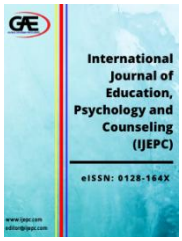
International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 10 Issue 61 (December 2025) PP. 607-623
DOI 10.35631/IJEPC.1061043



INTERNATIONAL JOURNAL OF EDUCATION, PSYCHOLOGY AND COUNSELLING (IJEPC)
www.ijepc.com

TRANSLATING CULTURAL SYMBOLS INTO STUDIO LEARNING: A P–E–F FRAMEWORK FOR 3D HERITAGE TASKS TO ENHANCE MOTIVATION AND ENGAGEMENT IN HIGHER EDUCATION

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Article Info:

Article history:
Received date: 30.09.2025
Revised date: 15.10.2025
Accepted date: 11.11.2025
Published date: 07.12.2025

To cite this document:

Jing, Z., Zainuddin, N., Sulaiman, S., & Mustapha, A. (2025). Translating Cultural Symbols into Studio Learning: A P–E–F Framework for 3D Heritage Tasks to Enhance Motivation and Engagement in Higher Education. *International Journal of Education, Psychology and Counseling, 10* (61), 607-623.

DOI: 10.35631/IJEPC.1061043

Abstract:

Younger learners' engagement with Miao Traditional Festival Costumes (MTFCs) remains low because existing digital work rarely links cultural grammar to classroom-ready 3D tasks. This paper addresses that gap by consolidating four design principles (hierarchy, symmetry, repetition, ritual orientation) and five design elements (pattern, colour, structure, material, wearing) into a unified P–E–F core, then extending it with a P–E–F–M–E pathway that translates directly into studio assignments and rubrics. A systematic content analysis of 52 sources (2000–2024) shows stable consensus on principles (e.g., ritual orientation: 80.8%; symmetry: 73.1%) and elements (pattern and colour: 90.4%), providing reliable anchors for task design. We package the outputs as parameterised prompts for CLO3D/Unity, a two-axis rubric (cultural fidelity × learning outcomes), and low-cost evidence options (two 5-item mini-scales plus a short reflective note) for adoption without specialised labs. The contribution is a curriculum-ready blueprint that operationalises semiotic structure into reproducible modelling operations and student-centred evaluation. While no user testing is reported in this paper, we provide a clear route for subsequent classroom validation focused on motivation, perceived usability, and affective uptake.

Keywords:

Miao Traditional Festival Costumes; Art & Design Education; Studio Learning; Student Engagement; 3D Learning Tasks; Cultural Heritage

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Introduction

Traditional Miao Festival Costumes (MTFCs) are often described as 'history written on the body,' encoding ethnic identity, cosmological beliefs, social hierarchy, and a sophisticated symbolic system (Chinese Artists Association, 2011; Yang, 2015; Li et al., 2022). These costumes represent China's internal cultural diversity and embody its rich heritage. However, younger generations are showing a decline in engagement with MTFCs, as they are increasingly drawn to digital media, such as television and the internet (Luo, Xu, & Gao, 2022). This generational shift poses a serious threat to the transmission and preservation of Miao cultural heritage, underscoring the need for effective digital strategies to attract and educate younger audiences. This study positions MTFCs as a learning resource and reframes digital translation as pedagogical design within higher education in art & design. In the Malaysian higher-education context, integrating MTFCs into studio courses offers a timely pathway to foster cultural literacy while improving motivation and engagement in digital learning environments.

Current museum-based preservation remains static, mainly failing to capture the performative and ritual dynamics embedded in MTFCs (Chen & Lin, 2023). In contrast, the emergence of real-time rendering, 3D animation, and immersive interface platforms offers new visual channels for expressing the structural and symbolic dimensions of ethnic attire, moving beyond static imagery or two-dimensional archival documentation (Wu & Guan, 2011; Norman, 2004). Digitally driven cultural-symbolic design approaches not only enable the reproduction of costume elements but also support controlled reconstruction and structural mapping. Such approaches facilitate parameterized modeling of complex visual grammars, ensuring semantic clarity and structural integrity in digital environments (Shneiderman & Plaisant, 2010). This "symbol–visual–structure" translational method is particularly well-suited to costume systems that incorporate ritual symbols, high symbolic logic, and dense visual rhythm.

However, current digital studies on MTFCs remain fragmented. Most efforts concentrate on image archiving or motif extraction, lacking an integrated framework that connects design principles, visual elements, and modeling workflows (Zhou & Abdullah, 2024). More critically, the complex cultural contexts and visual grammar embedded in ethnic costumes have yet to be translated into parameterized models, leading to symbolic discontinuity and structural flattening in digital reconstructions.

Gap and Contributions — Revised Ending of Introduction

Prior digital efforts on MTFCs remain fragmented: motif extraction and image archiving seldom connect design grammar to parameterised modelling or to classroom practice. This yields symbolic discontinuity (flattened meaning), weak implementation fidelity (limited links from principles/elements to tools), and low pedagogical utility.

This study makes three contributions. First, it consolidates a P–E–F core from 52 peer-reviewed sources and quantifies its stability to justify curriculum anchoring. Second, it translates P–E–F into a P–E–F–M–E pathway that maps semiotic rules to modelling steps in CLO3D/Unity and to rubric criteria. Third, it specifies feasible classroom evidence for student motivation, perceived usability, and brief affect checks that can be collected without lab-grade instruments.

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Aims. (a) To consolidate P/E/F as curriculum-ready constructs; (b) To specify a reusable P–E–F–M–E pipeline for 3D tasks and rubrics; (c) To outline low-cost evaluation options for later classroom validation.

Literature Review

A systematic search was conducted across Scopus, Web of Science, CNKI, and Google Scholar (in both English and Chinese) from 2000 to 2024, using the keywords 'Miao costume' combined with 'digital,' 'interactive,' or 'design.' After title and abstract screening, 87 records were identified, of which 52 full-text articles met the inclusion criteria (peer-reviewed, empirical or theoretical, with an explicit focus on costume). The complete reference list is provided in Appendix A.

Following the aggregation protocol proposed by Kamaruddin and Sulaiman (2018), all instances of visual rules or material composition were coded, normalized, and aggregated across the corpus to enable comparative analysis.

Design Principles, Elements, and Features of MTFCs in Existing Literature

Early ethnographic studies derived symbolic–functional principles from ceremonial roles of Miao costumes, highlighting their contribution to identity construction within social hierarchies (Pratt & Rafaeli, 1997). While these works provided interpretive frameworks grounded in cultural context, they lacked clearly defined visual rules applicable to design practice. Later contributions identified layout, structural layering, and color contrast as key visual traits of tradition.

National Asian costumes (Presley & Campassi, 2013) form essential references for digital modeling.

In the field of information design, Bertin (1983) first proposed a mapping between 'visual variables' and 'information structures,' emphasizing the cognitive significance of layering, sequencing, and density. Tufte (2001) further advanced the principle of 'visual hierarchy' in chart design, arguing that coherent visual layering enhances clarity and perception. However, these principles primarily address static visualizations and do not offer parameterized mechanisms for interactive or digital applications.

Two paradigms dominate the categorization of design elements: (1) the "pattern–color–material" triad, commonly used in studies of elderly women's ethnic dress preferences (Zhang et al., 2021), and (2) the 'pattern–technique–structure–wearing style' tetrad, validated in the semiotic analysis of Chinese dragon robes (Wang & Zhang, 2024). These models provide structural foundations for constructing the parameter framework proposed in this study.

Theoretical support for digital translation of ethnic costumes also derives from semiotic models. Kress and van Leeuwen (2006) argued, through multimodal discourse analysis, that visual symbols follow a structured grammar capable of conveying meaning through nesting, balance, and spatial layout. However, their model focuses on static texts and advertising visuals, lacking extension to dynamic, body-worn cultural artifacts such as ethnic costumes. A translatable chain linking image, structure, and function has yet to be developed.

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Feature-oriented studies have concentrated on cultural identity and aesthetic style, exploring ritual in organizational attire (Siebert, 2020), regional color coding (Hashim, 2024), and identity construction (Kang et al., 2011). However, most findings remain conceptual and fail to establish a parameterized mapping from principles to elements to features, limiting cultural controllability and visual fidelity in digital modeling.

To address this challenge, we propose a typology of cultural–digitalization gaps observed in the literature and coding annotations, as shown in Table 1.

Table 1: Typology of Cultural–Digitalization Gaps in MTFC Research (G1–G4)

Gap Code	Gap Type	Definition	Typical Indicators	Aligned RQ
G1	Literature Gap	Key design elements consistently underrepresented across MTFC scholarship	Very low citation or coding frequency of specific features in major sources	RQ1
G2	Digital Translation Gap	Elements are conceptually addressed but lack structured or parameterised modelling in digital tools	Lacking integration in 3D modelling, AR/VR simulations, or UX frameworks	RQ2
G3	User Perception Gap	Misalignment between culturally meaningful features and user interpretation or emotional response	Low emotional resonance, misunderstanding of symbols in user studies	RQ3
G4	Semantic Saturation Gap	Overrepresentation of visual aspects while neglecting deeper symbolic or ritual semantics	Visually dominant features (e.g., colour) overshadow cultural meaning	RQ2 /RQ3

Source: Author's synthesis from

This typology, derived from corpus review and semantic annotation, offers a structured lens for critically assessing gaps between design elements and cultural features. Each gap type corresponds to specific layers of the research questions (RQ1–RQ3) and helps frame subsequent methodology and design implications.

Systemic Construction of MTFC Representation

In response to the gaps identified above, this section establishes a semiotic theoretical framework grounded in the Peirce–Morris model, integrating visual encoding, structural hierarchy, and cultural pragmatics. It identifies three key variables critical to digital modelling and cultural translation of MTFCs: design principles, design elements, and cultural features. This tripartite structure serves not only as a translatable model of cultural expression but also as a methodological foundation for parameter annotation and content structuring in interactive design contexts.

Design Principles

This study adopts a framework that synthesizes Peirce's triadic model (representamen–object–interpretant) and Morris's syntactic–semantic–pragmatic segmentation (Peirce, 1931–1958; Morris, 1938). From a systems perspective, four core design principles repeatedly identified in 52 scholarly works between 2000 and 2024 are distilled (see Table 2):

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Table 2. Academic Support Landscape for Key MTFC Design Principles

Design Principle	Strength of Academic Support	Key Scholars & Years
Hierarchy principle	Explicitly articulated	Fayzullina & Khristidis (2020); Mainy & Kukhta (2020)
Repetition principle	Corroborated by multiple studies	Barthes (1983); Zhou & Abdullah (2024); Okadigwe (2015)
Symmetry principle	Widely observed	Owyong (2009); Yang, Qinling & Chen (2020); James & James (2020)
Ritual-orientation principle	Structural reinforcement evident	Mainy & Kukhta (2020); Dmytruk (2016)

These principles constitute the deep aesthetic structure of MTFCs and serve as visual anchors in subsequent digital modelling. Drawing on Symbolic Interactionism (Blumer, 1969), these principles also support an understanding of the mechanisms of meaning negotiation during virtual reconstruction.

Design Elements

Design elements act as mediators between abstract principles and concrete cultural features, forming the core units of parameterized modelling and visual encoding. Based on Peirce's classification of signs (icon–index–symbol), five high-frequency elements are systematized: pattern, colour, structure, material, and wearing method. Each is aligned with a dominant semiotic mechanism, as shown in Table 3:

Table 3. Academic Support Landscape for Key MTFC Design Elements

Sign Type	Definition & Distinguishing Features	Corresponding Design Element	Functional Illustration	Representative Sources
Icon	Meaning arises from formal resemblance that triggers immediate recognition.	Pattern motifs	Butterfly, phoenix-bird, and terraced-field motifs visually echo ancestral myths.	Wang & Kolosnichenko (2024); Kilstrup (2015)
Symbol	Meaning is assigned through shared cultural convention.	Colour system	Red = festivity and blessing; black = ancestor veneration.	Mirzoeff (1999); Zhou & Abdullah (2024); Xu, Luo & Zhong (2024)
Icon + Index	Formal resemblance combines with situational cues to anchor meaning.	Garment structure	Tiered pleated skirts and cinched waists depict butterfly wings and signal clan status.	Lee, Yoon & Han (2007); Ermilova (2020)
Pragmatic Anchor	Contextual use and material tactility	Fabric &	Silk and repoussé silver connote	Wang & Lau (2023); Fayzullina & Khristidis (2020)

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	shape experiential tone.	materials	prosperity and ritual prestige.	
Index	Meaning derives from spatial or causal association.	Wearing method	Layering of chest plates or headpieces signifies marital rank and social identity.	Zhou & Abdullah (2024); Sedakova & Vlaskina (2016)

This classification provides a parameterized foundation that integrates visual features, semantic functions, and interactive responses, ensuring that digital costume modeling is not merely a visual replication but a meaningful symbolic encoding.

Features

As the final tier in the framework, cultural features capture the cognitive and symbolic responses activated by design grammars and semiotic elements within specific cultural contexts. While recent studies on ethnic costumes have explored totemic metaphors and colour symbolism, most remain at a simple representational level, lacking integrated accounts of how structural design and usage context contribute to cultural meaning. Some researchers have noted that the organization of symbols and situational use play crucial roles in identity construction, yet these aspects are seldom modeled systematically (Fayzullina & Khristidis, 2020; Sedakova & Vlaskina, 2016).

Based on literature synthesis and semiotic model translation, this study operationalizes MTFC cultural features into three interrelated dimensions that support interactive modeling workflows and parameter control systems:

Symbolic–Cosmological Dimension: Patterns and color schemes activate mythic narratives, reflecting ancestral belief systems and cosmological worldviews (Peirce, 1931–1958; Turner, 1969).

Cognitive–Aesthetic Dimension: Visual symmetry and chromatic contrast stimulate perceptual pleasure and affective response (Lakoff & Johnson, 1980; Zeki, 1999).

Structural–Identity Dimension: The spatial organization of garments encodes social information, such as marital status, age cohort, and lifecycle roles (Chandler, 2007; Barthes, 1969).

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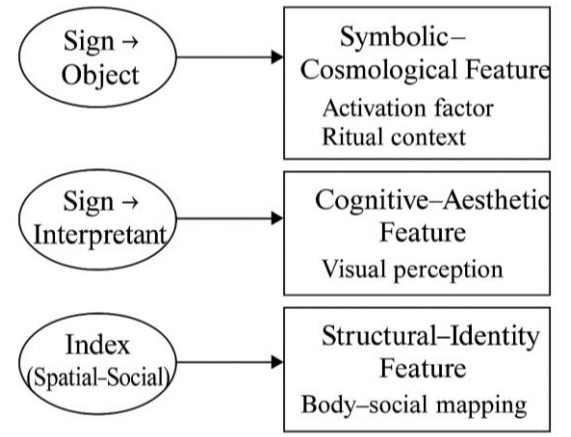

Figure 1. Cultural Features of MTFC

Methodology

Research Design Overview

The study follows a three-step design-science logic: consolidation of P/E/F from a 2000–2024 corpus (n=52) using NVivo 14. Translation of consolidated constructs into a P–E–F–M–E pipeline with parameterised task prompts and rubric anchors. Moreover, operational packaging of low-cost evidence options (two 5-item mini-scales and a short reflective note) to enable later classroom validation.

Data Selection and Sampling Strategy

A systematic literature sampling strategy was employed to collect peer-reviewed studies on MTFCs published between January 2000 and May 2024, using the Boolean search string 'Miao Festival Costume' AND ('digital' OR 'interactive' OR 'design'). Searches were conducted across Scopus, Web of Science, Google Scholar, and CNKI databases. After title–abstract screening and removal of duplicates and irrelevant sources, 52 academic records were retained for their relevance to visual structures or design principles.

Table 4. Inclusion and Exclusion Criteria for Literature Sampling

Criterion	Inclusion	Exclusion
Publication Type	Peer-reviewed journal articles, conference papers, master's/PhD theses	Grey literature, book reviews, news items
Topical Focus	Empirical or theoretical discussion of MTFCs or comparable ethnic costumes	General fashion studies lacking reference to MTFCs
Data Relevance	Provides visual/material data or explicit design analysis suitable for coding	Purely sociological or linguistic papers without visual/structural content
Language	English or Chinese	Other languages

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Analytical Tool: NVivo 14

All full-text documents were imported into NVivo 14. A three-tier node tree based on the PEF Ontology (Principle–Element–Feature) was predefined, along with a process-coding branch derived from Mead's symbolic interaction cycle (i.e., Recognition → Interpretation → Re-encoding). Auto-stemming and a custom synonym dictionary were enabled to minimize lexical noise. For Chinese-language sources, the THUOCL synonym set and ICTCLAS tokenizer were used to ensure consistent cross-lingual stem normalization.

Coding Process

Open coding yielded 1,126 references, which were then organized axially according to the P–E–F structure. Selective coding was applied to resolve conceptual overlap and consolidate terms into a structured matrix comprising nine parent nodes and 37 sub-nodes.

Reliability and Validity

Inter-coder reliability was assessed on a 20% random subsample (n = 11). Agreement on principle nodes reached $\kappa = 0.82$, while element nodes ranged from $\kappa = 0.79$ to 0.85—classified as "almost perfect" according to Landis and Koch (1977). Validity was further reinforced using a two-pronged triangulation strategy:

(a) Frequency counts were cross-checked against coding memos.

(b) Two external MTFC experts reviewed items (iii), (iv), (v), and (viii).

Output: Semiotic Transmission Pipeline

Coded data were interpreted using an Input–Mediation–Output (IMO) scheme, as outlined in Table 5.

Table 5. Integrated IMO Framework for Semiotic Translation of MTFC

Phase	Theoretical Anchors	Operational Role in This Study
Input	Peirce's icon–index–symbol taxonomy; Morris's syntactic–semantic–pragmatic layers (Peirce, 1931–1958; Morris, 1938)	Design principles, elements, and cultural features are treated as sign tokens and imported as top-level nodes in NVivo.
Mediation	Mead's Symbolic Interaction Theory (Mead, 1934)	The three cognitive steps—Recognition, Understanding, Re-encoding—are mapped onto UX Honeycomb dimensions: Findable & Usable, Credible & Accessible, Valuable & Desirable (Morville, 2004). These serve as parent nodes for process coding.
Output	Norman's visceral–behavioral–reflective model (Norman, 2004)	Emotional uptake is assessed via eye-tracking heatmaps (visceral), user task logs (behavioral), and post-task interviews (reflective). Performance thresholds are set across the seven UX Honeycomb dimensions, with an added Cultural-Identity metric capturing narrative internalization (Barthes, 1969; Chandler, 2007).

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In future classroom studies, emotional uptake can be examined via eye-tracking heatmaps (visceral), user task logs (behavioural), and brief post-task interviews (reflective). In this paper, we only specify thresholds and instruments as classroom-feasible options; no user testing was conducted. The coding outputs are packaged as task prompts and rubric anchors so that educators can adopt them without lab-grade instruments, aligning with IJEPC's application-oriented remit.

Justification of Methodological Design

This chapter proposes a semiotic-structural methodology grounded in theoretical coherence and reproducible coding logic. By focusing on:

The visual-cognitive construction of MTFCs, the cultural-symbolic layers of costume design, and the parameterization pathways for modeling.

The study offers a computation-assisted yet interpretation-centered approach to cultural translation in digital fashion.

Rather than prematurely generalizing from affective validation or user testing, this method prioritizes ethnographic specificity and semiotic precision, offering a robust theoretical infrastructure for digital costume modeling.

Analysis And Findings

Corpus Overview and Coding Framework Recap

This study analyzed a corpus of 52 peer-reviewed publications retrieved from Scopus, Web of Science, CNKI, and Google Scholar, spanning the period from 2000 to 2024. The research scope was limited to Miao Traditional Festival Costumes (MTFCs) from the Qiandongnan region. A four-stage semiotic–affective framework was constructed, titled P-E-F-M, as visualized in Figure 2.

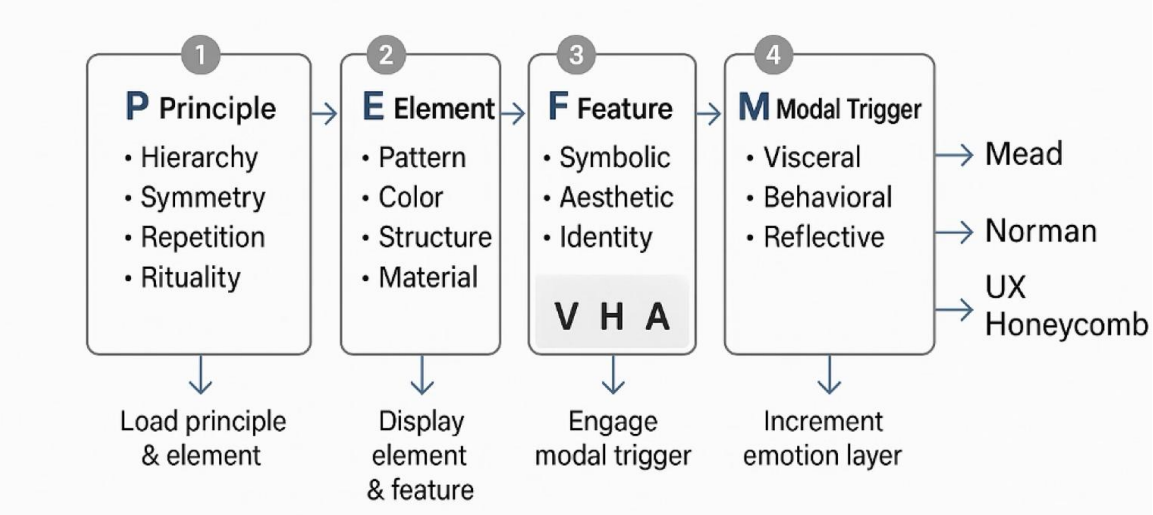

Figure 2. PEFM Symbolic–Emotion Workflow for MTFC Digitalization

Source: The workflow integrates Peirce–Morris's semiotics (P–E), symbolic–cognitive–affective features (F), and emotion modeling (M) based on Mead's interaction theory, Norman's emotional design, and the UX Honeycomb.

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Curriculum-Ready Frequency Landscape of Principles and Elements

Frequency analysis across 52 sources confirms stable anchors for curriculum design: ritual orientation (80.8%), symmetry (73.1%), repetition (71.2%), and hierarchy (69.2%). At the element level, pattern and colour are referenced by 90.4% of studies, with structure (82.7%), material (76.9%), and wearing method (73.1%) also salient. These stable constructs justify mapping each principle/element to parameterised assignment prompts and rubric rows.

At the design element level, over 90% of sources referenced patterns and color usage, with structure and material also receiving substantial attention. This suggests a high degree of consensus on visual conventions within MTFC scholarship. These stable constructs can anchor lesson objectives, scaffold task difficulty, and support criterion-referenced marking in studio courses.

Table 6. Frequency of MTFC Design Principles and Elements in Literature (n = 52)

Design Principle / Element	Frequency	Percentage (%)
Design Principles		
Hierarchy	36	69.2
Repetition	37	71.2
Symmetry	38	73.1
Ritual Orientation	42	80.8
Design Elements		
Pattern	47	90.4
Color	47	90.4
Structure	43	82.7
Material	40	76.9
Wearing Method	38	73.1

Frequency of Ternary Cultural Features

Operationalization of Indicators:

Aesthetic Feature: Descriptions of symmetry, color harmony, embossed layering, and other visual aesthetics. Symbolic Function: Semiotic interpretations related to ancestral worship, cosmological motifs, and nature-based belief systems. Identity Marker: Visual encodings of marital status, age group, or sub-ethnic affiliation.

Each feature type was mapped to a ternary axis in a radar chart. If a publication included at least one substantive discussion of a feature, it was counted once. Radius = frequency (%), n = 52.

This distribution suggests that the existing literature on MTFCs prioritizes aesthetic dimensions, with symbolic and identity-related aspects receiving secondary but significant attention. However, the relative imbalance highlights interpretive gaps, paving the way for the Gap Mapping section.

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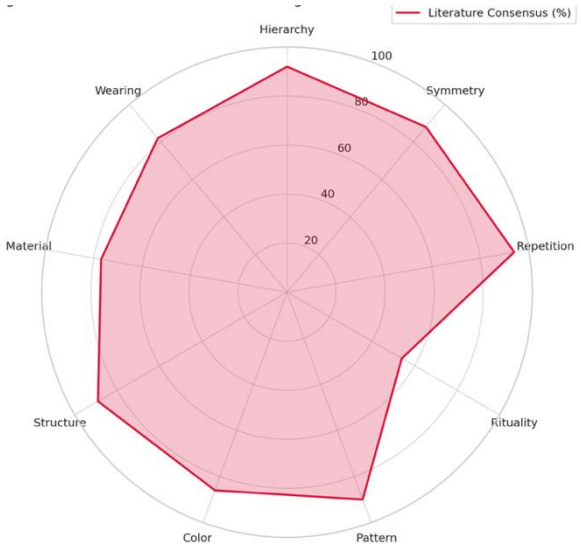

Figure 3: Radar Chart of Cultural Features in MTFC Literature

Structural Patterns: Hierarchical Clustering Heatmap

Using Ward's method for hierarchical clustering based on principal–element co-occurrence weights, the analysis yielded two major clusters (see Figure 4):

Structural–Ritual Cluster: Comprising Hierarchy, Ritual, Structure, and Material—emphasizing the contextual and social functions of costumes in ceremonial settings.

Visual–Color Cluster: Comprising Symmetry, Repetition, Pattern, and Color—focusing on aesthetic appearance and symbolic representation.

The pattern reveals a dual logic within MTFC scholarship: a parallel focus on ritual function and visual rhetoric, each representing distinct interpretive priorities in cultural heritage design research.

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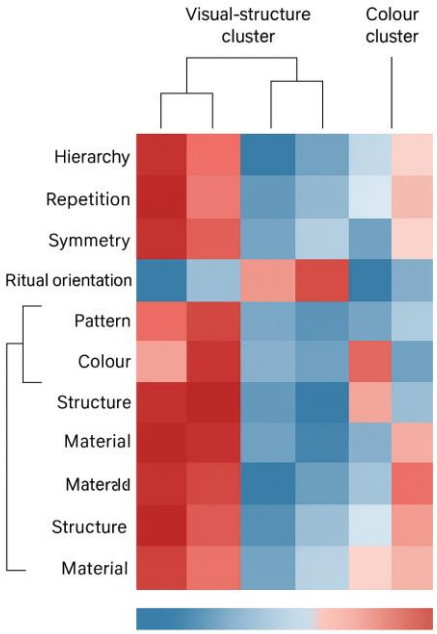

Figure 4: Hierarchical Cluster Heatmap of High-Frequency MTFC Design Principles and Elements

Coupling Patterns among Design Principles, Elements, and Features

Based on high-frequency co-occurrence analysis, Table 7 identifies three semantic clusters aligned with the core design dimensions of MTFC. Keyword patterns reveal the following insights:

At the level of design elements, patterns and colors emerged with the richest lexical diversity, often forming compound phrases alongside structure and material, indicating a strong coupling between visual motifs and physical media.

At the level of design elements, patterns and colors emerged with the richest lexical diversity, often forming compound phrases in conjunction with structure and material, indicating a strong coupling between visual motifs and physical media.

At the level of cultural features, aesthetic and symbolic terms frequently co-occurred, while identity-related features tended to manifest as externalized encodings of ethnicity or marital status.

Table 7. Summary of MTFC Design Dimension Keywords

Category	Dimension	Merged Keywords (Synonym Grouping)
Design Principles	Hierarchy	"Primary–secondary structure," "headwear centric," "ritual sequencing"
	Symmetry	"Bilateral symmetry," "axial layout," "visual balance"
	Repetition	"Motif looping," "border rhythm," "book-frame effect"
	Rituality	"Annual festivals," "spirit-sending rites," "dance-related adornment"

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Design Elements	Pattern	"Butterfly motif," "fish motif," "swastika pattern"
	Color	"Red-black contrast," "blue-silver pairing," "dominant–accent color combination"
	Structure	"Double–triple weave," "waistband joint structure," "layered pleats"
	Material	"Silver ornaments," "wool fabric," "silk thread," "cotton–linen blend"
	Wearing Method	"Headpiece placement," "strap-tying style," "earring direction"
Cultural Features	Aesthetic	"Refined," "symmetrical beauty," "three-dimensional embossing"
	Symbolic	"Ancestral worship," "natural cosmology," "life regeneration"
	Identity Marker	"Marital status coding," "ethnic subgroup recognition"

A co-occurrence matrix between design elements and cultural features was constructed and analyzed using the Louvain community detection algorithm. Three dominant semantic clusters were identified:

Pattern–Symbolic Cluster: Centered around recurring motifs such as butterflies and phoenixes, this group encodes ancestral myths and ritual cosmologies through visual symbolism.

Color–Aesthetic Cluster: Emphasizes the visual appeal of chromatic contrast and saturation, forming the core of affective visual grammar.

Structure/Material–Identity Cluster: Highlights how layered constructions (e.g., tiered skirts) and metallic materials (e.g., repoussé silver) serve as visual markers of social identity.
This result confirms that each design element is tightly coupled to a dominant cultural function, providing a valid operational basis for subsequent development of parameter–semantics mapping tables and UX-based emotional inference models.

Keyword–Gap Mapping

To visually synthesize both the cognitive focus and systematic omissions in MTFC-related literature, this study constructed a quadrant-based Keyword–Gap Mapping diagram (see Figure 5). High-frequency keywords were plotted across two axes: Cultural vs. Technological (horizontal) and Visual vs. Interactive (vertical). Each term was further annotated according to its corresponding gap type (G1–G4).

The visualization reveals three key insights:

G2 keywords cluster around ritual and material–texture coupling, indicating a lack of robust technological translation mechanisms.

G3/G4 keywords are in the interactive design quadrant, highlighting the need for future UX validation and engagement frameworks.

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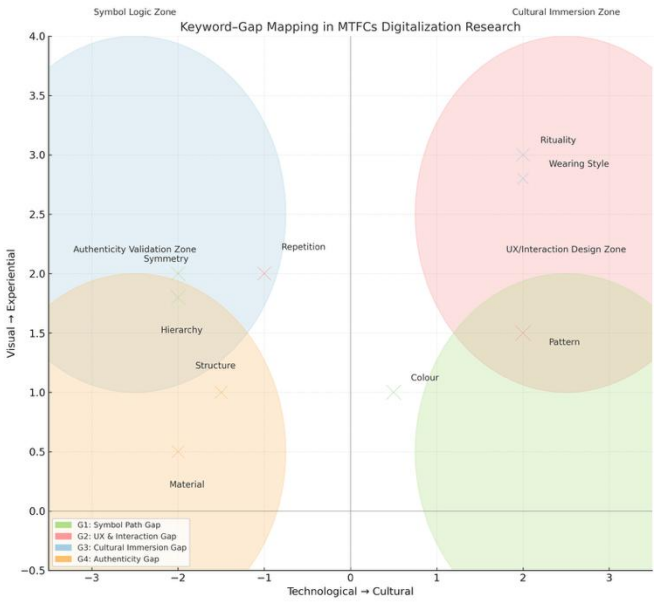

Figure 5: Keyword–Gap Mapping in MTFC Digitalization Research

Discussion

Gap Prioritization and Semantic Imbalance

By cross-referencing the keyword gap matrix from 52 core texts, this study systematically maps the four identified gap types (G1–G4) to corresponding technical or methodological interventions, ensuring the discussion extends beyond diagnosis to actionable design strategies.

G1 – Literature Gap

A design principle or element with a keyword frequency ≤ 4 (under 10%) is marked as underrepresented. To avoid overlooking potentially significant concepts, this study recommends expanding data sources to include grey literature and forming Delphi panels of cultural custodians to validate and refine the initial ontology, thereby addressing RQ1 on theoretical completeness.

G2 – Digital Translation Gap

Represents high-frequency concepts (e.g., ritual) lacking parameter integration in digital assets. To bridge this, the modeling workflow can incorporate virtual fabric physics (e.g., Marvelous Designer API or USD-Z material shaders) and embed ritual logic as Unity animation state machines, directly supporting RQ2 on implementation fidelity.

G3 – User Perception Gap

Occurs when semantic differential ratings fall below 2.5/5 or eye fixation durations are under 200 ms, suggesting that the symbolic intent failed to resonate emotionally. A proposed solution is to embed micro-narratives (text/audio) at interaction hotspots, combined with emotion-AI logging for iterative A/B testing, addressing RQ3 on cultural resonance.

International Journal of Education, Psychology and Counseling
IJEPC
EISSN : 0128-164X
Volume 10 Issue 61 (December 2025) PP. 607-623
DOI 10.35631/IJEPC.1061043

G4 – Expression Saturation Gap
Arises when visual interfaces overemphasize decorative layers (e.g., color or pattern dominance with more than 70% screen coverage), neglecting deeper contextual cues. A technical solution involves layer thinning, semantic zooming, and LOD-adaptive shading, redistributing visual density across HUD elements while balancing usability and symbolic depth, serving both RQ2 and RQ3.

In sum, the gap–solution mapping closes the loop between identification (RQ1) and design response (RQ2 & RQ3), aligning with the design science logic of diagnosis → intervention → evaluation. It offers a reusable strategic toolkit for future digital heritage projects involving ethnic costume systems.

A Parameterized 3D Modelling Framework
Building on the semantic insights in Sections 5.1–5.2, this study proposes a parameterized 3D modelling framework (see Figure 5), which systematically maps Design Principles, Elements, and Features into machine-readable geometric and material parameters.

Color Scheme: The primary palette employs hex codes #AA1C1C (sacrificial red) and #201916 (ancestral black), corresponding to the principles of ritual orientation and yin–yang contrast. HSL channel locking ensures visual consistency across rendering platforms.

Pattern Density: Weighted texture maps emphasize high-density embroidery across the shoulder-to-chest axis, reinforcing the "body-as-text" concept. Peripheral density is gradually attenuated (α: 1 → 0.4) to minimize visual noise.

Material Mapping: A dual metallic–roughness texture map differentiates flexible textiles from rigid silver ornaments, reconstructing the tactile stratification of traditional MTFC garments.
Symmetry Axis: Mirror constraints are applied along both left–right and top–bottom axes, reflecting the Miao cosmological notion of yin–yang equilibrium while optimizing mesh generation efficiency.

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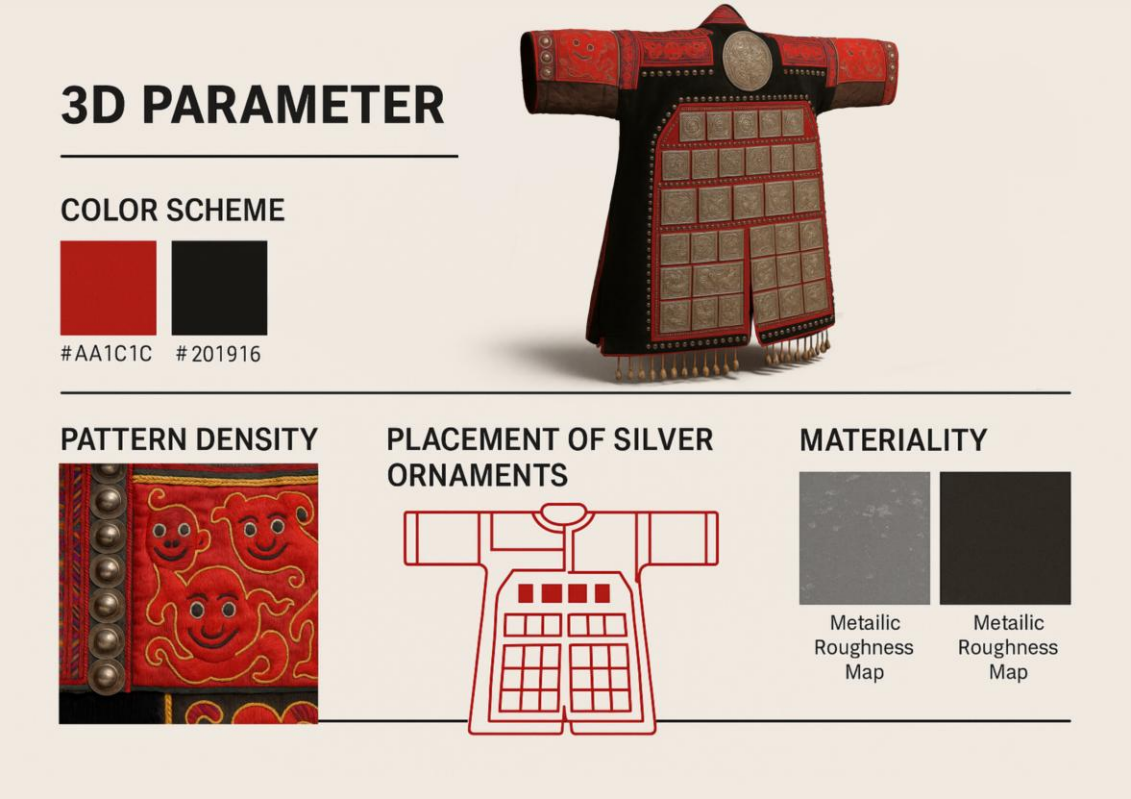

Figure 6: Parameterized 3D Framework for MTFC Design

This framework operationalizes the P–E–F–M–E (Principle–Element–Feature–Modal-trigger–Emotion) pipeline, translating cultural logic into procedural geometry. Outputs can be deployed within Unity or WebXR environments and embedded via <metadata> JSON nodes to preserve semantic labels.

The system ensures semiotic consistency across the design–rendering workflow, establishing a scalable foundation for cultural narrative modelling and metadata standardization in digital heritage pipelines. Although this study does not empirically validate the emotional or usability impact, the framework defines a reproducible baseline for future user-centred testing—e.g., integrating eye-tracking or facial emotion recognition to assess correlations between pattern and colour density and emotional arousal.

Contributions

The study delivers: (a). A consolidated P–E–F core with documented stability (n=52) to anchor teaching; (b). A reusable P–E–F–M–E pipeline that maps semiotic rules to parameterised 3D tasks and a two-axis rubric; and (c). Low-cost evidence options for motivation, perceived usability, and brief affect checks.

Scope and Limitations

Evidence is corpus-based; no user testing is reported. Modelling guidance targets CLO3D/Unity workflows and may require adaptation for mobile GPU budgets.

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Next Steps

We outline a classroom validation protocol that compares rubric scores with mini-scale outcomes and short reflective notes, enabling replication and cumulative improvement in art & design programmes.

Acknowledgements

The authors carried out the conceptualization, methodology design, data collection and curation, formal analysis, software scripting and visualization, writing – original draft preparation, and writing – review & editing. They approve the final manuscript and accept full responsibility for all aspects of the work.

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