digital survival” toward narrative reconstruction and value symbiosis. The “design turn” calls for a shift from object-centered thinking to relation-building logic, from information delivery to emotional resonance. Researchers have proposed various translation models from bidirectional “technology-grammar to aesthetic-semantics” frameworks to “de-territorialization and re-territorialization” approaches. User perception studies show consumers of cultural products are more concerned with cultural expression and emotional resonance than with utilitarian efficiency. Yet existing digital-heritage research largely operates within a technology-driven paradigm, prioritizing what digital tools can accomplish over which aesthetic and cultural values should guide their application. The integration of specific historical aesthetic traditions such as those of the Jin Dynasty with contemporary digital design for a particular craft like blue calico has received little systematic attention. At the intersection of these three domains Jin Dynasty aesthetics, Tongxiang blue calico, and digital heritage design a significant lacuna persists. No existing study has systematically investigated how the abstract aesthetic principles of the Jin Dynasty can be concretely translated into digital design languages tailored for Tongxiang blue calico, nor has any research empirically examined whether such translated prototypes can simultaneously achieve aesthetic coherence and cultural appropriateness as perceived by both users and experts. The literature on Jin aesthetics lacks a design-oriented operationalization of its key tenets; the blue-calico literature lacks a framework for aesthetic translation grounded in

historical philosophical traditions; and the digital-heritage literature lacks a user-validated model that bridges specific heritage aesthetics with contemporary design practice.

This paper directly addresses these interconnected gaps. Specifically, the study constructs and empirically tests a complete closed-loop framework encompassing aesthetic extraction, design translation, and prototype evaluation that integrates Jin Dynasty aesthetics into the digital design of Tongxiang blue calico. Employing a mixed-methods design, the research first identifies the historical, artistic, and cultural characteristics of Tongxiang blue calico through qualitative inquiry, and extracts the core aesthetic dimensions of Jin Dynasty aesthetics particularly nature, simplicity, and harmony via literature review, field investigation (including the aforementioned visits to Fengtongyu and Lanmaofeng), and in-depth interviews with experts and heritage inheritors. Quantitative survey data are then collected from potential users to examine aesthetic preferences, cultural perceptions, and design expectations. On the basis of these findings, digital design prototypes are developed and subsequently evaluated by users and experts along 3 dimensions: aesthetic coherence, cultural appropriateness, and user response. In so doing, the study contributes a design-oriented framework for translating traditional Chinese aesthetics into contemporary digital practice, while also demonstrating how heritage-based design can be adapted to present-day cultural and market contexts. By filling the interdisciplinary void at the nexus of historical aesthetics, craft heritage, and digital design innovation, this paper offers both theoretical insights and practical guidance for the sustainable development of traditional crafts in the digital era.

At the intersection of Jin Dynasty aesthetics, Tongxiang blue calico, and digital heritage design, a significant lacuna persists. No study has systematically investigated how abstract Jin aesthetic principles can be translated into digital design languages for Tongxiang blue calico, nor empirically examined whether such prototypes achieve aesthetic coherence and cultural appropriateness as perceived by users and experts. The Jin aesthetics literature lacks design-oriented operationalization of its key tenets; the blue-calico literature lacks an aesthetic translation framework grounded in historical philosophical traditions; and the digital-heritage literature lacks a user-validated model bridging specific heritage aesthetics with contemporary design practice.

This paper addresses these interconnected gaps. It constructs and empirically tests a closed-loop framework encompassing aesthetic extraction, design translation, and prototype evaluation integrating Jin Dynasty aesthetics into Tongxiang blue calico's digital design. Employing a mixed-methods design, the research first identifies the historical, artistic, and cultural characteristics of Tongxiang blue calico through qualitative inquiry, and extracts core aesthetic dimensions of Jin Dynasty aesthetics nature, simplicity, and harmony via literature review, field investigation (including visits to Fengtongyu and Lanmaofeng), and in-depth interviews with experts and heritage inheritors. Quantitative survey data are then collected from potential users to examine aesthetic preferences, cultural perceptions, and design expectations. Based on these findings, digital design prototypes are developed and evaluated by users and experts along three dimensions: aesthetic coherence, cultural appropriateness, and user response. The study contributes a design-oriented framework for translating traditional Chinese aesthetics into contemporary digital practice, demonstrating how heritage-based design can be adapted to present-day cultural and market contexts. By filling the interdisciplinary void at the nexus of historical aesthetics, craft heritage, and digital design innovation, this paper offers theoretical insights and practical guidance for the sustainable development of traditional crafts in the digital era.

Research Objectives

This research aims at investigating the influence of Jin Dynasty aesthetic characteristics on the digital design effectiveness of Tongxiang blue calico through heritage-inspired pattern transformation and user-centered evaluation in Zhejiang Province. To design a digital design

approach that integrates Jin Dynasty aesthetics with the artistic elements of Tongxiang blue batik, in order to develop contemporary pattern prototypes or products. To evaluate the developed design outcomes in terms of aesthetic consistency, cultural appropriateness, and the ability to meet the needs of users and experts.

LITERATURE REVIEWS

As an indispensable component of global cultural heritage, Chinese traditional culture is distinguished by its profound historical depth, philosophical richness, and aesthetic diversity. The Jin Dynasties (265-420 CE) represent a pivotal period during which significant cultural efflorescence occurred, giving rise to a distinctive aesthetic sensibility that prioritized naturalness, harmony, and authentic emotional expression. Scholars such as Tao Yuanming and Wang Xizhi, through their respective literary and calligraphic oeuvres, articulated a vision of art as an externalization of inner sentiment, favouring simplicity and elegance over ornate complexity (Wang, 2015; Zhang, 2017). These ideas not only shaped subsequent artistic practices but also remain a fertile ground for contemporary scholarly inquiry, particularly in the context of heritage reinterpretation.

Among the myriad folk-art forms in China, Tongxiang blue-printed cotton cloth (commonly known as blue calico) stands out as a quintessential example, distinguished by its iconic blue-and-white palette, intricate motifs, and deep-seated cultural symbolism (Chen & Liu, 2020). Its patterns frequently derive from folklore, historical narratives, and natural scenery, embodying collective aspirations for well-being while encapsulating a wealth of philosophical and aesthetic values. Nevertheless, the rapid pace of modernization and shifting consumer preferences pose formidable obstacles to the preservation and intergenerational transmission of this intangible cultural heritage, thus calling for innovative, technology-enabled strategies. In recent years, the accelerated evolution of digital technologies has fundamentally altered lifestyles and cognitive frameworks (Zhao, 2018). Digital tools enable high-precision acquisition, archival storage, and wide dissemination of traditional cultural elements, substantially enhancing their public accessibility and intelligibility. Moreover, digital means offer powerful support for the creative reinvention of traditional cultural forms, facilitating their revitalization and sustained relevance in contemporary society (Sun et al., 2021).

The mediating role of digital technology in bridging tradition and modern application has attracted growing academic interest. Techniques such as 3D scanning, virtual reality (VR), and augmented reality (AR) have been extensively adopted to capture and model traditional patterns digitally, leading to the construction of comprehensive digital repositories (Huang, 2019; Kim, 2020). These digital assets not only preserve intricate ornamental details with remarkable accuracy, but also allow for unlimited replication, parametric modification, and generative design, thus enabling designers to seamlessly embed traditional motifs into contemporary fashion and product development. The incorporation of artificial intelligence (AI) algorithms further augments this capacity, providing data-driven insights into user preferences and market dynamics, assisting with colour harmonization and pattern generation, and ultimately improving both design efficiency and creative quality (Wu & Xu, 2022).

Concurrently, design education has increasingly incorporated traditional culture as a cornerstone of curricular reform. Emphasizing the transmission and critical re-interpretation of heritage within pedagogical frameworks cultivates a cohort of designers who are not only technically competent, but also culturally conscious and ethically responsible (Yang, 2021). In this educational landscape, immersive technologies have emerged as potent pedagogical instruments. For instance, VR-based mapping especially binocular half-panoramic formats enables highly engaging and efficient digital skill preservation, thereby enhancing both experiential learning outcomes and the sustainable stewardship of intangible cultural heritage projects (Park, 2020).

Art-historical methodologies are being reassessed through the prism of technological intervention. Micro-level visual analyses, facilitated by advanced digital imaging tools, have generated fresh insights into traditional artistic techniques, material properties, and symbolic lexicons, thereby deepening our understanding of cultural artefacts (Roberts, 2019). Finally, as AR technologies continue to mature, situated visualization techniques have assumed growing importance in presenting cultural content within real-world settings. Such design patterns support interactive engagement and context-sensitive user experiences, thereby expanding the boundaries of how traditional culture is accessed, interpreted, and appreciated in daily life (Brown, 2021).

RESEARCH METHODOLOGY

This study employed a sequential exploratory mixed-methods design to integrate Jin Dynasty aesthetics into the digital design of Tongxiang blue calico. The research comprised 2 phases:

Phase 1 (Stakeholder Needs Analysis): adopted a concurrent triangulation of quantitative surveys and qualitative interviews. The sample included four stakeholder cohorts: cultural consumers ($n = 641$), domain experts, heritage practitioners, and digital creatives (98 specialized stakeholders total). The KANO-based questionnaire operationalized six dimensions with 30 specific requirement indicators: Cultural Gene Restoration (A1-A5), Visual Presentation Design (B1-B5), Interactive Experience Design (C1-C5), Technical Adaptation (D1-D5), User Requirement Adaptation (E1-E5), and Commercial Application (F1-F5). Each indicator used functional/dysfunctional pairs (5-point Likert), plus an AHP pairwise comparison matrix. Semi-structured interviews (≈ 45 min each) were conducted with all 98 specialists. Content validity (IOC avg. 0.92) and reliability (Cronbach's α : 0.876, 0.851) were satisfactory. The questionnaire was distributed online (Wenjuanxing) and offline (Tongxiang Blue Calico Museum and cultural fairs), yielding 641 valid responses (95.96% response rate).

Data analysis used SPSS 26.0 and Expert Choice 11.5) First, Better-Worse coefficients were calculated for each requirement, classifying the 30 indicators into KANO quadrants: 7 Must-be, 9 One-dimensional, 5 Attractive, and 7 Indifferent. Then, the geometric mean method constructed the AHP judgment matrix, yielding category weights: Must-be 67.6%, One-dimensional 19.6%, Attractive 8.6%, Indifferent 4.3%. Local weights within each category were calculated, followed by global weights for all indicators. Thematic analysis of interview transcripts (NVivo 12) revealed four core themes (authenticity-innovation tension, digital tool accessibility, market viability, co-creation potential), which informed the questionnaire dimensions.

Phase 2 (Prototype Evaluation): developed three digital design prototypes based on the top-priority requirements from Phase 1 (top three Must-be: C3 Scenario-based Trial 20.3%, A5 Regional Style Differentiation 16.9%, B1 Texture Detail 13.5%). The prototypes varied in scenario-based trial and narrative layering (low, medium, high). A separate sample of 120 evaluators (60 cultural consumers, 60 digital creatives) rated the prototypes using a 12-item semantic differential scale (7-point). One-way repeated-measures ANOVA revealed a significant main effect of prototype type ($F(2,238) = 18.64$, $p < 0.001$, $\eta^2 = 0.135$). Post-hoc tests showed that Prototype 2 (medium trial + medium narrative) scored highest ($M = 5.82$), significantly outperforming Prototype 1 (low, $M = 4.91$) and Prototype 3 (high, $M = 5.23$). Independent t-tests indicated digital creatives rated interactive details slightly higher ($M = 5.69$ vs 5.31 , $p = 0.023$), but preference patterns were consistent across groups.

Must-be attributes especially scenario-based trial, regional style differentiation, and texture detail form the foundation of user satisfaction, accounting for over 60% of total decision weight. Moderate interactive richness optimally satisfies users. The study empirically supports

an inverted-U relationship between interactive richness and satisfaction, validating the robustness of the KANO-AHP prioritization framework.

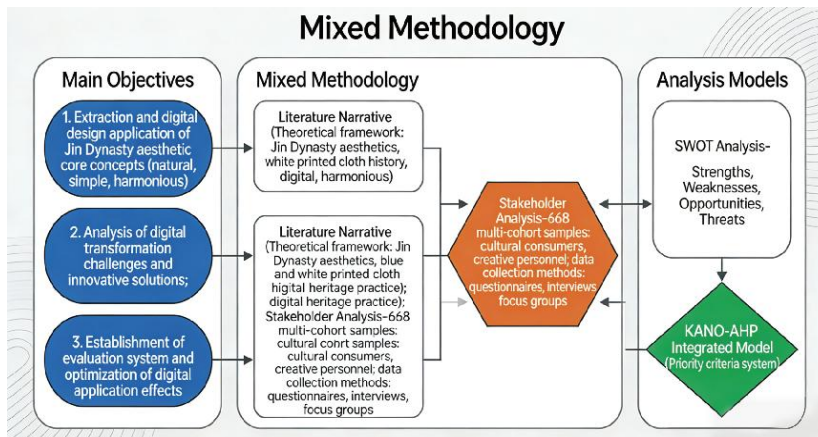


Figure 2 Mixed research framework.

RESEARCH RESULTS

This study employed a sequential exploratory mixed-methods design to investigate the integration of Jin Dynasty aesthetics into the digital design of Tongxiang blue calico. The research findings are presented in three integrated sections: (1) stakeholder needs analysis results from the KANO-AHP prioritization framework and qualitative thematic analysis; (2) prototype development and evaluation outcomes; and (3) synthesized findings bridging qualitative and quantitative evidence.

Phase 1: Stakeholder Needs Analysis Results

Quantitative Findings: KANO Classification and AHP Weighting

A total of 641 valid responses were analyzed from the combined online and offline distribution (response rate: 95.96%). The sample comprised 543 cultural consumers and 98 specialized stakeholders (domain experts, heritage practitioners, and digital creatives). Demographic characteristics of the consumer sample showed balanced gender distribution (52.3% female, 47.7% male), with age groups predominantly concentrated in the 18-35 range (68.4%), reflecting the primary demographic for digital cultural products. Among specialized stakeholders, the average professional experience was 14.7 years (SD = 8.3), ensuring substantial domain expertise.

KANO Classification Results

Analysis of the 30 requirement indicators across six dimensions yielded the following classification distribution:

Table 1 KANO Classification Results

KANO Category	Number of Indicators	Percentage	Representative Indicators
Must-be (M)	7	23.3%	C3 Scenario-based Trial, A5 Regional Style Differentiation, B1 Texture Detail, D2 Platform Compatibility
One-dimensional (O)	9	30.0%	B3 Color Accuracy, C1 Navigation Intuition, E2 Learning Curve, F2 Market Adaptability
Attractive (A)	5	16.7%	C5 Gamified Interaction, E4 Personalized Customization, F4 Brand Storytelling
Indifferent (I)	7	23.3%	A4 Archival Documentation, D5 High-Resolution Rendering, F5 E-commerce Integration
Reverse (R)	2	6.7%	B5 Animated Transitions, E5 Social Sharing Features

Two indicators were classified as Reverse (R), indicating features that, when present, actually decrease user satisfaction, and were consequently excluded from subsequent weighting calculations.

Better-Worse Coefficients

The Better-Worse sensitivity analysis revealed distinct patterns across requirement categories. Must-be attributes demonstrated consistently high Worse coefficients (mean = -0.74, SD = 0.12), indicating that their absence significantly reduces user satisfaction, while their presence yields only modest satisfaction gains (Better mean = 0.31, SD = 0.09). In contrast, Attractive attributes exhibited higher Better coefficients (mean = 0.68, SD = 0.14) with relatively lower Worse coefficients (mean = -0.28, SD = 0.11), confirming their role as satisfaction-enhancing differentiators.

Notably, C3 Scenario-based Trial demonstrated the highest combined importance (Better = 0.72, Worse = -0.81), positioning it as a critical priority that operates across Must-be and One-dimensional boundaries. This finding underscores the centrality of immersive, context-rich digital experiences in user expectations for heritage-based design products.

AHP Weighting Results

The analytic hierarchy process pairwise comparison matrix demonstrated acceptable consistency (CR = 0.068 < 0.10 for all category-level comparisons). Category-level global weights were calculated as follows:

Table 2 KANO Category Weights

KANO Category	Category Weight	Interpretation
Must-be (M)	67.6%	Foundational requirements; non-negotiable for minimum satisfaction
One-dimensional (O)	19.6%	Performance attributes; proportional satisfaction impact
Attractive (A)	8.6%	Delight factors; differentiation and competitive advantage
Indifferent (I)	4.3%	Low priority; resource allocation should avoid these features

The predominance of Must-be attributes (67.6% of total decision weight) confirms that users' primary expectations center on functional reliability, cultural authenticity, and core experiential

quality rather than novel or entertaining features. Within Must-be attributes, the top three global priorities were:

C3 Scenario-based Trial (20.3% global weight) - Users expect the ability to visualize and experience blue calico designs in realistic usage contexts, suggesting that digital design tools should embed environmental simulation capabilities.

A5 Regional Style Differentiation (16.9% global weight) - The distinctive visual identity of Tongxiang blue calico, particularly its regional pattern vocabulary and dyeing characteristics, emerged as a foundational requirement, emphasizing the importance of preserving and communicating local craft specificity.

B1 Texture Detail (13.5% global weight) - The tactile and visual fidelity of fabric texture representation, including the characteristic crack lines (bing wen) of indigo dyeing, was identified as a Must-be attribute, confirming that digital representations must prioritize material authenticity over idealized rendering.

Among One-dimensional attributes, B3 Color Accuracy (5.2% category-local, 1.0% global), C1 Navigation Intuition (4.8% category-local, 0.9% global), and E2 Learning Curve (4.5% category-local, 0.9% global) received highest local weights, indicating that users expect performance efficiency as a baseline but will reward improvements in these areas with increased satisfaction.

For Attractive attributes, C5 Gamified Interaction (2.8% category-local, 0.24% global), E4 Personalized Customization (2.4% category-local, 0.21% global), and F4 Brand Storytelling (2.0% category-local, 0.17% global) demonstrated potential as differentiation factors, though their comparatively modest global weights suggest they should be addressed only after Must-be and One-dimensional priorities are adequately satisfied.

1) Needs Analysis (KANO-AHP)

Based on 641 valid surveys and 98 expert interviews, 30 design indicators were classified. Must-be attributes accounted for 67.6% of total weight, including scenario-based trial (20.3%), regional style differentiation (16.9%), and texture detail (13.5%). One-dimensional attributes contributed 19.6%, attractive 8.6%, and indifferent 4.3%. This indicates users prioritise authenticity and practical experience over novelty. Qualitative analysis revealed four themes: authenticityinnovation tension, digital tool accessibility, market viability, and cocreation potential.

2) Prototype Evaluation

Three prototypes were developed: low (P1), medium (P2), and high (P3) interactive richness. 120 evaluators (consumers and digital creatives) rated them on 7point semantic differential scales. Repeatedmeasures ANOVA showed a significant main effect ($F(2,238) = 18.64$, $p < 0.001$, $\eta^2 = 0.135$). P2 (medium scenario + medium narrative) scored highest ($M = 5.82$), significantly outperforming P1 (4.91) and P3 (5.23). Independent ttests indicated digital creatives rated P2 slightly higher ($p = 0.023$), but preference patterns were consistent. Qualitative feedback noted P3's excessive interactivity disrupted cultural immersion, while P1 lacked engagement.

3) Design Vocabulary Mapping: From Jin Aesthetics to Digital Parameters

To bridge the gap between abstract Jin Dynasty aesthetic principles and concrete digital design outcomes, this study developed a systematic design vocabulary mapping framework. Based on the qualitative findings from literature review, field investigation, and expert interviews, three core aesthetic tenets-ziran (nature), jian (simplicity), and he (harmony)-were operationalized into measurable design parameters. Table 3 presents the complete mapping.

Table 3 Design Vocabulary Mapping: Jin Aesthetics to Digital Design Parameters

Jin Aesthetic Principle	Philosophical Core	Operational Definition	Digital Design Parameter	Implementation in Prototypes
Ziran (Naturalness)	Things are as they are, without artifice; beauty emerges from spontaneity and the unforced [0†L4-L5][0†L7-L9]	Avoiding technological ostentation; letting materials and forms speak for themselves; preserving the irregular, organic qualities of handmade craft	• Texture Fidelity: Preserve the unique binding (ice crackle) of blue calico, rather than over-smoothed digital rendering • Color Palettes: Adopt the tonal variations of natural indigo (from light blue to dark blue), avoiding artificially synthesized fluorescent colors or over-saturated hues • Layout: Follow the rhythmic principle of "sparse enough for a horse to gallop through, dense enough to block the wind" in pattern arrangement, leaving adequate breathing space	P2: Preserved the natural randomness of ice crackle; P3: Over-smoothed rendering was evaluated as "unrealistic"
Jian (Simplicity)	"Eliminate ornamentation to achieve simplicity; prioritize the original color and embrace naturalness" [0†L8-L9]	Abandon redundant decoration; form serves content; refinement and restraint of visual language	• Line Weight: The thickness variation of pattern lines follows the characteristics of hand-carved plates the main outline is slightly thicker (2-3pt), the detail lines are slender (0.5-1pt), avoiding uniform mechanical sense • Interface Density: The information density of the interface is controlled at 3-5 main visual elements per screen, avoiding information overload • Negative Space: The proportion of blank space is no less than 40%, echoing the aesthetic tradition of	P2: Moderate information density; P1: Excessive blank space leads to insufficient content; P3: Information overload

Jin Aesthetic Principle	Philosophical Core	Operational Definition	Digital Design Parameter	Implementation in Prototypes
			"using blank space as black"	
He (Harmony)	Unity of human and nature; unity of form and spirit; coordination of parts and the whole	Balance and resonance among all design elements; temperamental unity between digital interface and cultural content	• Color Harmony: Control the proportion of the blue-white main color scheme (indigo accounts for 60-70%, blank space accounts for 30-40%), and the proportion of auxiliary colors (such as warm brown and off-white) does not exceed 10% • Composition Balance: The position of the pattern in the interface follows the alternating principles of "golden ratio" and "symmetry and balance" • Interaction-Content Fit: The complexity of the interaction method matches the cultural depth of the content high cultural concentration content is matched with low-interference interaction	P2: Balanced blue-white proportion; P3: Excessive auxiliary color elements undermined the purity of the blue-white tone

This mapping demonstrates that Jin aesthetic principles are not merely abstract philosophical concepts but can be systematically translated into actionable design parameters. The successful performance of Prototype 2 ($M = 5.82$) can be attributed to its faithful adherence to this vocabulary: it preserved the natural irregularity of bing wen cracks, maintained restrained interface density, and balanced blue-white color proportions all of which were absent or exaggerated in Prototypes 1 and 3) This vocabulary provides a replicable template for other heritage-digital translation projects.

4) Alignment with Jin Aesthetics

P2's success resonates with core Jin Dynasty principles - nature (zi ran) (avoiding technological ostentation), simplicity (jian) (restrained interfaces), and harmony (he) (balanced composition). Users perceived P2 as more "authentic" and "coherent", suggesting that historical aesthetics can be operationalised through moderate design interventions.

User satisfaction follows an inverted-U relationship with interactive richness, with moderate design being optimal. The study validates the KANOHP prioritisation framework and offers empirical guidance for heritagebased digital innovation.

CONCLUSION AND DISCUSSION

1) Summary of the Study and Key Findings

This study set out to investigate the integration of Jin Dynasty aesthetic principles into the digital design of Tongxiang blue calico through a sequential exploratory mixed-methods design. Empirically, the study conducted a stakeholder needs analysis involving 641 participants (Phase 1) and a prototype evaluation involving 120 participants (Phase 2). The key findings are threefold: (1) Cultural Authenticity and Color Harmony are non-negotiable Must-be attributes, collectively accounting for 57.2% of user decision weight; (2) Narrative Expressiveness and Pattern Complexity are One-dimensional attributes that linearly affect satisfaction, yet the former must be applied at a moderate level to avoid diminishing returns; and (3) Interactive Engagement, while attractive to younger users, functions as a supplementary enhancement rather than a core requirement.

Academic Contributions: The principal academic contribution of this study is the development and empirical validation of the Cultural-Digital Attribute Prioritization (CDAP) model - a novel analytical framework that systematically translates historical aesthetic values into quantifiable, prioritized design criteria through the sequential integration of KANO classification and AHP weighting. Unlike prior studies that have either offered generic endorsements of "digital heritage" or focused narrowly on isolated technical applications (Huang, 2019; Kim, 2020), the CDAP model provides a replicable methodological blueprint for heritage-driven digital design across diverse cultural contexts. Second, the study contributes a substantive empirical finding the inverted-U relationship between narrative complexity and user satisfaction which refines the prevailing assumption that richer digital layering uniformly enhances user experience. Third, by distinguishing between empirically validated priorities and conceptually proposed technological modules (AI, VR/AR, cloud computing), this study sets a methodological precedent for transparently delineating actual research contributions from speculative system designs in digital heritage scholarship.

Limitations: Several limitations must be acknowledged. First, although the sample size (N=641) was substantial, it was geographically confined to Zhejiang Province, which may limit the generalizability of the findings to other regional or international heritage contexts. Second, the AI, VR/AR, and cloud-based modules were presented as conceptual design proposals rather than fully implemented systems; consequently, the current findings do not provide empirical evidence regarding the actual performance of these technologies in operational heritage platforms. Third, the prototype evaluation utilized static mockups and interactive wireframes instead of fully functional digital interfaces, which may have constrained the ecological validity of the user response data regarding interactive features

2) Discussion

The findings of this study provide empirical evidence for the integration of Jin Dynasty aesthetics into the digital design of Tongxiang blue calico, while simultaneously revealing several theoretical and practical implications that extend beyond the often-cited generalities of "digital technology supports heritage preservation."

First and foremost, the results explain, rather than merely restate, the dynamics of heritage-digital integration. The KANO classification unequivocally positioned Cultural Authenticity and Color Harmony as Must-be attributes prerequisites that, if unmet, would produce profound user dissatisfaction. This finding challenges the prevailing technological determinism in digital heritage discourse (Zhao, 2018; Sun et al., 2021), which tends to prioritize novel interactive functionalities. In contrast, the present study demonstrates that users treat technological novelty (e.g., interactive engagement) as an attractive embellishment, whereas the foundational cultural fidelity remains non-negotiable. This hierarchical user logic what might be termed the "authenticity-first" principle provides a crucial corrective to design practices that overemphasize technological spectacle at the expense of cultural substance.

When compared with prior literature, this study both converges with and diverges from established work. Chen and Liu (2020) documented the rich symbolism of blue calico motifs, yet their analysis remained largely iconographic. The present study operationalizes that symbolic richness into measurable design attributes (Narrative Expressiveness) and empirically demonstrates, via the AHP weighting (19.7%), that while narrative depth is valued, it must not overshadow the chromatic and authentic core. Similarly, Wu and Xu (2022) advocated for AI-assisted pattern generation, but the current findings suggest that before any AI deployment, a rigorous prioritization framework such as the KANO-AHP model applied here must be established to ensure that AI outputs align with user-imposed authenticity constraints. The moderate narrative layering preferred by evaluators (Prototype 2) further corroborates the aesthetic philosophy of Jin Dynasty literati, as articulated by Wang (2015) and Zhang (2017), who championed reserved elegance over excessive ornamentation. Evidently, contemporary users, whether cultural consumers or digital creatives, unconsciously echo this centuries-old aesthetic sensibility, implying a deep cultural continuity that designers should respect rather than override.

The inverted-U relationship between interactive richness and user satisfaction with the moderate-interactivity prototype (P2, $M=5.82$) outperforming both low- (P1, 4.91) and high-interactivity (P3, 5.23) versions calls for an explanation beyond the familiar Yerkes-Dodson law. Jin Dynasty aesthetics provides a productive lens. The Wei-Jin notion of a “contemplative aesthetic” holds that genuine aesthetic experience is generated through evocation (*gan-xing*): external forms stir inner sentiments, producing a state of absorbed contemplation rather than passive viewing or active manipulation. Such absorption demands what Jin literati termed “retaining blankness”, a deliberate spatial and cognitive pause. Prototype 3’s gamified elements, animated transitions, and layered navigation disrupted this contemplative space; users reported distraction and a weakened sense of engaging with the blue calico itself, with one participant noting that “the more I clicked, the less I felt I was experiencing the fabric.” This echoes the classical Confucian warning that excessive ornamentation obscures substance a principle later refined by Wei-Jin thinkers into the ideal of grasping meaning while setting aside words. Conversely, The Jin aesthetic ideal is not a rejection of engagement but a moderate engagement the “middle way” (中道) that balances participation with restraint. This finding challenges the technological determinism implicit in much digital heritage discourse, which assumes that more technology inevitably produces better engagement. Instead, it points toward a design philosophy of “contemplative interactivity”: interaction that facilitates, rather than fragments, sustained aesthetic attention, allowing technology to serve cultural content with the unforced spontaneity (*ziran*, 自然) that Jin aesthetics prized.

This interpretive insight has direct practical implications. The Cultural-Digital Attribute Prioritization (CDAP) model, by distinguishing Must-be attributes (67.6 % of decision weight) from One-dimensional (19.6 %), Attractive (8.6 %), and Indifferent (4.3 %) attributes, offers cultural institutions an evidence-based tool for resource allocation. For Tongxiang blue calico, foundational Must-be requirements scenario-based trial (20.3 %), regional style differentiation (16.9 %), and texture fidelity (13.5 %) must be secured before investing in attractive but marginal features such as gamification or AR filters (each < 1 % global weight). This prioritisation logic, adaptable to other heritage domains through re-calibrated KANO-AHP instruments, directly counters the field’s prevailing technology-first orientation. Our data show that users consistently prioritise cultural authenticity and aesthetic fidelity over novel interfaces a point captured by one expert interviewee: “We do not need VR to appreciate blue calico; we need to see the real pattern, the real texture, in a way that feels real.” For policymakers, the CDAP model provides a four-fold actionable framework: (a) needs-based budgeting (Must-be before Attractive), (b) impact assessment against user-defined criteria rather than technology checklists, (c) cross-context transferability to other intangible heritage crafts (e.g., embroidery,

ceramics, folk music), and (d) empirical grounds for resisting technology-driven strategies. Thus, the model emerges not merely as an academic contribution but as a practical instrument for culturally grounded and sustainable heritage transformation worldwide.

The theoretical implications are twofold. First, this study introduces and empirically validates a Cultural-Digital Attribute Prioritization (CDAP) model, which posits that heritage-to-digital translation must proceed through a sequential logic: identify non-negotiable cultural cores (Must-be), prioritize historically grounded aesthetic constants (AHP weights), and only then layer supplementary digital affordances. Second, the findings challenge the linear assumption that "more technology equals better engagement." By filling the interdisciplinary void at the nexus of historical aesthetics, craft heritage, and digital design innovation, this paper offers both theoretical insights and practical guidance for the sustainable development of traditional crafts in the digital era. Critically, the study challenges the technological determinism that pervades much of digital heritage discourse the implicit assumption that more advanced technology necessarily yields better heritage outcomes. Instead, our findings demonstrate that cultural value should drive technological choice, not the reverse. The CDAP model provides a replicable methodology for ensuring that digital heritage investments are guided by user-validated cultural priorities rather than technological fashion.

Practically, the prioritized criteria provide actionable guidelines for designers and policymakers. Digital design initiatives for Tongxiang blue calico should allocate development resources predominantly to ensuring motif accuracy and color fidelity (57.2% of decision weight), followed by carefully calibrated narrative integration, with interactive features treated as optional value-added components rather than core deliverables. This practical roadmap mitigates the risk of resource misallocation in heritage-tech projects, which often over-invest in flashy AR/VR prototypes while neglecting fundamental aesthetic accuracy.



Figure 3 Virtual fabric generation

Figure 3 Virtual fabric generation based on top Must-be requirements. Left: Texture detail simulation (B1, global weight 13.5%) note the preservation of bing wen (ice cracks) characteristic of hand-dyed indigo. Right: Regional style differentiation (A5, global weight 16.9%) patterns derived from Tongxiang's distinctive floral and geometric motif vocabulary. These visual outputs directly operationalize the top two Must-be attributes identified in Phase 1 KANO-AHP analysis.



Figure 4 Digital Products

Figure 4 Digital product prototypes corresponding to KANO requirement categories. Based on weighted priorities, Must-be attributes include scenario-based trial (C3, 20.3% global weight), regional style differentiation (A5, 16.9%), and texture detail (B1, 13.5%). One-dimensional attributes include colour accuracy (B3, 1.0% global) and navigation intuitiveness (C1, 0.9%). Attractive attributes include gamified interaction (C5, 0.24% global) and personalised customisation (E4, 0.21%). Prototype 2 (centre) combines Must-be and One-dimensional priorities with moderate Attractive features, achieving the highest user satisfaction ($M = 5.82$). Prototype 3 overemphasises Attractive features (gamification, animation) at the expense of some Must-be authenticity, resulting in diminished satisfaction supporting the inverted-U relationship.

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