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Original Paper

Research on Interactive Design of Intangible Heritage APP Based on CA/QFD/TRIZ Integration Method

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Abstract

This study addresses challenges in intangible cultural heritage (ICH) development under cultural digitalization strategies by optimizing ICH app design using an integrated CA/QFD/TRIZ approach. User needs were identified through CA analysis of app feedback, utilizing ROST CM6 software for word frequency and social semantic network analysis to categorize primary and secondary demand categories. These needs were translated into product features using QFD theory, which also identified key contradictions. TRIZ theory was then applied to resolve these contradictions and generate solutions. Based on this process, specific ICH app design strategies were formulated and validated through a case study, resulting in a comprehensive design solution. The integrated CA/QFD/TRIZ paradigm quantitatively clarified user needs, optimized design directions, and provides a valuable framework for future app design research, empowering the digital transformation of traditional ICH.

Keywords

CA method, QFD theory, TRIZ theory, intangible cultural heritage, APP design, integrated methods research

1. Introduction

In the context of cultural competition under the new wave of digital globalization, the digital transformation of intangible cultural heritage (ICH) has become a key focus for China's efforts in ICH preservation and development. The rapid advancement of China's internet infrastructure and communication technologies has highlighted the cultural dissemination potential of mobile apps, which feature low dissemination costs, broad audiences, high user engagement, convenient access, innovative browsing experiences, and rich informational content. These attributes have driven the innovative development of ICH digitization, positioning ICH-related apps as pivotal platforms for ICH protection and dissemination.

Currently, ICH-related apps in China remain in their nascent and developmental stages. In terms of user engagement, these apps face challenges such as low download rates and weak user retention due to their niche appeal compared to social, e-commerce, lifestyle, news, multimedia, and gaming apps. Regarding content, most ICH apps focus on digital showcases of specific crafts or regional traditions, offering unidirectional, informational displays that lack interactive elements, emotional resonance, and in-depth, diversified content exploration. Slow or stagnant content updates further undermine user experience. From a design perspective, visual interfaces tend to be static and lack interactivity, resulting in low engagement. These limitations render ICH apps mere digital replicas of printed materials, failing to achieve transformative and innovative dissemination of ICH.

Existing studies on ICH app design have made valuable contributions. For instance, Ren et al. (2022) utilized conjoint analysis to identify user needs across three dimensions—visual presentation, functional attributes, and interaction experience—and translated these into design principles for ICH app interfaces, validating their approach through the Qing Sha Culture app. Zhang et al. (2020) applied Garrett's user experience model to analyze design principles and logical relationships at different levels, constructing a user experience model for ICH apps and validating it with the design of the Twenty-Four Solar Terms app. Wu (2017) adopting a user-centered design (UCD) perspective, addressed pain points in ICH app design and usage. While these studies have enriched the field, they primarily rely on single theories and methods, limiting their depth of analysis.

To address these shortcomings, this study proposes an integrated CA/QFD/TRIZ methodology to ensure scientific rigor and accuracy in the research process. This approach enables a deeper analysis of ICH app design, assisting researchers in creating apps that better align with user needs while effectively promoting ICH dissemination.

2. Research Methods and Design Process

2.1 The Integrated CA/QFD/TRIZ Method

Content Analysis (CA) is a quantitative, systematic, and objective social science research method for analyzing human communication content. Introduced by U.S. scholar Berelson, CA encodes and quantitatively describes information in communication content, enabling deep analysis and inference of significant features(Yan et al., 2024). This study employs CA to collect and analyze user reviews of ICH-related apps, extract analytical units of user needs, encode and categorize results, and translate user feedback into app design elements.

Quality Function Deployment (QFD) is a systematic quality management and product design framework developed in the 1960s by Japanese scholars Yoji Akao and Shigeru Mizuno. The core concept, the House of Quality (HOQ), uses matrices to quantitatively map user needs to product features (Xiong et al., 2024). This study uses QFD to decompose user needs into specific app characteristics derived from CA analysis. These characteristics are prioritized and refined to ensure the designed app aligns with user expectations.

The Theory of Inventive Problem Solving (TRIZ), created by Soviet engineer Altshuller in 1946, provides tools and principles for systematically addressing contradictions in innovative problem-solving. TRIZ identifies solutions based on 40 inventive principles derived from historical innovation patterns (Tan et al., 2001). ICH app design inherently involves innovation; TRIZ addresses contradictions between user needs and product features, offering strategies to refine and optimize the app design process. After identifying contradictions via QFD, TRIZ principles guide the resolution of these conflicts, culminating in actionable app design strategies.

The CA/QFD/TRIZ methodology integrates the strengths of each method: CA identifies user needs, QFD translates these needs into app characteristics and reveals contradictions, and TRIZ resolves these contradictions to generate optimal solutions. This progressive, complementary framework ensures a reliable and scientifically grounded app design process, ultimately producing an ICH app that meets user needs and effectively promotes cultural dissemination. The integrated approach, characterized by its scientific, rigorous, and efficient nature, has been widely applied across disciplines and provides an innovative platform for ICH digital preservation.

By combining CA, QFD, and TRIZ, this study offers a multifaceted methodology to overcome the limitations of single-method approaches. Through theoretical integration and practical application, the research delivers an optimized ICH app design that addresses user and market demands while enhancing ICH digital dissemination.

2.2 ICH App Design Process Based on the Integrated CA/QFD/TRIZ Method

The design process for ICH apps, guided by the CA/QFD/TRIZ methodology, involves the following steps,As illustrated in Figure 1:

1. CA Phase: Collect and organize user review texts of ICH apps, extract analytical units, and construct coding categories. Conduct reliability tests to ensure objectivity, integrate content, and analyze results to extract user needs.
2. QFD Phase: Import user needs and their weights into the House of Quality to identify relationships between user needs and app features, as well as correlations among features. Calculate the weights of app characteristics.
3. TRIZ Phase: Use 39 universal engineering parameters to identify contradictions. Resolve conflicts through the TRIZ contradiction matrix and corresponding inventive principles. Translate solutions into specific design strategies for ICH apps.
4. Design Practice: Apply the developed strategies to the design and implementation of the ICH app.

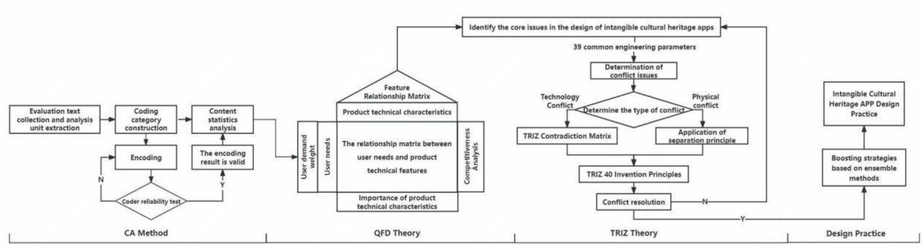

Figure 1. Design Technical Route

3. User Needs Extraction Based on the Content Analysis (CA) Method

3.1 Collection and Extraction of Analytical Units from ICH App Review Texts

First, user reviews of ICH-related apps from mobile application stores were collected for content analysis. User reviews provide crucial and authentic feedback on products, reflecting user activity levels and highlighting the features of an app that users prioritize. These reviews represent user needs, which directly influence product iteration and serve as a vital information source for app design(Ma et al, 2016). To ensure data reliability, the Apple App Store, as the earliest and most mature application platform, was selected as the source of research samples. The keyword "ICH" was used to retrieve apps, and results were sorted by the number of user reviews (as provided by the store's ranking system). The top five apps selected for this analysis were: Xichuangzhu (391,000 reviews), Craftsman (100,000 reviews), The Beauty of Poetry (13,000 reviews), China Treasure Gallery (12,000 reviews), and Folding Fans (2,000 reviews).

The reviews were further filtered based on the system's "Most Helpful" ranking. Comments that did not describe app features were excluded. From each app, 10 valid user reviews describing app attributes were selected, yielding a total of 50 review samples for analysis.

The collected review texts were processed to extract analytical units. The 50 review samples were imported into the ROST CM6 software for segmentation, word frequency calculation, and construction of a social semantic network matrix. Words with similar meanings or irrelevant terms were consolidated or removed during the word frequency analysis, resulting in the top 100 terms being selected as the analytical units for this study ,as illustrated in Table 1.

Table 1. 100 Analysis Units

Word segmentation/word frequency				
Games/27	Form/5	Attract/4	Simple/3	Aesthetics/2
Software/24	Experience/5	Study/4	Translation/3	Wonderful/2
Works/18	Pronunciation/5	Active/4	Appreciation/3	Environment/2
Culture/16	Place/5	Development/4	Uncommon/3	Interaction/2
Poetry/14	Developer/5	Interests/3	Pay/3	Article/2

Tradition/13	Settings/4	Screen/3	Click/3	Operation/2
Production/10	Love/4	Draft/3	Session/3	Model/2
Design/8	Structure/4	Willing/3	Feeling/3	Promotion/2
Application/8	Page/4	Verse/3	Ancient/3	suitable/2
Folding fan/8	Category/4	Comments/3	Project/3	Overall/2
Charge/8	Errata/4	apply /3	Free/3	Participation/2
Function/8	Time/4	Player/3	painting/3	Feeling/2
Mural/7	Knowledge/4	Phonetic/3	Understand/3	Studio/2
Art/7	Interface/4	Supplement/3	Ancient/3	Version/2
Select/7	Promote/4	Architecture/3	Demo/3	Copyright/2
Level/7	Exquisite/4	Imagination/3	History/3	Interpretation/2
Mortise and tenon/6	Help/4	Polyphonetic characters/3	Surprise/3	Comfort/2
China/6	Relax/4	First time/3	Collection/3	Background/2
Fan/6	Exit/4	Cancel/3	Re/3	Button/2
Rich/6	Conscience/4	Clear/3	Challenge/3	Style/2

3.2 Construction of App Coding Categories

The core of content analysis lies in content coding and classification. The identified analytical units were subjected to initial coding analysis, following one of three commonly used coding approaches: data-driven, research-based, and theory-guided coding (Zhang et al., 2020). The construction of categories adhered to two key principles: the principle of exhaustiveness, ensuring that all analytical units were covered by the constructed categories, and the principle of mutual exclusivity, ensuring that no overlap existed between categories and each analytical unit was assigned to a single unique category (NEUENDORF, 2016). Based on prior research, this study constructed primary and secondary categories, assigning values and codes to these categories to produce results suitable for statistical analysis.

The extracted analytical units were analyzed using the ROST CM6 software for social semantic network analysis, as illustrated in Figure 2. The resulting network showed a multi-node divergent structure with "culture" as the core node, connected to high-frequency terms such as "China," "art," "tradition," and "exquisite." These associations highlighted the centrality of "culture" in the content of ICH-related apps, particularly in aspects such as heritage preservation, educational inspiration, and cultural exchange, which are of critical importance to users.

The core diffusion layer of the semantic network comprised nodes such as "games," "culture,"and "software," and "interaction."

1) High-frequency terms associated with "games" included "settings," "free," "help," and "experience,"

reflecting the usability aspect of ICH apps.

2) Terms linked to "culture" included "tradition," "works," "promotion," and "love," emphasizing the content and experiential dimensions of these apps.

3) Words associated with "software" included "interface," "apply," "form," "developer," "player," and "active," reflecting the experiential and usability aspects of ICH apps.

4) Terms related to "interaction" included "select,""structure," and "art," highlighting the usability dimension of these apps.

This analysis underscores the multifaceted roles of ICH-related apps in balancing cultural content, user experience, and functionality, providing a robust foundation for subsequent design strategies.

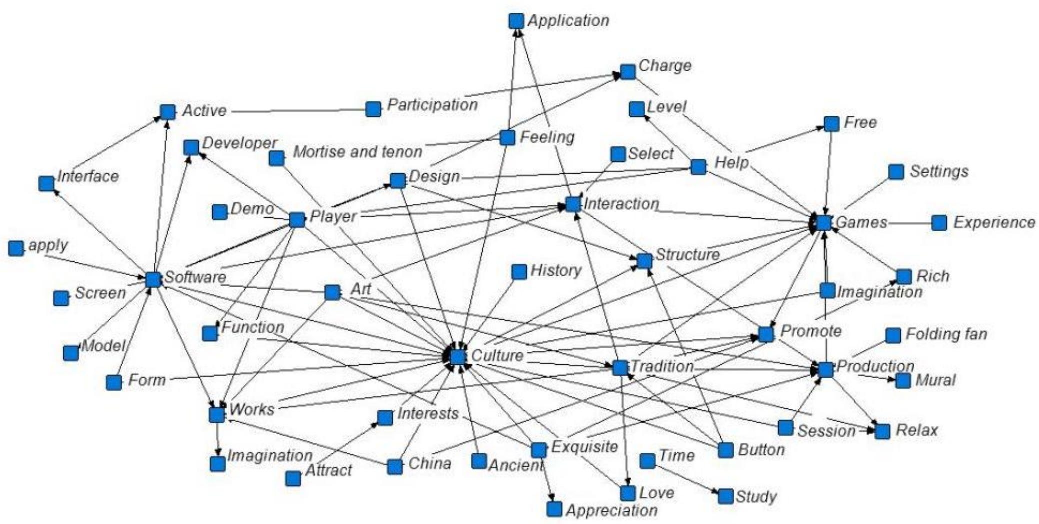

Figure 2. Social Semantic Network Analysis Diagram

Based on relevant research, theories, word frequency analysis, and social semantic network analysis, four primary categories were established for this study: content dimension, usability dimension, availability dimension, and experiential dimension.

1) Content Dimension: This category aims to enhance users' access to information related to intangible cultural heritage (ICH), deepen the cultural transmission of ICH, and encourage the creation of original value within the ICH domain.

2) Usability Dimension: This dimension focuses on aligning the product with users' cognitive and behavioral patterns, making the realization of product functionalities simple, efficient, intuitive, and seamless.

3) Availability Dimension: This layer addresses users' fundamental material-level requirements for the product, ensuring comprehensive functionality, consistent and reliable performance, and smooth, flexible interaction.

4) Experiential Dimension: Centered on a user-oriented approach, this category emphasizes creating user value while iteratively optimizing the product. It aims to fulfill users' personalized and social needs, enabling them to achieve self-worth, sustain ICH values, and generate societal value through a seamless user experience.

The social semantic network analysis employed co-occurrence matrices derived from high-frequency terms to visually represent the degree of association between these terms. Through summarization, 12 secondary codes were identified, As illustrated in Table 2.

Table 2. Construction of Coding Category

First level category	Secondary level Category
Content Dimension	1. Diverse themes 2. Cultural heritage 3. Interesting
Usability Dimension	1. Smooth operation 2. Clear interface 3. Timely feedback
Availability Dimension	1. Continuous optimization 2. Accurate information 3. Practical functions
Experiential Dimension	1. Emotional transfer 2. Visual attraction 3. Immersive interaction

3.3 Inter-Coder Reliability Testing

In the process of content analysis, it is necessary to involve two or more coders. Each coder independently evaluates the analytical units against the constructed categories and aims to reach consistent conclusions (Xu et al., 2005). In this study, two researchers were selected as coders. To ensure the objectivity and validity of the results, a reliability test was conducted prior to formal coding to assess the consistency and credibility of their coding. Upon passing the reliability test and ensuring that both coders were familiar with the coding criteria, a random sample from the database was used for a pilot coding test. Any ambiguities encountered during this process were resolved through coding adjustments. Only after both coders achieved an ideal level of consistency did the formal coding work proceed. At the conclusion of the coding process, the results from both coders were compiled and organized.

Cohen’s Kappa coefficient was employed as a statistical measure to evaluate the consistency of qualitative annotations and classifications between the two coders (Smeeton, 1985). This study utilized

Cohen’s Kappa in the DiVoMiner software to assess the reliability of the coding results. The calculated Kappa value was 0.856. According to the reliability standards outlined in Table 3, a coefficient between 0.81 and 1 is considered "excellent," demonstrating strong consistency between the coders. Therefore, the coding results in this study exhibit high reliability, confirming their validity.

Table 3. Cohen's Kapp a Coefficient Reliability Standard

Cohen’s Kappa coefficient	consistency
-1＜X＜1	Value range
＜0	Very bad
0≤X≤0.4	Faint/Weak
0.41≤X≤0.6	Moderate
0.61≤X≤0.8	Considerable (highly consistent)
0.81≤X≤1	Excellent

3.4 Results Analysis

Through data processing and analysis of the coding results, the secondary level categories were assigned and aggregated, yielding the word frequencies for secondary level categories, as illustrated in Table 4. By summing and ranking the word frequencies of the secondary categories, the word frequency sequence of the primary categories was determined as follows: Experiential Dimension (152) > Content Dimension (126) > Availability Dimension (97) > Usability Dimension (88). Through proportional distribution of first level category further facilitates an in-depth analysis and research of ICH-related apps.

Table 4. Content Analysis Statistics

First level category	secondary level categories	Coding results	Word frequency	Proportion/%	Total proportion /%
Content Dimension	Diverse themes	3, 20, 67, 70, 78	33	7.12	27.21
	Cultural inheritance	4, 6, 18, 23, 33, 35, 40, 55, 69, 72, 73, 76, 84, 85, 86	73	15.77	
	Interesting	24, 27, 45, 51, 56, 92	20	4.32	
Usability Dimension	Smooth operation	2, 7, 9, 39, 44, 66	53	11.45	19.01
	Clear interface	29, 34, 37, 61, 95, 98	19	4.10	

	Timely feedback	25, 31, 32, 59	16	3.46	
Availability Dimension	Continuous Optimization	21, 46, 48, 54, 65, 79, 88, 93, 94	26	5.62	20.95
	Accurate information	15, 28, 30, 60, 64, 96	23	4.97	
	Practical functions	8, 11, 12, 26, 47, 50, 53, 57, 62, 71, 90	48	10.36	
Experiential Dimension	Emotional Transfer	5, 10, 13, 17, 19, 38, 42, 49, 63, 74, 77, 89, 97	65	14.03	32.83
	Visual appeal	14, 16, 36, 41, 58, 75, 81, 82, 87, 100	36	7.78	
	Immersive Interaction	1, 22, 43, 52, 68, 80, 83, 91, 99	51	11.02	

In the primary categories, the experiential dimension accounted for 32.83%, highlighting the importance of user experience as a key reference for product development. This dimension emphasizes meeting users' emotional needs while optimizing the visual interface to provide an enhanced immersive interactive experience. The content dimension constituted 27.21%, reflecting users' expectations for engaging, thematically diverse cultural heritage content, particularly in an era characterized by fragmented and uneven information quality. The availability dimension accounted for 20.95%, underscoring the necessity of consistently and comprehensively fulfilling users' primary functional requirements. Lastly, the usability dimension represented 19.01%, emphasizing the need for products to align with users' cognitive and behavioral habits while ensuring simple and seamless operation.

In the secondary categories, users showed significant concern for cultural inheritance (73), emotional transfer (65), smooth operation (53), and immersive interaction (51). Other notable areas included timely feedback (16), clear interfaces (19), interesting (20), and accurate information (23).

The analysis of the coding results provides valuable insights for developers and designers, enabling them to better understand user experiences and identify issues encountered during app usage. These insights can inform iterative updates, fostering a positive cycle of improvement and enhancing the overall user experience. The analyzed statistical data is further presented in graphical form, As illustrated in Figure 3.

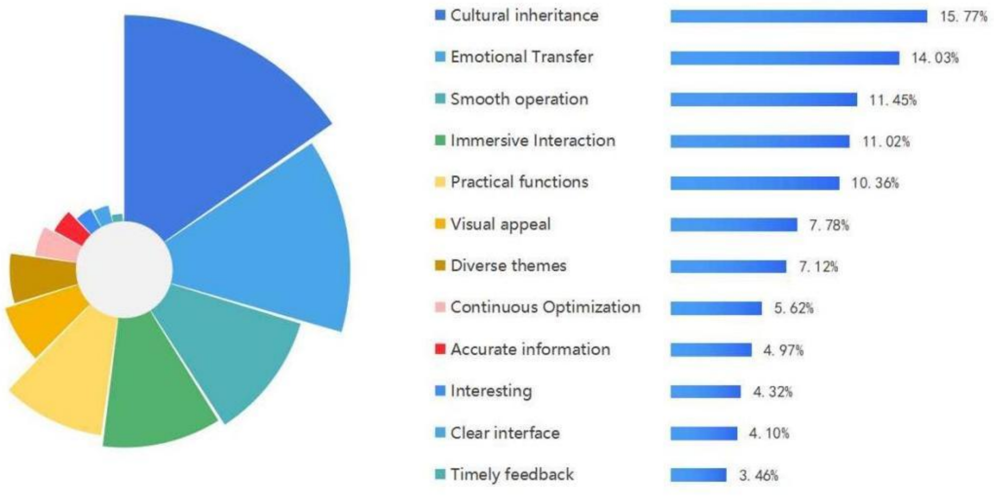

Figure 3. Proportion of User Preferences

4. User Need Translation Based on QFD Theory

After analyzing and calculating user need indicators for ICH-related apps using the CA method, QFD theory was employed to translate these needs into the technical characteristics of the product. This approach ensures a thorough understanding of user expectations and precisely converts them into actionable design guidelines. The core of this process is the construction of the House of Quality (HOQ), which establishes a direct mapping between user needs and product design elements. It emphasizes creating intuitive, user-friendly interfaces aligned with the theme of cultural heritage transmission while adhering to user experience design principles. This ensures a high degree of consistency between user needs, product design, and production, aiming to provide users with exceptional cultural and interactive experiences.

The user need indicators and their weighted results derived from the CA method were integrated into the HOQ to form the "left wall." Based on related literature and collected data, a comprehensive analysis was conducted to align user needs with the design objectives of ICH-related apps. This process translated user functional requirements into 10 product characteristics, which form the "ceiling" of the HOQ: interaction methods, functional architecture, user experience, content planning, personalization and customization, data analysis and feedback, education and training, sustainable maintenance, social interaction, and multimedia integration. The relationships between product characteristics were represented using "+" and "–" symbols to indicate positive and negative correlations, forming the "roof" of the HOQ. A relational matrix between user needs and product characteristics was populated to create the "rooms" of the HOQ. Priority values for product characteristics were calculated using weighted formulas and ranked on a scale of 1 to 10 to construct the "floor" of the HOQ.

This process resulted in the comprehensive construction of the HOQ for ICH-related apps (Dou et al., 2024;Wang et al., 2019), as illustrated in Figure 4.

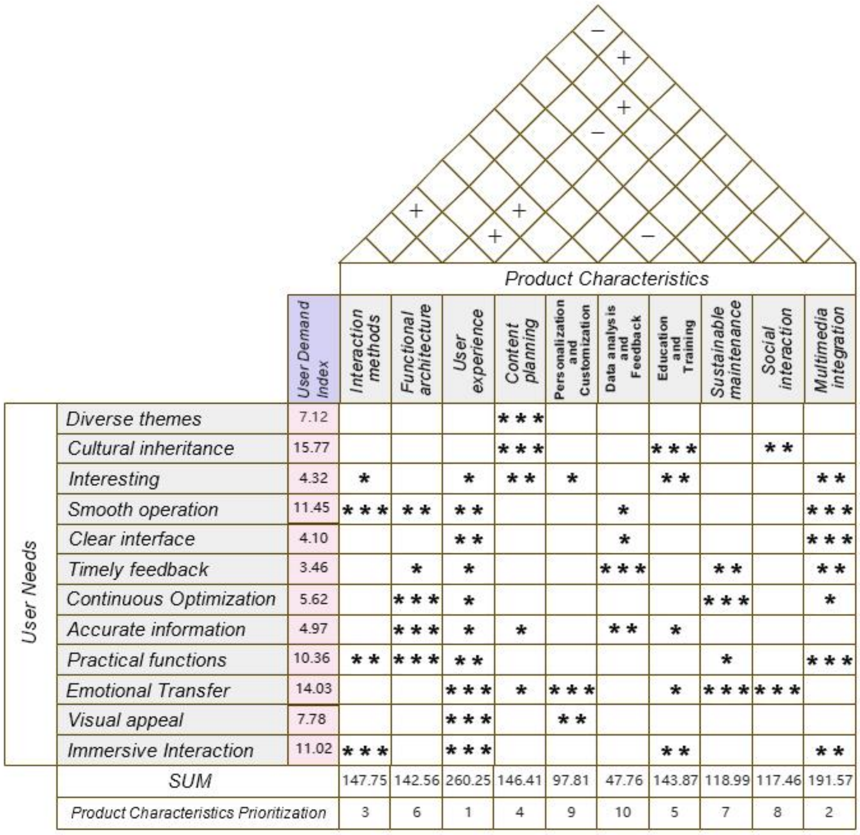

Figure 4. Intangible Heritage APP House of Quality Model

The relationship between user needs and product characteristics was analyzed and categorized into four levels of correlation: strong, moderate, weak, and none. Based on this classification, the correlation between each user need and product characteristic was annotated, as illustrated in Table 5.

Table 5. The Corresponding Assignment of Users' Emotional Needs and Technical Features

Degree	Strong	Moderate	Weak	None
Symbol	***	**	*	None
Points	5	3	1	0

Analyze the relationship between user needs and product characteristics, and calculate the corresponding total importance value (SUM) of product features. The calculation Equation (1) is:

$$SUM = \sum_{K=1}^{10} W \cdot M_k \tag{1}$$

In the formula, SUM represents the total importance value of product characteristics for ICH-related apps, M denotes the relative importance of user needs, and W refers to the numerical value assigned to the relationship matrix within the House of Quality (HOQ).

Based on the "basement" section of the HOQ model for ICH-related apps and the calculation of SUM, it was determined that content richness and diversity are the most critical features. The ranking of importance is as follows: user experience > multimedia integration > interaction methods > content planning > education and training > functional architecture > sustainable maintenance > social interaction > personalization and customization > data analysis and feedback.

Therefore, research on the design of ICH-related apps should focus on these technical characteristics in the order of their importance to guide the development process effectively.

5. Conflict Transformation and Resolution Based on TRIZ Theory

5.1 Identification and Analysis of Contradictions

First, the positive and negative correlations among the product characteristics that form the "ceiling" of the House of Quality (HOQ) model were determined. A "+" (positive correlation) indicates that improvements in one product characteristic will enhance the other. Conversely, a "–" (negative correlation) signifies that improvements in one characteristic will lead to a decline in the other. A blank indicates no correlation between the two characteristics. Based on these assessments, contradictions and conflicts among product characteristics were identified.

Three pairs of negatively correlated product characteristics were identified, reflecting conflicts between product features and user needs. These conflicts were translated into TRIZ problem models and categorized based on the corresponding contradiction types and generic engineering parameters, as illustrated in Table 6. TRIZ theory defines 39 generic engineering parameters, which were derived from extensive patent analysis conducted by the theory's founder. These parameters are organized into a Contradiction Matrix, which maps different forms of conflicts (Liu et al., 2021).

The following section provides an analysis of the three identified contradictions and their associated conflicts.

Table 6. TRIZ Transformation Analysis of Conflicts

Serial number	Negative correlation characteristics	General engineering parameters	Types of contradictions
1	Interaction methods Multimedia integration	NO.25 Time loss NO.36Complexity of the device	Technical contradictions
2	Data analysis and feedback Education and training	NO.37 Information loss NO.39 productivity	Technical contradictions
3	Sustainable maintenance User experience	NO.22 Energy loss NO.33 Operability	Technical contradictions

Conflict 1: Interaction Methods vs. Multimedia Integration

An increase in interaction methods may complicate multimedia integration within the application. Complex interaction methods could increase the time users spend navigating the app, negatively impacting user experience by introducing operational difficulties and errors, thereby reducing the app's usability.

Conflict 2: Data Analysis and Feedback vs. Education and Training

Excessive data analysis and feedback could compromise information completeness. Such information loss may lead users to question or distrust the educational content provided by the app, subsequently diminishing their willingness and efficiency in engaging with the educational training.

Conflict 3: Sustainable Maintenance vs. User Experience

To ensure the long-term development and sustainability of the app, continuous updates and improvements are required to address evolving user needs and technological environments. However, frequent updates may confuse or discomfort users, leading to reduced satisfaction and loyalty, ultimately affecting their willingness for long-term usage.

5.2 Resolution of Conflicts

The three conflicts were identified as technical contradictions within the framework of TRIZ theory. Technical contradictions are addressed by referencing inventive principles in Altshuller's Contradiction Matrix, which comprises 40 inventive principles offering guidelines for resolving technical or physical contradictions. By matching the conflicts to the relevant inventive principles in the matrix, potential solutions were identified. The associated contradiction matrix and the corresponding inventive principles for each conflict as illustrated in Table 7.

This structured approach provides actionable insights for resolving the identified conflicts and optimizing the design and functionality of ICH-related apps.

Table 7. Enumeration of Contradiction Matrix

Improved parameters / Deterioration parameters	NO.36	NO.39	NO.33
NO.25	NO.6、NO.29		NO.4、NO.10 NO.28、NO.34
NO.37	NO.1	NO.2、NO.18 NO.27、NO.35	
NO.22	NO.2、NO.10 NO.13、NO.35	NO.10、NO.28 NO.29、NO.35	NO.2、NO.13、 NO.19

Resolving Conflicts Based on the Inventive Principles in Table 7

Conflict 1: Interaction Methods vs. Multimedia Integration

1) Inventive Principle No. 6: Universality

By designing an interactive interface with multifunctionality, the system's efficiency and flexibility can be enhanced. For instance, a multi-mode interface could be developed, with each mode tailored to specific user needs and operational scenarios. A simple mode could support basic operations, while a more complex mode could facilitate in-depth exploration of multimedia content. Users can switch between modes based on their preferences, enabling a better experience of the app's functionality and content.

2) Inventive Principle No. 29: Pneumatics and Hydraulics (Pressure)

The application should identify solutions within the constraints of limited resources and technical capacity. By carefully designing interaction methods and multimedia integration, the app can minimize resource demands while enhancing user experience. For example, lightweight interaction designs and optimized multimedia content can reduce system performance requirements, thereby alleviating system stress and increasing adaptability.

Conflict 2: Data Analysis and Feedback vs. Education and Training

1) Inventive Principle No. 2: Taking Out

This principle suggests reallocating redundant or surplus resources to improve system efficiency. For instance, some resources dedicated to data analysis and feedback could be redirected to education and training. Useful insights derived from data analysis could directly inform updates and optimizations of educational content rather than merely being presented to users, maximizing resource utilization and enhancing training effectiveness.

2) Inventive Principle No. 27: Cheap Short-Lived Objects (Substitution)

More efficient educational methods could substitute some data analysis and feedback processes to achieve better outcomes. Adaptive learning systems or personalized recommendation algorithms, for example, can tailor educational content in real time based on user behaviors and preferences, reducing reliance on extensive data analysis while improving training efficiency and effectiveness.

3) Inventive Principle No. 35: Parameter Changes (Performance Transformation)

By leveraging system performance in one area to enhance another, the conflict can be addressed. For example, analyzing user behavior and feedback data can reveal preferences and learning needs. These insights can be directly applied to educational modules, recommending personalized content to improve learning outcomes and user satisfaction. In this way, data analysis and feedback not only provide accurate information to users but also become a key support for enhancing educational performance.

Conflict 3: Sustainable Maintenance vs. User Experience

1) Inventive Principle No. 2: Taking Out

This principle involves reallocating resources originally intended for frequent updates and long-term maintenance to enhance user experience. For example, resources such as manpower and technical support could be partially redirected to improving interface design, adding interactive features, and optimizing app responsiveness, thereby enhancing user satisfaction.

2) Inventive Principle No. 13: The Other Way Around (Reverse Action)

In this approach, enhancing user experience indirectly supports sustainability and long-term maintenance. By improving user satisfaction and loyalty, the app can increase its user base and engagement frequency. This expanded reach can generate greater resources and funding to support ongoing maintenance and development.

3) Inventive Principle No. 19: Periodic Action

Periodic and planned actions can resolve the conflict. For instance, implementing a regular user feedback collection schedule can inform updates and improvements. A structured plan for user experience enhancements could improve satisfaction and maintain app competitiveness. Periodic updates driven by user input not only enhance the app’s vitality but also ensure its sustainability and long-term maintenance.

These inventive principles provide a systematic and actionable framework for addressing the identified conflicts, ensuring a balanced development of features while meeting user needs and maintaining technical feasibility.

6. Design Practice for ICH-Related App

6.1 Functional Structure and Interaction Flow Design

Based on the analysis using the integrated CA/QFD/TRIZ methodology, user needs were deeply studied and precisely translated into technical characteristics to address specific design challenges. Leveraging the features of 5G-era apps, the design prioritizes user experience by directly mapping user expectations to interfaces and functions. The overall layout of the ICH-related app adopts a modular design with tab-style navigation. The bottom navigation bar includes five main modules: "Home," "Explore," "Guide," "Creative Works," and "My Profile."

1) Home: The "Home" page uses a waterfall layout to push user-preferred content, addressing Conflict 1 (Interaction Methods vs. Multimedia Integration) from the TRIZ Contradiction Matrix. Lightweight interaction design paired with optimized multimedia content minimizes cognitive load by streamlining and simplifying interactive elements such as buttons, links, and sliders. This improves operational smoothness and efficiency while reducing unnecessary steps.

2) Explore: The "Explore" module features multimedia content such as introductions to ICH projects, crafting processes, stories of inheritors, and exhibition activities. To enhance usability, the module retains a search bar at the top and employs an auto-carousel design to dynamically present diverse content. This addresses TRIZ Principle No. 6: Universality, dynamically balancing functionality and content diversity to increase user engagement.

3) Guide: The "Guide" module integrates an ICH map guide to resolve Conflict 2 (Data Analysis and Feedback vs. Education and Training) by applying TRIZ Principle No. 35: Parameter Changes (Performance Transformation). Analytical insights from user interaction data (e.g., dwell times and

interest points) are directly incorporated into the guide's functionality, allowing for real-time adjustments to routes and recommended sites. This personalized approach enhances both the touring experience and the app’s educational effectiveness.

4) Creative Works: This module features a streamlined transaction framework addressing Conflict 3 (Sustainability and Long-Term Maintenance vs. User Experience) by optimizing negative correlation characteristics in user experience. The design employs a clear page structure, a simplified shopping cart process, and periodic reviews of user feedback. This approach avoids excessive updates and maintenance while maintaining a smooth user experience.

5) My Profile: The "My Profile" module includes features for viewing personal settings, saved items, browsing history, feedback, and customer service. Additionally, it introduces an interactive community where users can share ICH-related experiences, upload images, and participate in discussions. This design aligns with findings from CA-based category construction, which identified the experiential dimension as the most critical user need. Consequently, "My Profile" focuses heavily on experiential aspects, serving as a vital component of the app's integrated ecosystem, as illustrated in Figure 5.

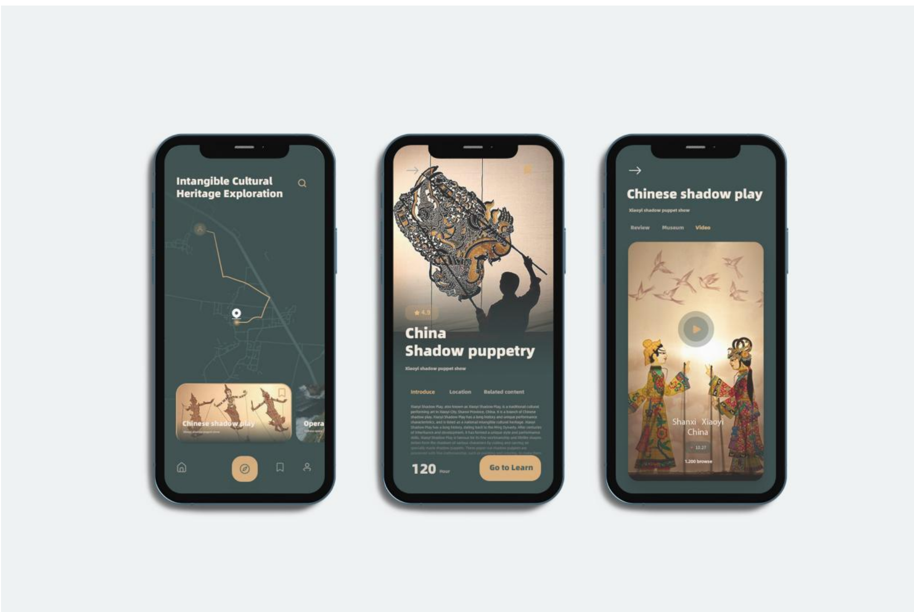

Figure 5. Intangible Heritage APP Interface Design

6.2 Content and Usage Mechanism Design

In designing the content and usage mechanisms, the conflict issues identified in the TRIZ Contradiction Matrix were addressed through four key dimensions:

1)Product Dimension: Building on foundational functionality, the app integrates advanced intelligent recommendation features to enhance the data-driven nature of ICH-related apps. This supports more sophisticated data collection and analysis, providing heritage organizations with detailed insights into user interests and behavioral patterns, thus enabling a more precise understanding of user needs.

2) User Dimension: Refined operations target both existing and potential users, offering personalized content recommendations and customized learning paths based on user interests and behaviors. This approach enhances user engagement and satisfaction by tailoring the content to individual preferences.

3) Content Dimension: Both private and public traffic channels are leveraged to develop innovative engagement strategies. These include viral marketing tools such as task-driven, incentive-based, and group-sharing mechanisms. By gamifying the dissemination of ICH content, the app creates engaging and interactive experiences that encourage users to deeply explore and participate in ICH culture, thereby fostering greater user involvement in cultural transmission.

4) Mechanism Dimension: Through decentralization, the content weighting mechanism is adjusted to incorporate intelligent distribution. Exclusive content recommendation mechanisms are established alongside feedback channels, encouraging users to share experiences and provide suggestions. This iterative feedback loop supports ongoing improvements to the app's mechanisms and user experience.

Examples of content and usage mechanism optimization as illustrated in Figure 6.

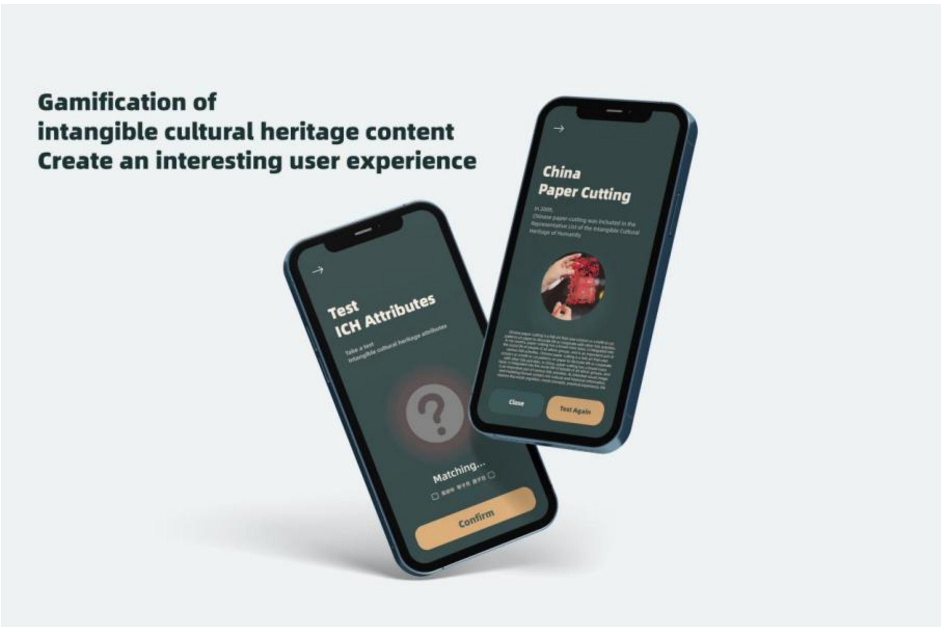

Figure 6. Examples of Content and Usage Mechanism Optimization

6.3 Design Evaluation

To validate the effectiveness of the ICH-related app design, a cognitive walkthrough method was employed to gather feedback from experienced users of ICH-related apps. The cognitive walkthrough is a usability testing method aimed at evaluating a user's ability to interact with a system while performing specific tasks. Compared to other usability testing approaches, its key advantages are cost-effectiveness and rapid execution (NIELSEN, 1994).

A detailed testing protocol was established to ensure the accuracy of the results. The testing process involved the following steps:

1) Initial Interface Review: Observing users' first impressions of the interface.

Functionality Understanding: Evaluating users' comprehension of the interface functionalities.

2) Task Execution: Identifying potential issues users may encounter during interactions.

3)Post-Task Feedback: Collecting user feedback after task completion.

Fifteen participants were selected for this evaluation. Each participant followed the specified testing protocol using a high-fidelity prototype on a mobile device. User interactions were recorded during task execution, and post-task feedback was analyzed. The results were combined with the coding category framework to create a design evaluation radar chart, which assessed the reasonableness of the design practice. Scores were assigned on a scale from 0 to 10, as illustrated in Figure 7.

Among the 12 evaluation indicators, 10 scored above 7, confirming the feasibility and effectiveness of the design practice.

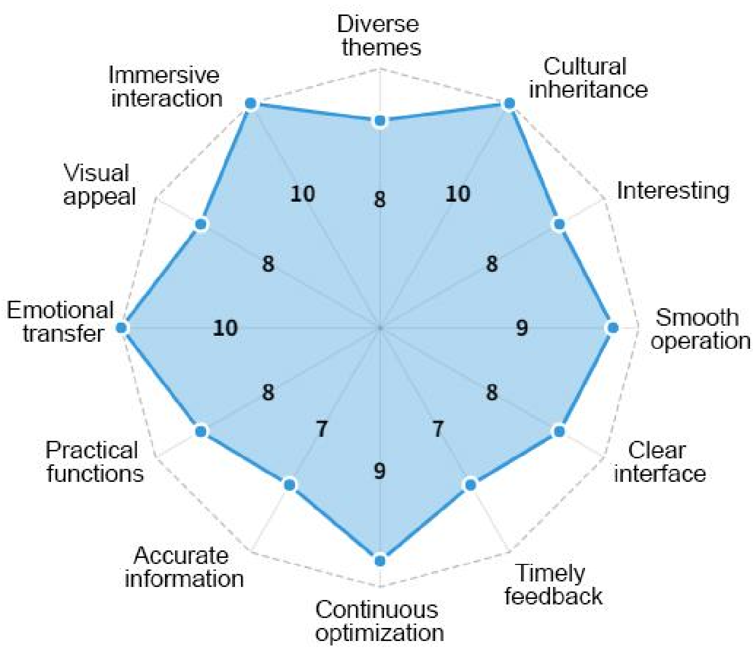

Figure 7. Design Evaluation Radar Chart

7. Discussion

This study employed the integrated CA/QFD/TRIZ methodology to address the challenges of designing ICH-related apps, successfully translating user needs into actionable design features and resolving key conflicts between functionality and user experience. The findings demonstrate that systematic methods can enhance the cultural and technical dimensions of app design, enabling a more user-centered approach to the preservation and dissemination of intangible cultural heritage (ICH). Compared to prior research, which often focused on isolated aspects of design, this study provides a holistic framework that bridges user preferences, technical feasibility, and cultural objectives.

The results confirm the validity of combining CA, QFD, and TRIZ to address the complex demands of ICH-related app design. The CA method effectively captured nuanced user needs through content analysis, while QFD systematically translated these needs into prioritized product features, ensuring alignment with user expectations. TRIZ further resolved conflicts such as interaction complexity, content richness, and sustainability by applying inventive principles, thereby demonstrating its utility in balancing user demands with technical and cultural requirements. These findings extend prior work by emphasizing the role of conflict resolution in achieving harmony between tradition and modern digital solutions.

In a broader context, the study highlights the critical role of digital platforms in responding to UNESCO’s call for innovative methods to safeguard ICH. The research underscores the importance of modular design strategies and adaptive functionalities in engaging diverse user groups and promoting cultural sustainability. However, limitations remain, including the need for greater innovation within the CA/QFD/TRIZ framework and more explicit theoretical-to-practical mappings across all app modules. Future research should explore integrating advanced technologies such as artificial intelligence and machine learning to enhance data analysis and personalization. Additionally, longitudinal studies assessing user engagement and cultural impact over time would provide deeper insights into the long-term efficacy of ICH-related apps. By addressing these areas, future work can build on this study’s contributions to advance the digital preservation and promotion of cultural heritage.

8. Conclusion

This study presents an integrated framework combining CA, QFD, and TRIZ methodologies to address the unique challenges of ICH-related app design, demonstrating its effectiveness in aligning user needs with cultural and technical objectives. By systematically analyzing and resolving conflicts, the proposed approach highlights the potential of digital platforms to bridge traditional heritage with modern technology. While the findings emphasize the importance of user-centered, modular design strategies in promoting cultural sustainability, they also reveal opportunities for methodological advancements and deeper exploration of long-term impacts. This research provides a foundational reference for future innovation in the digital preservation and dissemination of intangible cultural heritage.

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