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Design and Research of a Tie-Dye Virtual Simulation Platform Based on Service Design Thinking

Wei Xie[1], Li Sun*[1,2],Yujie Wang[1]

1 School of Art and Design，Jiangsu University of Technology, Changzhou, Jiangsu 213001,China

2 Artificial Intelligence Innovation Design Laborator， Jiangsu University of Technology,Changzhou, Jiangsu 213001,China

Abstract: Many valuable items of intangible cultural heritage (ICH) in China are characterized by high learning thresholds and limited dissemination. Digital transformation provides an effective means to address these challenges while enabling accessible and convenient ICH experiences. Taking tie-dye as a representative traditional craft, this paper presents the research and design of a tie-dye virtual simulation experience platform based on service design thinking. Through multi-dimensional investigations, the study identifies users' pain points, needs, emotions, and behavioral characteristics during tie-dye learning and experience. As a result, a practical and innovative tie-dye virtual simulation platform is developed, featuring simulated tie-dye production, integrated learning, artwork exchange, and market exploration. A key contribution is an AI-enabled digital learning mode that allows users to infer tie-dye techniques from visual patterns ("technique inference from patterns"). This study not only offers a design solution for the digitalization of tie-dye heritage, but also provides transferable approaches for the intelligent transmission and innovation of other ICH practices, contributing to the integration of traditional handicrafts and modern technology.[1]

Keywords: Tie-dye Experience, Virtual Simulation, Service Platform, Interface Design

1. Research Background and Literature Review

1.1 Research Background

Tie-dye (*jiaoxie*), a national-level intangible cultural heritage (ICH) of China, embodies significant historical, artistic, and cultural value and plays an important role in aesthetic education and cultural identity. Recent national policies, such as the *14th Five-Year Plan for Cultural Development*, have emphasized the digital protection and living transmission of ICH, providing institutional support for the modernization of traditional crafts.

Despite this support, traditional tie-dye transmission faces persistent challenges, including complex manual processes, high material and time costs, limited dissemination channels, and low accessibility for the general public. In particular, the non-intuitive relationship between tying techniques and resulting patterns increases learning difficulty and reduces transmission efficiency.

With the rapid development of digital technologies, such as virtual simulation and artificial intelligence, new opportunities have emerged for addressing these challenges. Service design thinking, characterized by its human-centered and system-oriented approach, focuses on optimizing stakeholder relationships, service touchpoints, and processes to maximize service value. Integrating service design with virtual simulation offers a promising pathway for creating accessible, engaging, and sustainable digital ICH experiences.

1.2 Literature Review

Existing research on ICH digitalization has largely focused on foundational approaches such as digital archiving, multimedia documentation, and virtual exhibitions. Studies have employed high-definition recording and motion capture for performing ICH, process visualization for craft-based ICH, VR-based reconstructions of traditional opera performances, and virtual museums that integrate diverse ICH projects for immersive browsing and interaction.Virtual reality (VR) technologies have been applied to reconstruct stage settings and performance details of traditional opera, enabling audiences to “participate” in virtual performances from immersive perspectives.[2]

However, most prior work emphasizes technological representation rather than user-centered service design. Insufficient attention has been paid to user needs, experiential continuity, and value creation, resulting in limited usability and low long-term engagement in some digital ICH platforms.Most existing research prioritizes technological representation and content display, while lacking systematic consideration of user experience, service processes, and value co-creation within digital ICH platforms.

2. Research and User Needs Analysis

2.1 Competitive Product Analysis

To clarify digital tie-dye market positioning, existing tie-dye apps were analyzed on major mobile platforms like Apple App Store and Android marketplaces. Apps such as Daranfang, Tie-Dye Design Art, and DIY Tie-Dye were evaluated for target users, core functions, distinctive features, limitations, and download performance.

The analysis focused on key dimensions including target user groups, core functions, distinctive features, advantages and limitations, and download volumes. Comparative evaluation identified market opportunities, trends, and unmet needs, providing reference for the proposed platform's design and strategy in Table 1.

Table 1. Competitive Product Analysis

Product	Target Users	Core Functions	Strengths	Limitations
Tie-dye Design Art	Children (5–10)	Color filling, pattern templates	Simple operation; visual appeal	Lacks procedural guidance and real craft logic
DIY Tie-dye	General users, beginners	Basic tie-dye tutorials, short videos	Combines learning and entertainment	Limited depth; weak community interaction
Ran Dye	Adults (18–45), designers, artisans	Cultural content, advanced techniques, customization	Professional knowledge and cultural depth	High learning cost; complex operation
Tie Dye Pro	Students and trend-oriented users (12–25)	Pattern simulation, fashion design	Focus on visual outcomes and styling	Insufficient cultural context; no physical production linkage

2.2 Participatory Experience Research

Participatory experience research was conducted to support process-oriented service design. Six participants from an offline tie-dye experience group were selected for shadowing research. Their activities were observed and documented, followed by focus group discussions. Experience diaries and user journey maps were developed, dividing the experience into pre-service, in-service, and post-service stages.

The analysis identified key touchpoints, pain points, and opportunity areas. Common issues included operational errors, unclear techniques, process complexity, and concerns about staining or material safety. Users expressed expectations for learning experiences that are intuitive, efficient, and easy to implement, forming an empirical basis for digital experience design.

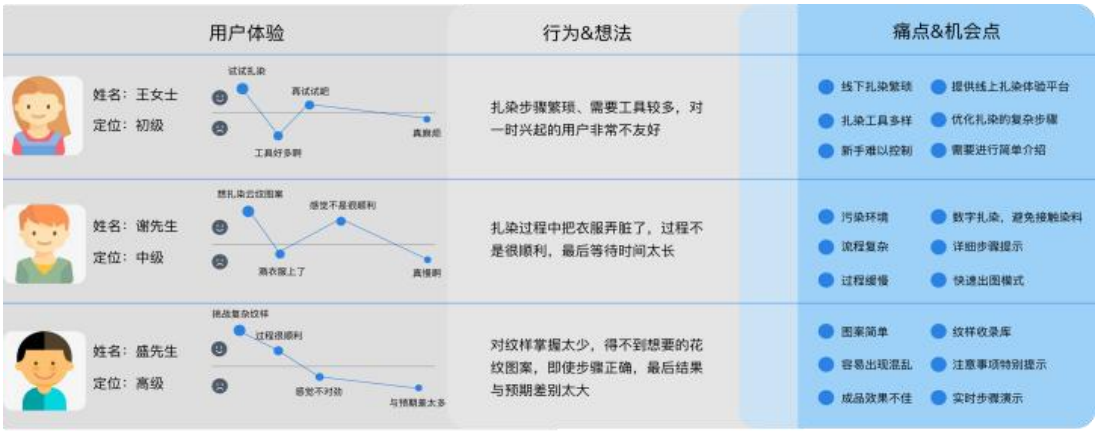

Figure 1. Analysis of Participatory Experience Research

2.3 Questionnaire Survey

A questionnaire survey was conducted to quantitatively validate findings from the qualitative research. A total of 208 valid responses were collected from participants aged 12–61, including students, artisans, educators, and general users.

Results showed that 87% of respondents were familiar with tie-dye, and 76.2% expressed interest in tie-dye as an ICH experience, yet only 16.8% had participated in offline activities. Among experienced users, 63% reported significant inconveniences, such as complex procedures, high costs, long waiting times, and difficulty controlling patterns. Meanwhile, 60.2% of respondents expressed interest in online tie-dye experiences.

Overall, potential users expected digital products to be easy to operate, engaging, and visually appealing, with integrated learning, creative, and community features.

3. Service Design of the Tie-Dye Virtual Simulation Platform

Guided by a human-centered and holistic service design framework, this study constructed a comprehensive service system for a tie-dye virtual simulation experience platform. The design process included user role modeling, stakeholder analysis, service ecosystem construction, and service blueprint development.

3.1 User Role Modeling Based on Design Positioning

Closely aligned with the overall design positioning, user role modeling was conducted for the virtual tie-dye experience platform to meet the learning, experiential, and dissemination needs of users at different levels. Through such modeling, targeted service pathways and interaction modes can be developed for diverse user groups, thereby ensuring that the platform effectively supports multi-level tie-dye learning, experience, and communication needs, as Figure 2.

Figure 2. User Role Modeling of the Tie-Dye Virtual Simulation Experience Platform

3.2 Construction of the Service Model Framework

A service model framework was constructed by integrating core users and stakeholders into a sustainable ecosystem. Ecosystem analysis was applied to identify potential partners, such as material e-commerce and cultural tourism platforms, and to define key connection points, including supply chain integration and cultural dissemination modules. In the tie-dye experience system, heritage-based products, techniques, and courses constitute the main revenue sources. Content creation

mechanisms, including cultural storytelling and product traceability, are incorporated to enhance user engagement and creative participation. This balanced service model supports both cultural transmission and long-term platform sustainability,as Figure 3.

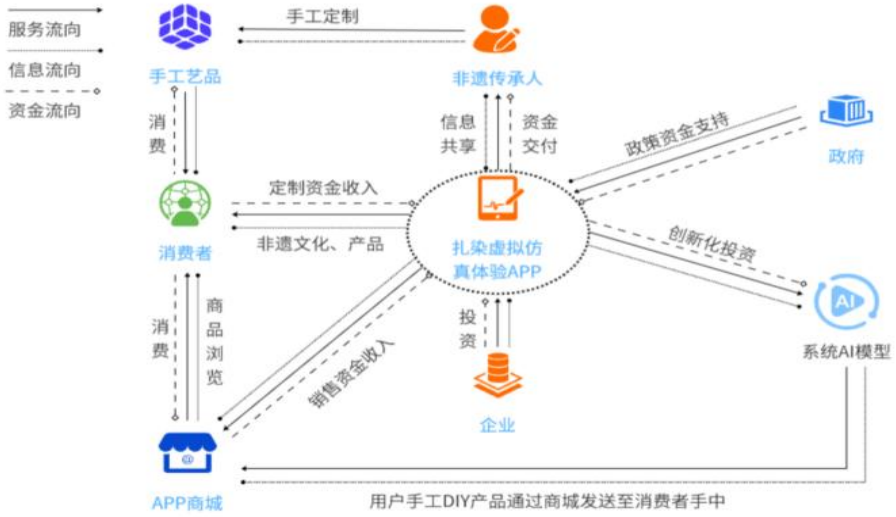

Figure 3.service ecosystem

3.3 Service Blueprint Design of the Tie-Dye Virtual Simulation Experience Platform

The service blueprint visualized frontstage functions (experience, learning, community, and marketplace) and backstage operations (content production, AI-based recommendation, transaction support, logistics, and data feedback).

Table2 Service Blueprint Design

Layer	Core Services	Key Stakeholders	Core Interactions
Front-End (User Interface Layer)	Virtual tie-dye experience (DIY)Integrated learning (text, video)Community co-creation and exchange Marketplace and customization AI voice assistant	General users Students and educators Designers and consumers	Guided learning workflows; interactive virtual tools; AI-based pattern–technique inference; content sharing and social interaction; customized product ordering
Back-End (Service Operation Layer)	Content production and management AI-based artwork matching Offline workshop connection Order and transaction management User data analysis and personal	Platform operators ICH practitioners Technical and data teams	Front–back resource matching; virtual-to-physical production workflow; learning-to-purchase path tracking; AI-assisted pricing and recommendation
Support Layer (Infrastructure Layer)	Tie-dye digital database AI and cloud computing services Open APIs and multi-party collaboration	Cultural institutions Educational organizations Enterprises	Pattern–technique mapping via AI models; cultural symbol annotation; standardized ICH data output; educational access and copyright settlement

4. Design of the Tie-Dye Virtual Simulation Experience App

The tie-dye virtual simulation app serves as the primary user interface and interaction medium within the service system, enabling an integrated experience from digital creation to product consumption. Its design includes functional planning, information architecture, and interface prototyping.[3]

4.1 Functional Design

Core functions include virtual tie-dye DIY, pattern and tying-method libraries, AI-assisted tie-dye generation, learning guidance, community interaction, collaboration with heritage inheritors, and an online marketplace. The app structure consists of modules such as Home, Discover, DIY Experience, Community, Learning, Marketplace, and Personal Center.

The Home module provides access to the core “DIY Creation Canvas,” which integrates tools, color selection, editing options, and AI-assisted generation, supporting both personalized creation and one-click intelligent design. Other modules support offline activity discovery, community interaction, and personalized experience modes based on user proficiency levels.

4.2 Interface Design

The interface design emphasizes clarity, efficiency, and stylistic consistency. Inspired by the blue-and-white gradient aesthetics of traditional tie-dye, the visual design preserves cultural characteristics while incorporating contemporary minimalist elements.[1]

Fig. 4 Virtual Tie-dyeing UI Design

Fig. 5 Virtual Tie-dyeing UI Design (Mobile Version)

5. Conclusion

Intangible cultural heritage demonstrates enduring cultural value across time and space. Tie-dye, in particular, represents not only a craft form but also a carrier of social customs, beliefs, and historical memory. Service design thinking, with its human-centered and system-oriented perspective, provides an effective methodological framework for ICH digitalization.

By integrating virtual simulation, AI technologies, and service design, this study proposes a new digital tie-dye experience that addresses user accessibility, learning efficiency, and engagement. The proposed platform supports virtual craftsmanship experience, creative exploration, and sustainable value creation, offering transferable insights for the digital transmission and innovation of other traditional cultural practices.

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Corresponding Author:

Li Sun, Associate Professor, PhD, Master’s Supervisor. Research interests include experience design