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COMPREHENSIVE ANALYSIS OF CULTURALLY SENSITIVE AI AND MULTIMODAL CRAFTSMANSHIP IN JADE DESIGN

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ABSTRACT

The incorporation of artificial intelligence into heritage-oriented design practices offers novel avenues for creative collaboration, while simultaneously prompting inquiries into cultural authenticity and material sensitivity. This research introduces a cognitive interface framework that elucidates how human–AI co-creation can enhance creative design processes within a Design Thinking framework. By merging concepts from the Task–Technology Fit (TTF) and the Technology Acceptance Model (TAM), the study investigates the interplay between designer attributes, AI tool functionalities, and task demands in shaping effective collaborative settings. The initial phase entails the cultural assessment of AI-generated proposals, wherein designers interpret computational results through symbolic meanings and heritage-based aesthetic principles. The second phase emphasizes the adaptation of these outputs to meet the physical and structural limitations of the material, underscoring the significance of tactile knowledge and material responsiveness. The concluding phase involves collaborative optimization, where iterative refinement between human expertise and algorithmic generation culminates in culturally coherent and technically viable design results. The findings further suggest a tripartite factor structure of cognitive adaptability, which includes technical function adaptability, cultural value adaptability, and cognitive interaction adaptability. Collectively, these dimensions demonstrate how AI systems can transcend mere automated generation to provide culturally attuned design support. The study concludes that effective human–AI co-creation requires the alignment of algorithmic logic with the tacit knowledge of artisans, enabling technology to function not merely as a tool but as a cultural mediator within contemporary design practice.

Keywords: Human–AI Co-creation; Cognitive Adaptability; Cultural Heritage Design; Artificial Intelligence in Craft and Design Thinking.

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1. IDENTIFYING KNOWLEDGE GAPS IN DIGITAL CRAFTSMANSHIP

The background and literature review outlined in this study are integral components of an ongoing research project undertaken by the author, focusing on the utilization of artificial intelligence in jade carving and design. Given that the study is presently in an exploratory phase, the available literature is somewhat limited. As a result, much of the discourse is shaped by the author's initial observations and early analytical insights gained from the research endeavor. Therefore, the interpretations and conceptual propositions put forth should be regarded as provisional findings that will be further validated through subsequent empirical analysis and a broader range of scholarly references.

Current multimodal systems are still limited by a type of superficial material cognition, particularly in their restricted ability to comprehend the spiritual significance and physical resistance present in raw stone and other heritage materials. These systems mainly process visual and textual representations, yet they fail to fully engage with the embodied and tactile aspects that influence traditional craft practices. Consequently, a significant knowledge gap exists regarding the scalability of these AI models to other forms of intangible cultural heritage, such as lacquerware and ceramics. These practices entail intricate interactions between material characteristics, tactile manipulation, and chemical transformations that develop throughout the crafting process. In these contexts, sensory feedback, material responsiveness, and experiential knowledge are crucial in shaping design outcomes. Thus, further research is necessary to explore how multimodal artificial intelligence frameworks can incorporate these materially embedded and process-driven forms of knowledge beyond visually focused design areas.

1.1 Synthesizing AI and Heritage Craft

The synthesis of findings from research on AI-enhanced jade carving reveals a notable shift from traditional digital automation to a more sophisticated model of Cognitive Interface Adaptability. This transition underscores the necessity for intelligent systems that can engage meaningfully with culturally rooted design practices, rather than simply executing automated visual generation.

The research delineates a three-phase cognitive negotiation process that is fundamental to the successful integration of artificial intelligence into conventional craft practices. The initial phase entails the cultural assessment of AI-generated proposals, wherein outputs are interpreted through established aesthetic standards, symbolic significances, and cultural narratives linked to jade carving traditions. The subsequent phase emphasizes the adaptation of these outputs to align with the physical limitations and structural characteristics of the material. During this stage, design concepts are modified in accordance with the resistance, texture, and technical constraints inherent in jade as a carving medium. The concluding phase involves collaborative optimization, where iterative refinement between human expertise and computational generation culminates in a more coherent and contextually suitable design result.

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In summary, these insights indicate that the function of technology within traditional craft settings transcends that of a mere functional tool. Rather, technological systems should serve as a cultural channel capable of bridging algorithmic reasoning and the implicit, experiential knowledge of artisans. Such alignment is crucial for ensuring that artificial intelligence enhances, rather than undermines, the cultural authenticity and material sensitivity integral to heritage craft practices.

1.2 Factors Structure of Cognitive Adaptability

A central contribution of this study is the proposal of a tripartite factor structure affecting what they term Cognitive Interface Adaptability. This approach recognizes that heritage-based design decisions emerge from a combined negotiation of technical function, task requirements, and cultural constraints. Unlike standard technology adoption models, this framework positions cultural value as a core determinant rather than a peripheral influence.

Technical Function Adaptability represents the system's ability to align with the procedural and task-specific needs of the artisan. In jade carving, this encompasses the necessity for design precision, form accuracy, and output feasibility. A system that lacks the capacity to account for the subtractive nature of stone carving or the specific material properties of jade will inevitably fail the fit requirement of the TTF model.

Cultural Value Adaptability addresses the preservation of heritage meanings. Artisans evaluate technological tools not merely for functional utility but for their capacity to respect, preserve, and meaningfully interpret cultural principles. This requires the AI to generate forms that retain symbolic coherence and respect indigenous aesthetic codes, thereby avoiding the risks of cultural misrepresentation or appropriation (Zhou,2025)

Cognitive Interaction Adaptability captures the extent to which users can intuitively engage in an iterative dialogue with the intelligent system. This dimension focuses on the designer's ability to refine outputs through cycles of prompt modification and aesthetic judgment, ensuring that human intuition remains the final arbiter of quality.

Understanding the integration of artificial intelligence within heritage-based design practices requires a framework that accounts for both technological functionality and culturally embedded craftsmanship. The tripartite factor structure of cognitive adaptability provides such a framework by identifying three interrelated domains that influence successful human–AI collaboration: technical adaptability, cultural adaptability, and cognitive interaction adaptability. Together, these dimensions explain how computational tools can be aligned with material processes, symbolic traditions, and the tacit knowledge of artisans.

Table 1 highlights that effective technological adoption in traditional craft contexts does not rely solely on algorithmic capability, but also on the system's ability to

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accommodate cultural meaning, aesthetic conventions, and iterative human judgement within the creative workflow.

Table 1: Tripartite Factor Structure of Cognitive Adaptability Illustrating the Interrelationship between Technical Function Adaptability, Cultural Value Alignment, and Human–Machine Cognitive Interaction in AI-Assisted Design Workflows.

Factor	Primary Component	Determinants of Success	Impact on Workflow
Technical Function Adaptability	AI Tool Characteristics	Precision, Algorithmic Logic, Form Accuracy	Procedural efficiency and task alignment
Cultural Value Adaptability	Cultural Heritage Alignment	Symbolic Coherence, Heritage Meaning, Aesthetic Codes	Preservation of cultural authenticity
Cognitive Interaction Adaptability	Human-Machine Dialogue	Iterative Refinement, Intuitive Engagement, Prompt Engineering	Strategic integration and creative agency

The relationship between these factors and the overall effectiveness of AI integration is summarized in the finding that task relevance, perceived usefulness, and perceived cultural alignment are the most significant predictors of designer acceptance. These factors collectively determine whether technologies enhance, reinterpret, or unintentionally disrupt culturally grounded design intentions.

The proposed tripartite factor structure conceptualizes cognitive adaptability as a multidimensional process that enables the meaningful integration of artificial intelligence within traditional craft practices. Each factor represents a distinct yet interconnected dimension that supports the translation of computational outputs into culturally and materially appropriate design outcomes.

The first dimension, technical function adaptability, emphasizes the operational capacity of AI tools to perform tasks with precision and algorithmic reliability. This dimension focuses on the characteristics of the technological system itself, including computational logic, accuracy of form generation, and the efficiency of automated procedures. Within the workflow, this adaptability supports procedural efficiency and ensures that algorithmically generated outputs remain structurally viable for design development.

The second dimension, cultural value adaptability, addresses the alignment between AI-generated outputs and the symbolic, aesthetic, and narrative traditions embedded within cultural heritage practices. In this context, determinants of success involve symbolic coherence, adherence to aesthetic codes, and sensitivity to heritage meaning. Cultural adaptability therefore ensures

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that technological intervention does not disrupt the authenticity of traditional design language but instead supports the preservation and reinterpretation of cultural identity.

The third dimension, cognitive interaction adaptability, concerns the dynamic dialogue between human expertise and computational systems. This dimension highlights iterative refinement, intuitive engagement, and prompt engineering as mechanisms through which artisans negotiate and reshape algorithmic outputs. Rather than functioning as a purely automated process, the interaction becomes a collaborative cognitive space where human judgement guides the evolution of the design.

These three factors demonstrate that cognitive adaptability operates through the balanced interaction of technological capability, cultural interpretation, and human–machine collaboration. The framework therefore provides a conceptual basis for understanding how AI systems can be integrated within heritage craft practices while maintaining both creative agency and cultural integrity.

1.3 Human-AI Co-Creation and the Research Model

The Research Model of Human-Machine Co-Creation Cognitive Interface developed by researcher (author’s own study) clarifies how designer characteristics, AI tool capabilities, and task requirements jointly shape the conditions for meaningful collaboration. Within this model, the designer engages with AI through mechanisms that balance intuitive human judgment with computational suggestions. This interaction is not a one-way transfer of data but an adaptive and iterative process of co-creation.

As designers selectively utilize, refine, or reinterpret AI outputs, strategic integration occurs. This process not only enhances user acceptance but also facilitates the production of innovative artefacts that preserve cultural narratives. The theoretical elevation of cultural adaptability within the TAM framework acknowledges that cognitive and cultural negotiations are inseparable from decision-making in heritage contexts.

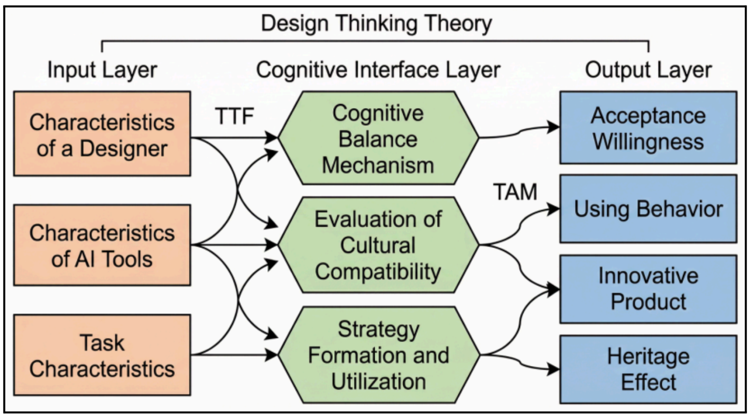

Figure 1: Research design flow

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The research design flow (Figure 1) conceptualizes a cognitive interface that explains how human–AI co-creation facilitates creative design processes within a Design Thinking framework. By integrating the principles of Task–Technology Fit (TTF) and the Technology Acceptance Model (TAM), the model clarifies how designer attributes, AI tool capabilities, and task requirements collectively shape the conditions necessary for effective collaboration.

Within this framework, designers interact with AI systems through mechanisms that balance intuitive human judgement with computationally generated suggestions. This interaction ensures that creative agency remains centered on human expertise while simultaneously leveraging algorithmic assistance to enhance ideation and problem-solving processes. The model also emphasizes the role of cultural compatibility, highlighting the need to align AI-generated outputs with symbolic meanings and heritage-based aesthetic principles, particularly in design domains where cultural expression constitutes a core component of creative practice (Yu and Hashim, 2024).

Through iterative engagement, designers critically evaluate, adapt, and reinterpret AI-generated proposals, enabling strategic integration within the design workflow. This process results in an adaptive co-creation dynamic characterized by continuous refinement and reciprocal feedback between human cognition and computational generation. Such interaction not only strengthens user acceptance and sustained engagement with AI technologies but also supports the development of innovative design artefacts that retain cultural narratives and contextual relevance.

Overall, the model demonstrates that human–AI co-creation can extend the boundaries of contemporary design practice by expanding creative possibilities while maintaining cultural continuity and heritage-informed design values.

2. THE THREE-PHASE COGNITIVE NEGOTIATION PROCESS

The practical application of AI in jade carving involves what the researchers describe as a Dynamic Cognitive Negotiation Process, structured as a three-phase cycle. This model was inductively derived from interviews with expert designers and validated through a single-case study involving a master jade carver.

The first phase, Cognitive Evaluation, involves the filtering, selection, and interpretation of emerging ideas generated by AI. Designers utilize heuristic prompts and reflective questioning to determine the cultural relevance and structural feasibility of a concept. This phase foregrounds mental filtering processes that allow designers to establish a creative direction before physical or digital transformation begins. The second phase, Transformation, emphasizes the iterative refinement of ideas. Expert practitioners use strategies such as subtraction, form adjustment, and dimensional adaptation to reshape AI-generated outputs. This negotiation is an active process of translation where technical possibilities are balanced against the designer’s tacit knowledge and embodied experience. The third phase, Optimization, involves the advancement of decision-making through structured refinement

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mechanisms. This includes prompt engineering, reverse training, and the establishment of collaborative standards. By creating stable and repeatable workflows, practitioners ensure that their interactions with intelligent tools remain contextually sensitive and culturally aligned.

2.2 Empirical Validation with Master Chen Yi

The theoretical models were validated through a collaboration with Chinese jade carving master Chen Yi in 2025. The study observed the master's interaction with a multimodal AI system, focusing on how he reinterpreted AI-generated prompts through his understanding of tradition and symbolism. Master Chen Yi's approach demonstrated that jade is not simply a material to be shaped but a cultural vessel carrying historical narratives and moral values.

The experimental procedure involved a four-phase evaluation methodology:
1. Orientation: Familiarizing the artisan with the AI system's features, including material simulation and stylistic suggestion modules.
2. Task Execution: Completing culturally grounded design tasks that vary in complexity and motif specificity.
3. Data Collection: Gathering observational data, system-generated outputs, and qualitative feedback from the artisan.
4. Data Analysis: Synthesizing the evidence to assess technical accuracy, cultural alignment, and user acceptance.

The idea presents an empirically informed framework of traditional jade carving practice derived from observational validation with master artisan Chen Yi. Table 2 maps the sequential stages of carving by integrating artistic focus, technical negotiation, and cognitive processes, illustrating how material interpretation and tacit craftsmanship guide decision making throughout the creative workflow.

Table 2: Empirical Mapping of Artistic, Technical, and Cognitive Elements in Traditional Jade Carving Practice.

Stage of Carving	Artistic Focus	Technical Negotiation	Cognitive Element
Initial Assessment 	Reading the stone's natural contours	Tonal variation and surface texture analysis	Heuristic prompt interpretation
Early Carving	Defining primary form and motifs	Calculated incisions and subtraction methods	Intuitive judgment and material sensitivity

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Refinement 	Detail enhancement and dimensionality	Smoothing transitional areas with fine tools	Iterative feedback and aesthetic coherence
Completion 	Final polishing and narrative integration	Harmonizing natural beauty with interpretation	Cultural meaning and symbolic resonance

The study from this validation confirmed that impactful AI-assisted jade carving emerges from the synergy between human artistic intelligence and the generative capabilities of computational systems. The master's deep understanding of material properties ensured that the final outcome respected both cultural heritage and material limitations, while AI contributed computational precision and rapid motif variations.

Empirical validation was conducted through collaborative observation and practice-based verification with the master jade artisan Chen Yi. The validation process aimed to examine whether the proposed cognitive framework of AI-assisted jade carving accurately reflects the authentic stages of traditional carving practice, particularly the interaction between artistic intention, material response, and tacit craftsmanship.

The analysis of the carving workflow demonstrates that each stage embodies a distinct integration of artistic focus, technical decision-making, and cognitive negotiation. During the initial assessment, Master Chen Yi emphasized the importance of reading the natural contours and internal characteristics of the stone. This stage involves surface texture evaluation and form anticipation, supported by heuristic interpretation developed through long-term experiential

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knowledge. The observation confirms that the artisan's first engagement with the material is fundamentally interpretive rather than mechanical.

In the early carving stage, empirical observation revealed a transition from visual interpretation to structural intervention. Master Chen Yi defines the primary motifs and compositional direction while applying calculated incision and subtraction techniques. Decision-making at this stage reflects intuitive judgement shaped by deep material sensitivity, confirming that carving actions are guided by both technical control and embodied cognition.

The refinement phase demonstrates how iterative feedback between visual form and tactile engagement shapes the emerging design. Fine tools are used to smooth transitions and enhance dimensional detail, while continuous aesthetic evaluation ensures coherence between the evolving form and the intended narrative expression.

Finally, during the completion stage, polishing and surface finishing are performed to harmonize the natural beauty of the jade with the carved imagery. Master Chen Yi described this stage as a process of narrative integration, where symbolic meaning and cultural resonance are finalized.

The empirical validation confirms that traditional jade carving operates through a layered cognitive process in which artistic interpretation, technical manipulation, and cultural understanding are inseparably linked. The findings support the proposed framework by demonstrating that successful integration of computational assistance must respect these sequential stages of material interpretation, structural transformation, and cultural articulation within the artisan's workflow.

2.2 Extension: Strategic Framework for Multimodal Haptic and Affective AI in Heritage Design

The integration of advanced artificial intelligence within heritage-based design practices requires frameworks that move beyond visual computation toward a more holistic engagement with material, sensory, and cultural dimensions of craft. A strategic framework for multimodal haptic and affective AI in heritage design therefore seeks to bridge the gap between computational intelligence and the embodied knowledge traditionally held by artisans. While contemporary AI systems demonstrate strong capabilities in visual pattern recognition and generative design, many heritage practices such as carving, ceramics, or lacquerware depend on tactile feedback, material resistance, and emotional interpretation that are not fully captured by conventional digital interfaces.

Multimodal haptic and affective AI introduces the potential to simulate or interpret these experiential elements by integrating sensory inputs such as touch, gesture, and affective response into the design interaction process. Within this framework, AI systems function not merely as generative tools but as adaptive interfaces capable of responding to human intuition, emotional evaluation, and culturally embedded aesthetic judgement. Such systems may support designers by

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translating tactile interactions, material behaviour, and emotional cues into computational insights that guide design refinement.

The strategic framework therefore emphasizes the alignment of technological capability with cultural meaning and material sensitivity. By integrating multimodal interaction, haptic simulation, and affective interpretation, the framework aims to support a more culturally responsive model of human–AI collaboration that strengthens both innovation and continuity within heritage design practices.

While the current research establishes a strong foundation in visual and cognitive AI integration, a significant opportunity exists to extend this work into the realm of multimodal haptic and affective design systems. Heritage craftsmanship is fundamentally an embodied and sensory practice. To fully replicate the fit between task and technology, future systems must address the tactile and emotional dimensions of the artisan's experience (Yuan et al., 2026).

i. The Tactile Frontier: Haptic Feedback and Material Cognition

Haptic feedback systems provide the necessary sensory depth to simulate the tactile qualities of traditional materials. In high-precision crafts like jade carving or jewellery engraving, the sense of touch is the primary channel for material cognition. Progress in this study suggests that haptic integration can improve cultural comprehension by enabling users to identify material characteristics more accurately.

The current market for haptic technology is evolving from simple vibrational notifications to sophisticated multisensory devices that integrate pressure, skin stretch, and temperature (Alexandra, 2025). For heritage craft, the distinction between cutaneous feedback (skin receptors) and kinesthetics feedback (musculoskeletal force) is critical.

Table 3: Empirical Mapping of Artistic, Technical, and Cognitive Elements in Traditional Jade Carving Practice.

Haptic Actuator Type	Technical Mechanism	Applications in Heritage Design	Performance Trend
Linear Resonant Actuator (LRA)	Electromagnetic vibration	Surface texture simulation, notification	Rising adoption due to configurability
Voice Coil Motor (VCM)	Direct force actuation	Precision tool resistance, impact	Expanding market share in high-fidelity VR
Piezoelectric Actuator	High-frequency shape change	Micro-detail tactile rendering, clicky feel	Preferred for ultra-fine surface haptics
Fluidic Actuator	Pressurized liquid/air	Soft robotics, variable stiffness surfaces	Gaining traction in wearable textiles

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Integrating these technologies into the TTF-TAM framework involves creating a Technical Function Adaptability that includes force-feedback loops. For instance, a digital carving system could use VCMs to simulate the varying resistance of jade depending on its density or internal fractures, allowing the designer to feel the material virtually before physical intervention (Shi, 2024).

ii. Multimodal Fusion and Affective Computing

A truly intelligent heritage design system must be capable of Affective Computing in identifying and responding to the designer's emotional and cognitive state. Recent advancements in multimodal AI fusion integrate visual, auditory, and tactile signals to create a coherent interpretation of human intent (Dritsas et al., 2025).

A proposed multimodal information presentation model driven by emotional feedback can map sentiment tendencies into virtual reality environments. This allows for personalized, multilayered cultural information visualization that enhances the visitor's or designer's interest and emotional involvement. The system accuracy of such multimodal frameworks has reached levels as high as 94.8% in identifying cultural subgroups and user sentiments.

The technical architecture for such a system involves a five-layer distributed system:
1. Pattern Recognition Layer: Analyzing visual motifs and historical data through convolutional neural networks.
2. Temporal Depiction Layer: Using bidirectional LSTM networks to capture the historical evolution of a craft technique.
3. Semantic Comprehension Layer: Leveraging transformer-based models for natural language processing and prompt engineering.
4. Haptic/Tactile Layer: Synchronizing real-time force feedback with visual outputs.
5. Affective Feedback Loop: Adjusting system parameters based on the user's physiological or behavioral response to the design process.

iii. Digital Twins and Heritage Simulation

The concept of the Digital Twin has emerged as a transformative tool for heritage preservation and design. By combining a 3D model with live data from sensors, designers can simulate environmental conditions and predict material behavior. In the context of jade or stone carving, a digital twin allows the artisan to conduct virtual stress tests on a design concept, identifying potential structural failures or misalignments with cultural motifs before the first cut is made (World Heritage Day, 2025).

Case studies from 2025 demonstrate that AI-driven simulated play can even be used to identify rules for ancient board games or reconstruct

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prehistoric tools by analyzing use-wear patterns. These simulations provide a recipe for digital storytelling and material interaction that democratizes access to expert knowledge while ensuring academic and cultural rigor (Mikkel, 2025).

3. METHODOLOGY

The experimental procedure was developed to systematically investigate the technical and cultural requirements associated with AI-assisted jade carving and jewellery design through collaborative engagement with a master carver. A four-phase evaluation methodology was adopted to provide a structured framework for examining how AI-assisted systems may be meaningfully integrated into traditional jade carving practices. Each phase represents a distinct stage of interaction between the artisan, the technological system, and the evolving design outcomes. This staged evaluation enables a comprehensive assessment that considers both the technical performance of the AI tools and the preservation of cultural authenticity within the design process.

The experimental protocol was structured to examine the technical and cultural integration of AI-assisted design within jade carving and jewellery development through collaborative engagement with a master artisan. A four-phase evaluation procedure was implemented to systematically capture the stages of interaction between the artisan, the AI system, and the resulting design outputs.

The first phase, Orientation, focuses on familiarising the master carver with the AI-assisted design environment. This stage is essential to establish confidence and operational fluency with the digital interface, as effective human–AI collaboration depends on the user’s ability to navigate system functions and interpret algorithmically generated outputs. During this phase, the participant was introduced to the multimodal AI-assisted design system and its core features, including visual input processing, material simulation capabilities, and stylistic suggestion modules. Guided training sessions clarified system functionalities and limitations while ensuring that the artisan’s established creative processes remained central to the design workflow.

The second phase, Task Execution, required the artisan to complete a series of culturally grounded design tasks that reflected both traditional jade carving motifs and contemporary jewellery design considerations. Tasks were structured with varying levels of complexity and motif specificity to evaluate the system’s capacity to support motif generation, stylistic interpretation, and alignment with symbolic traditions. Throughout this phase, the artisan interacted iteratively with the AI interface to generate design alternatives, refine visual outputs, and evaluate the relevance of computational suggestions within the creative decision-making process.

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The third phase, Data Collection, employed multimodal methods to document the interaction process and resulting artefacts. Video and image recordings captured real-time engagement with the system, including hand movements, interface navigation, and iterative design adjustments. Verbal think-aloud protocols and semi-structured interviews conducted after task completion elicited reflections on technical functionality, cultural appropriateness, and creative utility. These interviews, lasting approximately 60–90 minutes, were designed to explore dimensions associated with the Task–Technology Fit and the Technology Acceptance Model. In addition, design artefacts such as AI-generated outputs, revised digital iterations, and carved prototypes were systematically documented together with task metadata, including task type, cultural intensity, and craft complexity. This documentation enabled triangulation across behavioural observations, reflective insights, and tangible design outcomes.

The final phase, Data Analysis, synthesised the collected qualitative and quantitative evidence to evaluate how AI-assisted systems align with heritage-based jade carving practices. A stratified analytical approach examined three principal dimensions: technical precision, cultural relevance, and user acceptance. The analysis employed a three-stage coding procedure based on thematic analysis as outlined by Virginia Braun and Victoria Clarke (2023). Initial open coding identified recurring patterns, including issues related to motif misinterpretation and frequent design revisions. Axial coding subsequently organised these observations into broader thematic categories, namely Technical Function Adaptability, Cultural Value Adaptability, and Cognitive Interaction Adaptability. Through selective coding, a central conceptual theme of Cognitive Interface Adaptability emerged, describing how artisans engaged with AI tools through iterative phases of evaluation, transformation, and optimisation.

The validity of the findings was strengthened through triangulation across data sources and member-checking with the participating artisan. This analytical process extends the theoretical application of the Task–Technology Fit and Technology Acceptance frameworks by foregrounding cultural adaptability as a primary determinant in the integration of artificial intelligence within traditional craft contexts. Overall, the findings demonstrate that AI-assisted systems can support cultural design innovation while preserving the material sensitivity and tacit knowledge fundamental to artisanal practice.

4. SYNTHESIS OF FINDINGS AND FUTURE RESEARCH DIRECTIONS

The acceleration of AI development has outpaced cultural governance, raising questions about authorship, ownership, and cultural sovereignty. Experts at MONDIACULT 2025 have called for a new governance paradigm that prioritizes human creative agency and prevents the unfair use of artistic work (UNESCO, 2025).

National AI strategies must integrate culture, prioritizing risk assessment for intangible heritage and fostering transnational collaboration to bridge the digital divide (UNESCO World Conference on Cultural Policies and Sustainable Development, 2025). This includes investing in cultural AI literacy that balances technical skills with critical creativity, ensuring that future generations of artisans can navigate the opportunities and risks of intelligent systems (Orbit, 2025).

The future of heritage preservation will likely see a harmonious blend of archaeologists, architects, artisans, and AI specialists working together to tackle complex challenges. The Mirror Technology approach, where AI reflects and extends skilled practice rather than replacing it, offers a path toward a sustainable and resilient cultural future (Bianco et al., 2026).

The research presented by Weng and Hashim, combined with the broader trends in multimodal AI, suggests that the future of traditional design lies in a balanced partnership between human intuition and computational power. The study of jade carving confirms that task relevance and cultural alignment are the primary drivers of technology acceptance, and that design thinking provides the iterative environment necessary to negotiate these values.

As we move forward, the research agenda for AI-enhanced traditional design should focus on:

1. Refining Haptic and Tactile Fidelity: Developing devices that can accurately simulate the embodied knowledge of the artisan, particularly in micro-detail carving and engraving (Shi, et al., 2024).
2. Enhancing Culturally Intelligent Interfaces: Creating AI systems with deeper semantic understanding of heritage symbols to avoid appropriation and homogenization (Orbit, 2025).
3. Investigating Skill Transformation: Longitudinal studies on how the use of GenAI impacts the development of fundamental artistic skills among students and practitioners (Lee, 2025).
4. Empowering SMEs through AI: Strategies for helping small and medium-sized craft enterprises adopt AI tools to enhance their competitiveness without losing their artisanal identity (Bianco et al., 2026).

The integration of AI and human expertise demonstrates that meaningful innovation does not require abandoning tradition. Instead, it grows from a disciplined engagement with technology that respects material sensitivity, cultural intention, and the unique sensitivity of the human artisan. This evolving relationship ensures that intangible cultural heritage remains a living, breathing part of the global creative landscape.

By strictly adhering to the frameworks of Task-Technology Fit and Technology Acceptance, and by expanding these models to include sensory and emotional dimensions, the design community can develop tools and processes that are not only technologically coherent but also culturally sensitive and cognitively supportive. The resulting hybrid craftsmanship will be a testament to the enduring power of human creativity in the age of artificial intelligence.

AI-assisted jade carving represents a significant convergence between heritage craftsmanship and emerging digital design technologies. The findings indicate that meaningful outcomes emerge when technological capabilities are carefully aligned with human artistic intelligence and experiential knowledge. Rather than functioning as a substitute for traditional practice, artificial intelligence operates as a generative catalyst that expands the designer's creative scope by offering alternative visual variations, structural configurations, and exploratory design directions that may not readily arise through conventional processes alone.

Despite these technological contributions, the essence of jade carving remains deeply grounded in cultural symbolism, material responsiveness, and the interpretive expertise of the artisan. These human dimensions continue to shape the emotional resonance, symbolic significance, and aesthetic integrity that define the craft tradition. The integration of AI within the design process therefore illustrates that innovation in heritage-based practices does not require the displacement of tradition. Instead, it emerges through a balanced collaboration in which technological systems support creative decision-making while enabling greater refinement of form, contour, and narrative expression.

This evolving relationship between human expertise and computational assistance suggests new opportunities for contemporary jade design to remain culturally meaningful while responding to the dynamics of a rapidly transforming creative landscape. Furthermore, the insights derived from this study highlight the broader potential of artificial intelligence to contribute to other heritage-based craft practices. Future research may therefore explore how similar human–AI collaborative frameworks can enhance innovation while preserving the cultural knowledge and artisanal values embedded within traditional design disciplines.

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