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Research on Cultural Transmission in AI-assisted Cultural and Creative Product Design: A Semiotic Perspective

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Abstract

With the rapid development of artificial intelligence (AI) technology, the field of cultural and creative product design is undergoing a profound paradigm shift. Based on Peircean semiotic theory, this research establishes an innovative cultural semiotic translation framework to explore the cultural value transmission mechanism in creative product design under AI intervention. The study employs a mixed-methods approach, combining qualitative semiotic analysis with quantitative questionnaire surveys, using the cultural and creative product design of Nanjing Confucius Temple as a case study to examine the impact of AI technology on the production and decoding process of cultural signs. The research finds that AI technology creates a new paradigm of cultural value transmission by reconstructing the relationship between signifiers and signified; in the digital translation process of cultural

signs, the integration of traditional cultural elements and modern design language demonstrates multi-dimensional characteristics of cultural cognition, spiritual resonance, and aesthetic integration. This study not only enriches semiotic theory in the digital age but also provides a new methodological perspective for the modern transformation of cultural heritage. It has significant theoretical and practical implications for promoting innovation and development in the cultural and creative industries.

Keywords: cultural semiotics, creative product design, cultural heritage transmission, artificial intelligence, Nanjing Confucius Temple

1. Introduction

In the context of globalization and digitalization, cultural inheritance faces unprecedented challenges and opportunities. Cultural symbols, as important carriers of cultural values, are undergoing fundamental changes in their production and transmission methods (Xue et al., 2023). These changes involve not only technological innovations but also deeply touch upon philosophical propositions of cultural authenticity, cultural identity, and cultural value transmission.

From a semiotic philosophical perspective, cultural symbols are both carriers of cultural meaning and mediators of cultural value construction (Kang & Nagasawa, 2023). In the digital age, with the intervention of artificial intelligence (AI) technology, new paradigms have emerged in the production and transmission of cultural symbols; this not only changes the way culture is created but also raises fundamental philosophical considerations about cultural authenticity, subjectivity, and value judgment (Hsiao, 2023). In the contemporary context, how should we understand and evaluate the impact of AI participation in cultural creation on the essence of cultural symbols? This question involves fundamental issues such as the relationship between signifiers and signified, criteria for judging cultural authenticity, and the positioning of human subjectivity in cultural creation (Lin, 2021).

From an axiological perspective, we need to consider: how to ensure authentic transmission of cultural values in the process of technological intervention in cultural creation? How to find balance between innovation and tradition? Do cultural symbols lose their authenticity in the process of digital translation? These questions concern not only the methods of cultural inheritance but also the standards of cultural value judgment and the construction of cultural identity. The core of cultural value transmission lies in understanding and expressing the deep structure of specific cultural symbol systems (Aririguzoh, 2022). Taking Chinese traditional culture as an example, its core values such as Confucian thought (benevolence, righteousness, propriety, wisdom, and trust), the tradition of respecting teachers and valuing education, and the advocacy of knowledge pursuit form a complex network of symbols.

This study takes Nanjing Confucius Temple in the field of Chinese traditional culture as an example to explore how cultural symbols achieve value transmission through new technological means in the digital age. As an important carrier of Confucian culture, the Confucius Temple's cultural symbol system contains rich philosophical connotations and value orientations (Wu & Chen, 2021). This provides us with a unique perspective to explore

the relationship between technology and cultural inheritance. In the intersecting vision of semiotics and artificial intelligence technology, the creative product design of the Confucius Temple is not only a cultural practice but also a process of value reconstruction and cultural identity. Through in-depth analysis and innovative expression of cultural symbols, we attempt to explore how to expand the possibilities of cultural transmission while maintaining cultural authenticity using new technology. The exploration involves not only specific practices of technological application but also points to philosophical reflections on cultural inheritance in the digital age. Specifically, this study addresses the following research questions:

RQ1: How do users perceive and decode cultural symbols in AI-assisted cultural creative products?

RQ2: How can semiotic theory guide the encoding and transmission of traditional cultural elements in AI-assisted design processes?

RQ3: What are the key dimensions of cultural value transmission in AI-generated cultural creative products?

By addressing these questions through a mixed-methods approach, this research aims to provide both theoretical insights and practical guidance for cultural transmission in the digital age.

2. AI Mode in Creative Design from a Semiotic Perspective

In the early 20th century, Swiss linguist Saussure's semiotic theory represented not only a significant breakthrough in linguistics but also provided a deep philosophical framework for cultural value transmission (Velmezova & Fadda, 2022). Saussure distinguished signs into two dimensions - signifier and signified, constructing a binary theoretical system. The signifier refers to the material carrier or form of expression of the sign, including sounds, text, or images; the signified refers to the concepts or meanings carried by the sign. This binary relationship transcends simple correspondence, reflecting the complexity and multidimensionality of cultural symbols in the transmission process (Lagopoulos & Boklund-Lagopoulou, 2020).

2.1 The Ontological Dimension of Semiotics and Cultural Inheritance

At the ontological level, the relationship between signifier and signified is not static and determined, but dynamically constructed within specific cultural contexts. This constructive nature reflects the dialectical relationship in cultural inheritance: on one hand, the symbol system needs to maintain relative stability to ensure continuous transmission of cultural meaning; on the other hand, the interpretation and understanding of symbols must constantly update with the evolution of social culture (Thellefsen, 2024). The intervention of contemporary digital technology has brought new characteristics to this dialectical relationship, where the construction process of symbols is no longer limited to human subjects but extends to the field of human-machine interaction.

In the epistemological dimension, symbols play a dual role in cultural inheritance: they are both material carriers of cultural meaning and mediating tools for the dynamic construction

of cultural value. This dual nature determines the complexity of the symbol transmission process, involving three levels: first, the recognition of symbolic form, namely the perception of the signifier; second, the interpretation of meaning, namely the understanding of the signified; and finally, the internalization of cultural value, namely the integration of symbolic meaning with individual experience (Salvatore et al., 2021). This layered understanding provides a theoretical foundation for grasping the transmission mechanism of cultural symbols.

The application of semiotic theory in creative design embodies three core principles: first, the integrity of symbol selection, meaning selected cultural elements should form a complete meaning system; second, the rationality of the transformation process, meaning design transformation should respect the essential properties of symbols; and third, the effectiveness of the reception process, ensuring target audiences can accurately interpret cultural meanings. This application is not a simple formal appropriation but involves deep philosophical thinking and creative transformation of cultural symbols.

This design thinking based on semiotics provides theoretical guidance for exploring new paths of cultural inheritance in the digital age. It reminds us that when using new technology for cultural innovation, we should both maintain reverence for traditional cultural symbol systems and be good at using modern design language for creative transformation, thereby achieving effective transmission and innovative development of cultural values. This modern transformation of semiotic theory enables us to better understand the new characteristics and requirements of cultural inheritance in the digital age, providing a solid theoretical foundation for creative design.

In this study, Saussure's concepts of signifier and signified serve as the analytical foundation for examining how AI technology mediates the transformation of cultural symbols in creative design. This theoretical lens enables us to systematically analyze both the material forms (signifiers) and cultural meanings (signified) in AI-generated products, thereby illuminating the mechanisms of cultural value transmission.

2.2 Artificial Intelligence and Cultural Creation: An Axiological Perspective

In the digital age, when artificial intelligence participates in cultural creation, we face a fundamental philosophical proposition: how to maintain the authenticity and subjectivity of cultural values. This proposition involves not only technological applications but also touches upon the essence of cultural inheritance (Santoro et al., 2020). From an axiological perspective, AI's intervention in cultural creation presents three levels of profound transformation. The first is the transformation of creative subjects, expanding from single human subjects to composite subjects of human-machine collaboration. This transformation requires a re-examination of the positioning of subjectivity in cultural creation, including the definition of AI's creative qualifications and the essential changes in human subjects' roles (Shen & Yu, 2021). The second is the innovation in creative methods. Deep learning technology, especially the application of Generative Adversarial Networks (GAN), has brought unprecedented possibilities to the production of cultural symbols. However, this technological innovation also brings potential risks of cultural homogenization (Yan et al.,

2023). Finally, there is the reconstruction of cultural value judgment standards. In the context of AI participation in creation, the authenticity and value judgment criteria of cultural products need to be redefined.

AI has transcended its purely instrumental role in cultural value transmission. Large language models and cross-modal AI systems (such as DALL-E, Midjourney, Stable Diffusion) demonstrate deep understanding and creative abilities with cultural symbols (Xu, 2023). This capability is reflected not only at the formal level but also involves grasping cultural connotations. In the digitalization of cultural heritage, AI provides new possibilities for cultural transmission through deep learning of cultural contexts and historical meanings (Kasneci et al., 2023). However, AI faces three core issues in cultural creation: maintaining cultural authenticity, protecting cultural diversity, and establishing ethical boundaries. Particularly in terms of cultural property protection and defining creative subject responsibilities, many issues remain unresolved (Amankwah-Amoah et al., 2024). These challenges require us to maintain prudence and reflection in technological applications.

Looking to the future, AI applications in creative product design will develop towards more intelligent, personalized, and culturally profound directions. AI will participate more deeply in the entire design process, achieving end-to-end intelligent design. Meanwhile, AI systems will pay more attention to understanding and expressing cultural contexts, more accurately capturing and interpreting the essence of different cultures. Future AI systems may be able to automatically extract cultural elements from historical documents, artworks, and folk tales and integrate them into modern product design. Emerging technologies can further enhance the creative design process(Wu et al., 2024; Wu & Wang, 2024). These developments will bring revolutionary changes to creative product design, pushing the cultural and creative industries to new heights. However, how to use AI tools to enhance rather than replace human cultural creativity, and how to ensure AI-generated cultural content is both innovative and respectful of tradition, will be important directions for future research. These efforts will help achieve harmonious unity between technological innovation and cultural inheritance, promoting effective transmission of cultural values in the AI era.

2.3 Semiotic-Based Theoretical Model

Building upon the previously discussed ontological perspective of semiotics, this paper constructs a creative design model based on semiotics (as shown in Figure 1). The model, grounded in Saussure's semiotic dichotomy, divides the design process into two dimensions: signifier and signified. The signifier dimension encompasses cultural elements (such as architecture, crafts, cultural relics, etc.) and product characteristics (including function, style, appearance, etc.). The signified dimension involves the AI system (cultural understanding, semantic and visual imagery, creative generation, design optimization) and user experience (including cultural cognition and spiritual resonance).

The model's core lies in the transformation between signifier and signified through AI technology. Specifically, designers first select and categorize relevant cultural elements based on user needs, encoding and transforming these elements through AI tools. The AI system processes these inputs deeply, converting cultural understanding into concrete design

solutions. The final cultural and creative products are then decoded by users based on their cultural cognition, forming a complete symbolic transmission process. This AI design method, based on semiotics, considers not only the external expression of cultural elements but also emphasizes the transmission of their intrinsic meanings, facilitating the creation of cultural and creative products that both embody cultural connotations and conform to modern aesthetics.

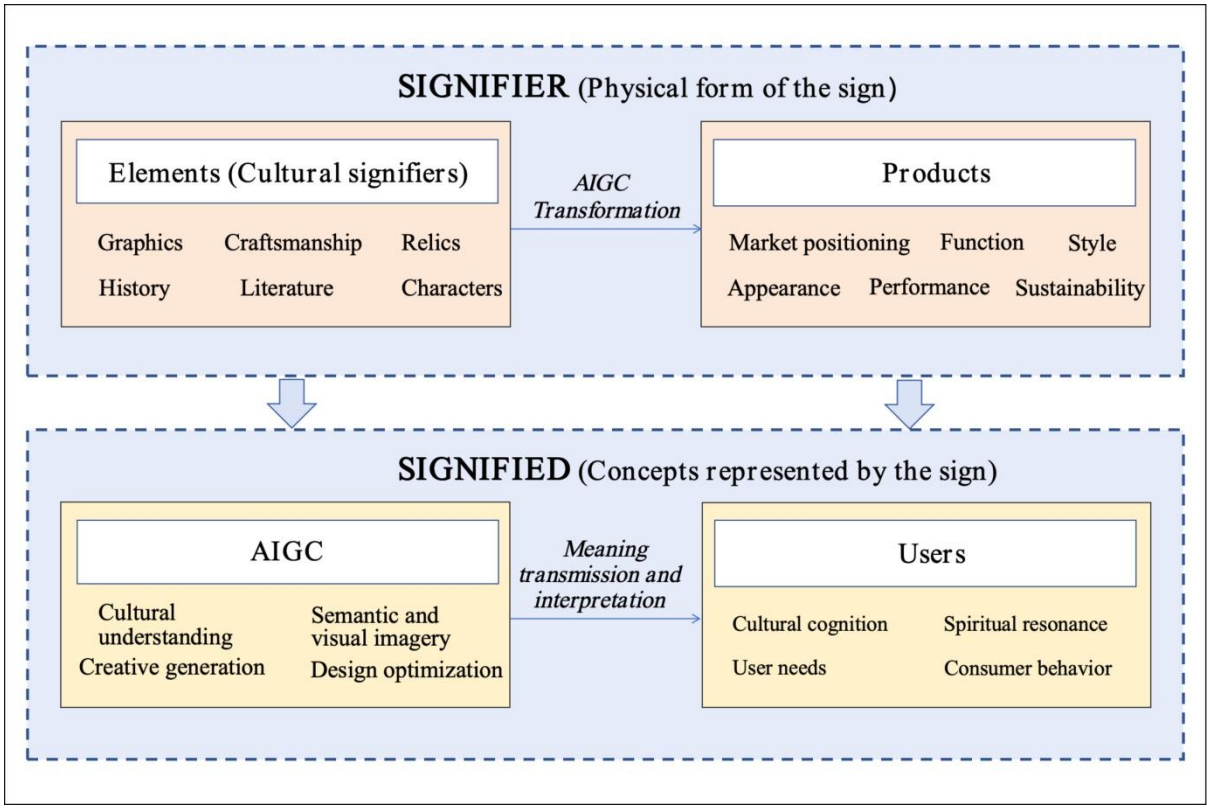

Figure 1. Design model based on semiotics

3. A Case Study of Nanjing Confucius Temple

The Nanjing Confucius Temple, built in 1034, transcends its mere architectural entity as a material carrier and spiritual symbol of Confucian culture, becoming a complex value representation system (Wu & Chen, 2021). From an ontological perspective, the Confucius Temple manifests its cultural value through three dimensions: as a materialized form of Confucian thought, as an institutional expression of social mobility, and as a living domain of cultural inheritance. Its core lies in the spatial presentation of value concepts such as "benevolence, righteousness, propriety, wisdom, and trust," transforming abstract cultural ideas into perceivable physical experiences, thus achieving the tangible transmission of values.

3.1 Cultural Background and Value

In the context of modern society, the Confucius Temple faces the essential proposition of how traditional values can engage in dialogue with contemporary life. This involves not only innovation in the forms of cultural transmission but also touches upon the issue of

reconstructing cultural values within the framework of modernity. How to achieve modern transformation of values while maintaining cultural authenticity has become key to understanding the cultural inheritance of the Confucius Temple. This transformation is not a simple formal transplantation but requires establishing organic value connections between tradition and modernity through semiotic mediation, allowing the thousand-year-old cultural context to gain new vitality through interaction with contemporary life.

3.2 Organization and Analysis of Cultural Elements

Based on the perspective of value philosophy, the cultural elements system of Nanjing Confucius Temple presents a three-tier hierarchical structure: material cultural elements, symbolic elements, and spiritual cultural elements (see Table 1). These three levels are not isolated entities but form a complete value transmission system from physical form through symbolic representation to spiritual core, reflecting the holistic thinking of Chinese traditional culture's concept of "unity of heaven and man."

At the material cultural elements level, the architectural complex represented by Dacheng Hall, Wende Archway, and Mingyuan Tower embodies the spatial expression of Confucian "ritual system" thought. The architectural layout of Dacheng Hall follows the ritual arrangement of "front court, rear chamber," reflecting the Confucian hierarchical order of "respecting the respected and caring for relatives"; the "parallel progression" spatial structure of the Imperial Examination Hall crystallizes the institutional values of fairness and rigor in the imperial examination system. From inkstones and writing brushes to top scholars' attire, each artifact not only has practical functions but also carries specific cultural connotations—the four treasures of study symbolize the ideal pursuit of "self-cultivation, family harmony, state governance, and world peace," while the top scholars' attire reflects the social mobility mechanism of "excellence in learning leads to officialdom."

At the symbolic elements level, historical figures, stories, legends, and decorative patterns form a complex cultural symbol system. The group portraits of Confucius and his disciples, through tales such as "standing in snow at Master Cheng's gate" and "three kneelings and nine kowtows," vividly interpret cultural concepts of "virtue makes the teacher" and "respect for teachers and the way." The anecdotes of talented scholars and beauties along the Qinhuai River, such as Liu Yong's "willow banks, dawn breeze and waning moon" and Li Qingzhao's "seeking and searching," demonstrate literati's unremitting pursuit of spiritual realms. The dragon and phoenix patterns and ruyi motifs on buildings are not simple decorations but visual expressions of heaven-human relationships and auspicious ideals, reflecting the perfect unity of Chinese traditional aesthetics and philosophical thinking.

At the spiritual cultural elements level, various ethnic customs and intangible cultural heritage constitute living carriers of value inheritance. The annual Confucius Memorial Ceremony is not just a ritual but transmits the value concept of "self-restraint and returning to propriety" through ritual and music education; traditional activities like the Confucius Temple Fair and releasing lanterns on the river during the Lantern Festival integrate cultural values into daily life through mass participation. Intangible cultural heritage such as Qinhuai lantern art, Nanjing brocade, and Jinling scripture engraving are not only inheritances of

craftsmanship but also tangible expressions of cultural values like "respecting heaven and ancestors" and "valuing culture and skills," reflecting the long-standing cultural traditions and profound accumulation of Chinese civilization.

Table 1. Classification of cultural elements in Nanjing Confucius Temple

Category	Attribute	Elements
Material Culture	Historical Architecture	Memorial Archway, Dacheng Hall, Wende Archway, Mingyuan Tower, Jiangnan Academy, Qinhuai Pavilion, Qinhuai River, Confucius Temple Small Street, Xuanwu Lake, Chaotian Palace, Taiping Heavenly Kingdom History Museum
	Practical Items	Imperial examination tools (inkstone, brush, examination paper), Four Treasures of Study, Top Scholar's attire, ancient teaching materials, Ming-Qing furniture
	Decorative Items	Ceremonial vessels, memorial tablets, ornamental screens, carved stone steles, hanging scrolls, ceremonial banners, decorative plaques, bronze bells and drums
	Official Relics	Ming-Qing period official clothing, seals, official items
Symbolic	Historical Figures	Confucius, Confucius' disciples, famous top scholars (such as Top Scholar Zhao Quan), Qin Hui Eight Traitors, Li Bai, Du MuStories and Legends
	Stories and Legends	Stories of talented Qinhuai scholars, legends of top scholars, stories of Confucius' teaching
	Historical Allusions	Golden Plaques, Spring Wind Cherishing Meaning, Standing in Snow at Cheng's Gate, Three Kneelings and Nine Kowtows
	Decorative Patterns	Dragon and phoenix patterns, osmanthus patterns, ruyi patterns, cloud patterns, geometric patterns
Spiritual Culture	Ethnic Customs	Confucius Temple Fair, Lantern Festival river lanterns, Confucius Memorial Ceremony, Top Scholar celebration customs
	Intangible Cultural Heritage	Qinhuai lantern art, Nanjing brocade, Jinling scripture engraving, Nanjing paper-cutting, Qinhuai secret melodies
	Cultural Thoughts	Confucian culture, Imperial examination culture, Jiangnan culture, Scholar-official education, Respecting teachers and rituals

4. Cultural and Creative Product Design Practice of Nanjing Confucius Temple

4.1 User Decoding and Experience Analysis

This study employed a convenience sampling approach combined with purposive sampling to recruit participants. Respondents were selected from two main groups: (1) visitors to Nanjing Confucius Temple who had experience with or interest in cultural creative products, and (2) design students and young professionals aged 18-45 from local universities and design

institutions. The selection criteria ensured that participants possessed basic understanding of both cultural products and AI technology concepts. Data collection was conducted through both online platforms and on-site surveys at the Confucius Temple cultural district.

This research conducted an in-depth survey on cultural value transmission in AI-assisted creative product design (sample size 200, effective recovery rate 72.5%). The survey questionnaire was designed based on a multidimensional semiotic framework, covering six major categories: cultural cognition, spiritual needs, aesthetic needs, functional needs, innovation needs, and consumption needs (see Table 2). Through reliability and validity analysis (Cronbach α = 0.83, KMO = 0.78), the study shows that the questionnaire has good reliability and validity. The questionnaire results show that young groups (19-40 years old, accounting for 91%) have a high acceptance of AI technology participating in creative design, reflected both in product innovation and cultural inheritance dimensions.

From a semiotic perspective, through factor analysis of the six categories of demand indicators in Table 2 (loading range 0.536-0.847), users' interpretation of AI-generated creative products presents three dimensions: cultural cognition (understanding of Confucian values and Jiangnan cultural elements), spiritual resonance (connection with traditional wisdom and cultural identity), and aesthetic integration (balance between classical and modern elements). The analysis results with cumulative explained variance reaching 65.4% indicate that these three dimensions constitute the main path of cultural value transmission. Particularly noteworthy is that in the post-technological era, the transmission of cultural symbols is no longer a simple symbolic reproduction, but achieves organic integration of traditional culture and modern technology through artificial intelligence as a medium.

At the practical level, according to the demand indicator analysis designed in Table 2, users' evaluation of AI-generated creative products shows a dual orientation: on one hand, they expect breakthroughs in innovation and practicality, and on the other hand, they emphasize the authenticity and depth of cultural connotations. This balance reflects a fundamental proposition in contemporary cultural inheritance: technological innovation should not weaken cultural authenticity but should become a new carrier for highlighting and spreading cultural essence. Through AI technology's reinterpretation and creative transformation of traditional cultural elements, new possibilities have been opened up for modern cultural inheritance.

Table 2. User demand survey questionnaire for AI-generated Nanjing Confucius Temple cultural and creative product design

Demand category	Survey content
Cultural Cognition needs	I believe AI-generated Nanjing Confucius Temple creative products can embody Confucian cultural essence
	I believe AI-generated Nanjing Confucius Temple creative products can reflect Jiangnan cultural characteristics
	I believe AI-generated Nanjing Confucius Temple creative products can showcase historical cultural value
Spiritual needs	I believe AI-generated Nanjing Confucius Temple creative products can convey traditional cultural wisdom
	I believe AI-generated Nanjing Confucius Temple creative products can stimulate my pride in Chinese culture
	I believe AI-generated Nanjing Confucius Temple creative products can fulfill my expectations for cultural inheritance
Aesthetic needs	I believe the design style of AI-generated Nanjing Confucius Temple creative products combines classical and modern elements
	I believe the color scheme of AI-generated Nanjing Confucius Temple creative products reflects Jiangnan charm
	I believe the selection and design of AI-generated Nanjing Confucius Temple creative products are innovative and unique
Functional needs	I believe AI-generated Nanjing Confucius Temple creative products have practical utility
	I believe AI-generated Nanjing Confucius Temple creative products can meet my daily life needs
	I believe AI-generated Nanjing Confucius Temple creative products have multiple functionalities
Innovation needs	I believe AI can bring new creative ideas to Nanjing Confucius Temple cultural products
	I believe AI-generated Nanjing Confucius Temple creative products can integrate with modern technology
	I believe AI can develop more functionalities for Nanjing Confucius Temple cultural products
Consumption needs	I believe AI-generated Nanjing Confucius Temple creative products have collection value
	I believe AI-generated Nanjing Confucius Temple creative products are reasonably priced
	I am willing to purchase AI-generated Nanjing Confucius Temple creative products

4.2 Cultural Elements Symbol Encoding Process

Under the guidance of semiotic theory, the encoding process of cultural elements needs to

simultaneously address the dialectical unity of the signifier and signified. Based on Saussure's semiotic theory, this research divides the cultural symbol encoding process of Nanjing Confucius Temple into two aspects: visual encoding and linguistic encoding. In terms of visual encoding, AIGC technology is used to extract images and abstract forms from physical carriers such as architectural features, spatial layouts, and decorative patterns, transforming them into visual symbols with modern design language. Linguistic encoding establishes connections between products and cultural connotations through the extraction of historical anecdotes and the integration of idiomatic imagery. This dual encoding strategy ensures the integrity and accuracy of cultural values during the symbol transformation process.

At the practical level, the encoding process follows the principle of "Cultural Association," establishing organic connections between material culture and spiritual connotations. For example, when dealing with the cultural symbol of the "Center of Culture Under Heaven" archway, attention is paid not only to the visual characteristics of its architectural form but also to exploring its historical dimension as a cultural and educational center in Jiangnan and its modern significance in educational inheritance. This approach reflects the unity of the "Historical Dimension" and "Modern Connection" in semiotics. Through AIGC technology's deep learning and creative transformation of cultural elements, new contemporary expressions are given while maintaining the authenticity of traditional culture, thereby achieving effective transmission of cultural values. As shown in Figure 2, the cultural elements symbol encoding process of Nanjing Confucius Temple is demonstrated.

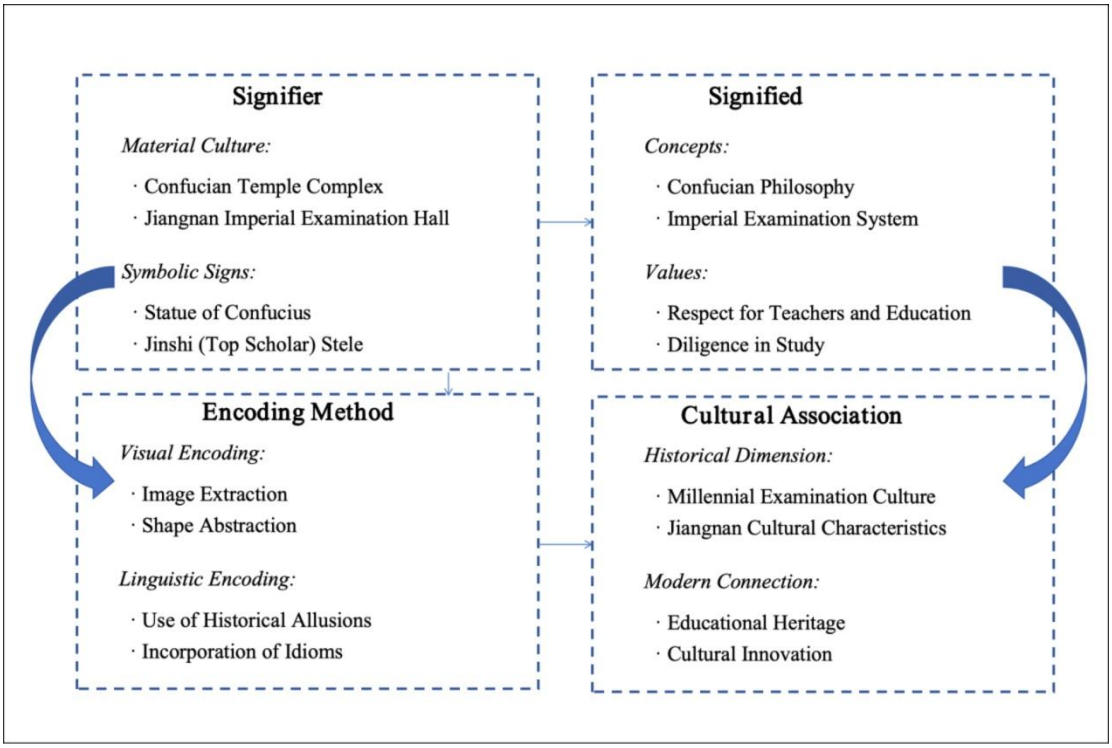

Figure 2. Semiotic analysis framework of Nanjing Confucian Temple cultural elements

4.3 Design Positioning of the "Top Scholar Success" Cup

To verify the feasibility of the Nanjing Confucius Temple's cultural and creative product

design model, this research, based on survey results, considered the varying understanding of cultural elements among different target user groups before decoding. Elements with relatively unified semantics and connotations were selected to enhance the universal appeal of cultural and creative products to user experience. Meanwhile, to improve users' decoding efficiency, when encoding element symbols selected from three thematic categories, care was taken to maintain coherence in imagery, symbolism, and indication, promoting alignment between the product and users' subjective thoughts during decoding. Addressing the target audience's needs and pain points, this research positioned the product as a practical lifestyle item, choosing ceramics as the primary material and employing traditional red coloring with gold accents to reflect the solemnity of Confucian culture and the dignified character of scholars and literati.

Based on target group characteristics, this research selected the Zhuangyuan hat - the ceremonial headpiece worn by the highest-ranking scholar in China's imperial examination system - as the primary design element, with the "Center of Culture Under Heaven" archway as a supporting element. This choice is particularly significant as the Zhuangyuan title, awarded to the scholar achieving the highest score in the highest level of imperial examinations, represented the pinnacle of academic achievement in a system that lasted over 1,300 years. As an essential daily utensil for scholars and intellectuals, the cup not only reflects the target group's cultural taste and aesthetic preferences but also incorporates profound cultural connotations while maintaining practicality. The Zhuangyuan hat element symbolizes the highest honor in the imperial examination system, aligning with the target group's pursuit of academic excellence. The cup's design incorporates architectural features of Jiangnan archways, with its top shaped like a Zhuangyuan hat, symbolizing academic success - a symbolism that continues to resonate deeply in Chinese culture today. The "Center of Culture Under Heaven" archway element reflects the Confucius Temple's significant status as an educational center, with its solemn form cleverly applied to the cup's overall design. The "Top Scholar Cup" text on the cup body features gold plating, highlighting the nobility and glory of the imperial examination culture. This cup, which integrates multiple cultural symbols, not only meets practical needs but also provides spiritual encouragement and cultural identity through its rich symbolism, allowing the cultural essence of Nanjing Confucius Temple to be inherited and promoted in daily life.

4.4 AI-Based Generation Process of the "Top Scholar Success" Cup from a Semiotic Perspective

First, this research selected the AI software Midjourney to generate products for the target user group. After extracting feature line drawings of the Zhuangyuan hat and "Center of Culture Under Heaven" archway as reference images, image generation was conducted through Midjourney's "/imagine" command, combining "prompt" instructions with reference image links. To enhance the accuracy of generated images, detailed design requirements were specified in the prompts, including style (simple, cartoon), perspective (frontal), drawing type (line drawing), and other attributes. Key parameters were also set, such as --iw (reference image weight, set to 1.5 to maintain similarity with original images), --ar (output image ratio set to 1:1), and --no (excluding unwanted elements like excessive decorations).

To ensure the quality and accuracy of generated images, this research adopted an iterative optimization approach. After each generation round, the most promising image among V1-V4 was retained, and prompts were continuously adjusted and optimized based on actual results. From initial basic descriptions to adding specific design detail requirements in the tenth iteration, the most ideal design solution was finally obtained in the twentieth iteration. Throughout the process, special attention was paid to the expression of traditional Chinese cultural elements, using precise prompts to guide AI in generating images that align with Eastern aesthetics. However, Midjourney showed limited controllability in image generation, with deviations in generated content and insufficient ability to redraw local details. Therefore, this research only used Midjourney-generated line drawings during the initial creative conceptualization phase of product design; subsequent detail optimization and final design still needed to be completed through traditional design methods. This human-machine collaborative design approach maintained precise expression of traditional cultural elements while improving the efficiency of creative ideation. Figure 3 illustrates the entire iteration process.

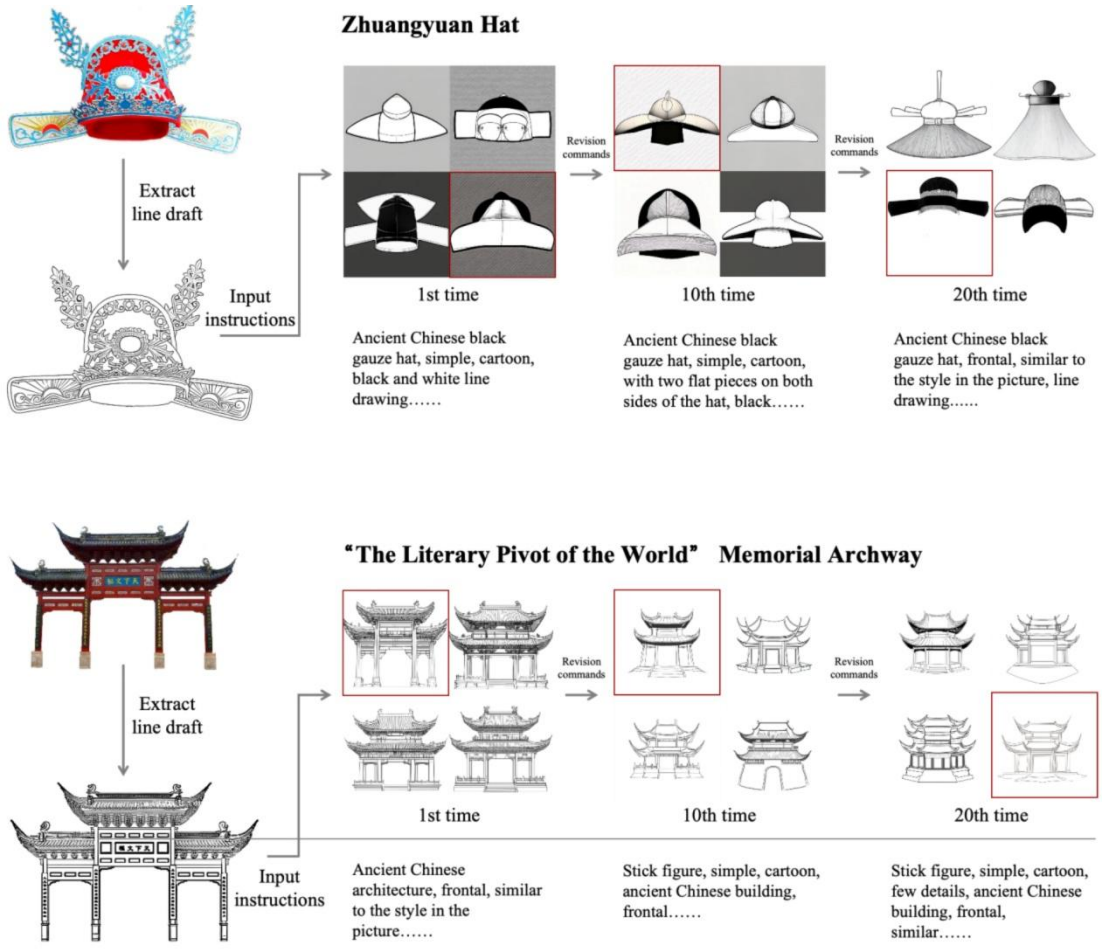

Figure 3. Midjourney design generation process

Based on the aforementioned design generation process, this research ultimately completed the design of a cultural and creative cup that integrates both the Zhuangyuan hat and "Center of Culture Under Heaven" archway elements. As shown in Figure 4, the cup employs simple

lines to outline its overall silhouette, with the top incorporating characteristic features of the Zhuangyuan hat, presenting an elegant and dignified visual effect. The cup body primarily uses vertical composition, with three traditional circular decorative patterns embedded in the middle section, while the bottom incorporates the roofline of the "Center of Culture Under Heaven" archway, creating a harmonious overall design with corresponding elements at the top and bottom. The overall design both preserves the essence of traditional cultural elements and, through modern minimalist expression, makes the product more relevant to contemporary use scenarios and aesthetic requirements.

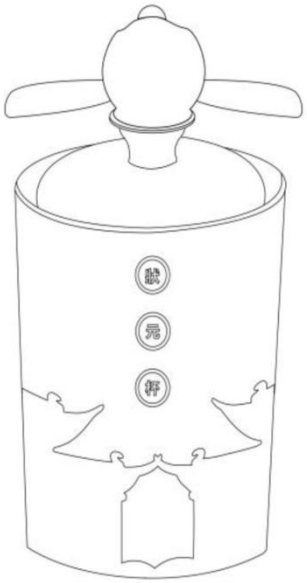

Figure 4. Vector diagram of cup line draft

Next, line drawings of the Zhuangyuan hat and "Center of Culture Under Heaven" archway were created and imported into Stable Diffusion's text-to-image board with appropriate keywords. While the prompts for overall product style remained consistent, prompts for detail depiction and product connotations were determined based on the elements being generated and continuously adjusted during the iteration process. As the Zhuangyuan hat served as the primary visual element in product encoding, the prompt language focused more on describing inherent meanings while considering external visual appearance, avoiding the loss of cultural significance. The "Center of Culture Under Heaven" archway, serving as a supporting visual element, contributed to the product's refined aesthetics through its graceful form, thus prompts for this element emphasized aesthetic expression. To enhance product innovation and further expand the designer's creative thinking, both the Zhuangyuan hat and "Center of Culture Under Heaven" archway underwent 20 iterations. Images meeting requirements were selected from results generated through continuous prompt modifications, with the "*iw*" value set at 2 to ensure closer alignment between output graphics and element symbols. Key elements were ultimately extracted to form the cup's sketch, as shown in Figure 4.

Furthermore, the preliminary line drawing of the Zhuangyuan hat cup was imported into

Stable Diffusion for processing. During implementation, the black and white line drawing was first transformed into an initial color scheme through simple color processing, establishing red and golden yellow as the primary colors. The chilloutmix NiPrunedFp32Fix.safetensors was used as the base model, with DPM++2S a ControlNet v1.1.411 as the sampling method and canny ControlNet v1.1.411 as the preprocessor. For prompt settings, positive prompts included: (a cup:2), (orange collocation:1.8), (photo_(medium):1.1), reality, (realistic:1.6), etc., to control basic product attributes and visual effects; negative prompts included: NSFW, (worst quality:2), (low quality:2), (normal quality:2), lowres, (monochrome), (grayscale), etc., to exclude unwanted rendering effects.

Multiple versions were generated using the "Text-to-Image" function, with batch settings of 4 and 4 options per batch. From multiple generation results, the version best matching the design intent was selected for further optimization. The final generation parameter configuration used Script: SD upscale, Upscaler: R-ESRGAN4x+Anime6B, Seed: 86128862. This iterative optimization process ensured the accuracy of product design and preservation of cultural characteristics. The final rendering showcased the perfect integration of the Zhuangyuan hat and archway elements, maintaining the elegant qualities of traditional cultural symbols while imparting practical value to modern product design, as shown in Figure 5.

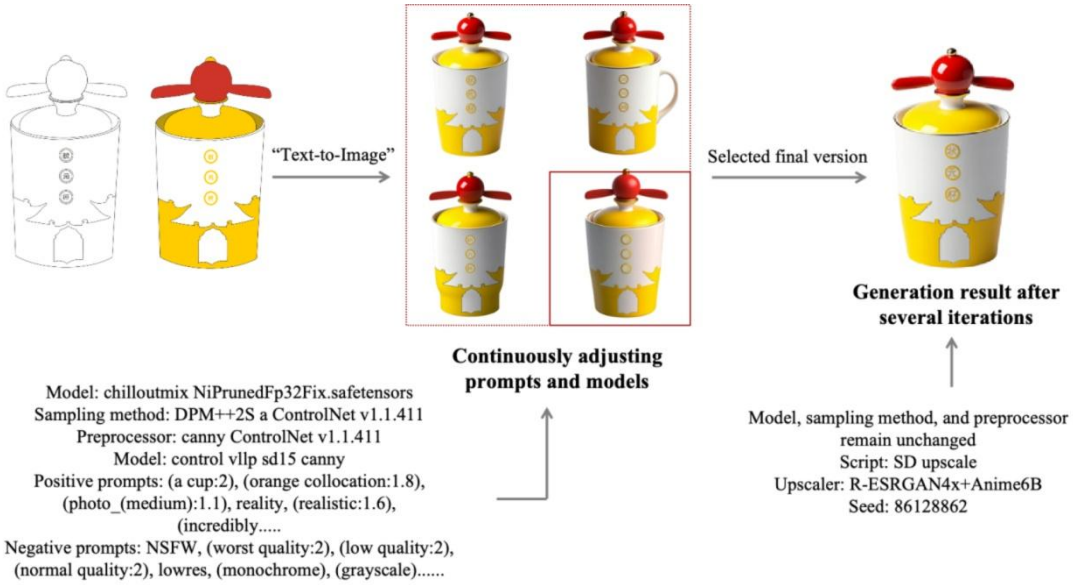

Figure 5. Stable Diffusion product generation flow diagram

5. Conclusion

This research explores the semiotic application paradigm of AI technology in the cultural and creative product design of Nanjing Confucius Temple. By constructing a design framework based on Peircean semiotics, it reveals new mechanisms for cultural inheritance in the digital age. The research demonstrates that AI technology, as a symbolic mediator, not only changes the generative logic of cultural symbols but also reconstructs the way cultural meaning is constructed. This reconstruction is manifested both in the technical level's digital translation

of traditional cultural elements and in the philosophical level's dialectical unity of cultural authenticity and innovation. Through the design practice of the "Top Scholar Success" cup, we find that AI technology can achieve creative transformation of cultural symbols while maintaining cultural authenticity, providing new possibilities for cultural and creative product design.

While this study provides valuable insights into cultural transmission in AI-assisted design, several limitations should be acknowledged. First, the sample size of 200 participants, though adequate for exploratory research in cultural semiotics and sufficient for factor analysis, represents a moderate scale that may limit generalizability across different cultural contexts and demographic groups. Future studies could benefit from larger, more diverse samples to validate these findings across various cultural heritage sites and creative product categories. Second, this research focuses specifically on Nanjing Confucius Temple as a single case study; comparative studies involving multiple cultural sites would strengthen the theoretical framework's applicability.

However, current AI technology still has limitations in processing cultural symbols, particularly in understanding complex cultural contexts and expressing details. Future research should focus on deepening the evolution of semiotic theory in the digital age, exploring AI models' mechanisms for deep understanding of Chinese traditional cultural elements, and establishing a more systematic cultural value evaluation system. This concerns not only technological innovation in cultural and creative product design but also fundamental propositions of cultural inheritance in the digital age. Through continuous theoretical exploration and practical innovation, we hope to promote innovative development in the cultural and creative industry while maintaining cultural authenticity.

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Authors' contributions

Dr. Xin Wu was responsible for the overall research design, theoretical framework construction, and the semiotic analysis of cultural elements. Dr. Jun Dong was responsible for data collection, questionnaire design and implementation, and statistical analysis of survey results. Dr. Ling Wu conducted the AI-based design experiments using Midjourney and Stable Diffusion, drafted the initial manuscript, and created all figures and visual materials. All authors contributed to manuscript revision, read and approved the final manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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The Publication Ethics Committee of the Macrothink Institute.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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