

Cloisonné Serious Game: AI Cognitive Apprenticeship Instructor for Intangible Cultural Learning

Zaimeng Zhang, Robyn-Ann Potanin and Xun He

Savannah College of Art and Design, Interactive Design and Game Development, USA

zaidaz1606@gmail.com

rpotanin@scad.edu

xunhe01@gmail.com

Abstract: Intangible cultural heritage (ICH) is the living skills, knowledge, and practices that communities pass down across generations, such as traditional craftsmanship including cloisonné. Cloisonné is a centuries old Chinese metal and enamel handcraft, in which colored enamel is fired within copper wire compartments on a metal body. This handcraft faces growing challenges in preservation and education, creating a need for digital approaches that can effectively engage younger generations. However, serious games built around such crafts often face two key limitations. First, many incorporate ICH only as decorative content or limited-time events, rather than embedding craft knowledge and cultural meaning into gameplay systems. Second, heritage education games often rely on static, encyclopedic text, which can weaken immersion and reduce players' motivation to learn about the craft's historical and cultural context. To address this gap, this study explores the educational and experiential impact of an AI-driven "master artist" in a cloisonné serious game, compared with a traditional static-text condition. The design is informed by cognitive apprenticeship and the Stimulus–Organism–Response (S–O–R) framework. Within the game, generative AI functions as a context-sensitive instructor that simulates an apprenticeship process by delivering cloisonné terminology, historical framing, and performance-based guidance during play. A between-subjects pilot study (N = 12, n = 6 per condition) was conducted, supplemented by a domain expert evaluation. Short-term knowledge retention was similar across conditions, but the AI condition produced stronger experiential outcomes—higher perceived social presence, a greater sense of actively learning a craft, and stronger cultural identification with cloisonné—and the domain expert confirmed the cultural authenticity of the AI-generated content. These findings suggest that the value of generative AI in heritage-focused serious games may lie less in immediate content mastery than in its role as an apprenticeship scaffold that enhances engagement, guides learning, and fosters cultural resonance, with implications for AI-supported heritage education, digital craft education, and interactive museum learning.

Keywords: Intangible cultural heritage, Serious game, Cloisonné, Generative AI, Cognitive apprenticeship

1. Introduction

Intangible Cultural Heritage (ICH), as framed by UNESCO's 2003 Convention, comprises the living practices, knowledge, and skills, such as traditional craftsmanship, performing arts, and oral traditions, that communities transmit across generations. Because it is embodied in people and practice rather than in fixed objects, it is lost once its practitioners disappear. Cloisonné (known in Chinese as Jingtai Blue) is a representative craft-based example: a Chinese metalworking art, in which thin copper wires are welded onto a metal body to form compartments that are then filled with colored enamel, fired, polished, and gilded. Its full production sequence runs from design and raw-material preparation through body forming, wire inlaying, enamel filling, firing, polishing, and gilding (Tang, 2004). The craft matured during the Jingtai reign of the Ming dynasty—from which its Chinese name derives—and entered China's first national list of intangible cultural heritage in 2006.

Cloisonné—one of China's Intangible Cultural Heritage (ICH) items—currently faces two primary challenges. First, its dissemination across both geographical space and time is insufficiently rapid in the contemporary digital era (its transmission currently relies predominantly on two forms: oral instruction from master to apprentice, and classroom-based teaching) (Chen, 2016; Tang, 2004). Second, declining interest among the younger generation in learning the craft, coupled with high occupational mobility among artisans, continues to threaten the continuity of its transmission (Ye et al., 2025). Consequently, there is an urgent need to pioneer new, broader, and faster methods of dissemination to attract more enthusiasts and practitioners, thereby facilitating its preservation and transmission.

Given the broad reach and rapid dissemination of games, this study uses a game format to convey the cultural significance and technical knowledge of Cloisonné as authentically and effectively as possible.

A key differentiator distinguishing this study from similar games lies in its leveraging of the latest advancements in Generative AI (GenAI)—specifically, the shift in AI's role from a mere content generator to an instructional agent. This transition aligns precisely with the principles of Cognitive Apprenticeship (Collins, Brown and Newman, 1989). By embedding AI-driven master artisans within a serious game focused on Cloisonné, this research explores both the player experience and the educational efficacy of simulating the traditional master-

apprentice transmission model within a digital gaming environment. Guided by the theoretical frameworks of Cognitive Apprenticeship and the S-O-R framework (Mehrabian and Russell, 1974), this study employs a mixed-methods pilot design to compare conditions involving AI-driven scaffolding against a control condition utilizing static text. Additionally, a domain expert in cloisonné craftsmanship was invited to review the game—with particular attention paid to the quality and accuracy of its generated content.

2. Background and Theoretical Foundations

In recent years, serious games have been widely employed for the dissemination of Intangible Cultural Heritage (ICH). Drawing on Self-Determination and Flow theories operationalized through the MDA framework, Chai-Arayalert and Puttinaovarat (2025) designed a serious game centered on Thailand's textile and handicraft ICH, finding that the game effectively enhanced engagement among Generation Z participants reporting high engagement on the Game Engagement Questionnaire (especially presence and absorption) alongside near-doubled knowledge-test scores, which the authors attribute to authentic cultural content and embodied tasks such as restoring a traditional loom rather than to high-end VR/AR. Furthermore, *The Fifth Great Invention* (2020)—a Chinese game focused on intangible heritage—garnered significant acclaim by transforming traditional Chinese mortise-and-tenon joinery into spatial puzzle-solving gameplay. However, the instructional and educational presentation of knowledge in such games still relies predominantly on static encyclopedic text or pre-scripted narration; consequently, the provision of personalized and contextualized guidance regarding craft techniques currently falls short of players' expectations. Recent studies indicate that players of this genre possess a high demand for cultural information and contextual depth. Ting and Min (2025) found that players of ICH games seek not merely entertainment but also aspire to explore and gain an understanding of the relevant culture and craftsmanship through gameplay. The research of Wang and Men (2025) further substantiated those respecting cultural traditions—and avoiding excessive gamification—exerts a positive influence on users' sense of cultural identity and their willingness to participate. Therefore, the central challenge in the design of ICH-focused serious games remains how to facilitate the authentic and effective transmission of craft knowledge while simultaneously preserving the game's playability.

Concurrently, generative artificial intelligence (AI) has evolved beyond mere dialogue generation to encompass roles such as personalized tutors and conversational instructional agents (Zhai et al., 2025; Bagdonaitė and Dagienė, 2025). Within the realm of gamified learning, developers are increasingly exploring the potential of large language models (LLMs) to serve as in-game characters or instructional guides. Xu et al. (2025) developed a 3D-scenario-based game that leverages generative AI to facilitate vocabulary acquisition, demonstrating that AI-powered conversational characters contribute to a more personalized learning experience. In the specific context of cultural heritage education, Nørtoft et al. (2025) validated the feasibility of embedding LLMs within DIY archaeology video games, illustrating how AI-driven, non-scripted verbal interactions can enrich players' engagement with cultural content. However, existing applications tend to focus primarily on tangible heritage (such as archaeological sites and historical narratives) rather than on intangible cultural heritage (ICH). Furthermore, the role of AI in these projects is typically defined at the level of content delivery or conversational text, rather than at the level of instructional scaffolding. Consequently, this study endeavors to extend the scope of inquiry from tangible heritage to ICH; guided by the theory of Cognitive Apprenticeship, it attempts to shift the role of AI from that of a conversational agent to that of a "Master" (mentor).

This study adopts two complementary theoretical frameworks: Cognitive Apprenticeship and the Stimulus-Organism-Response (S-O-R) model. Cognitive Apprenticeship (Collins, Brown and Newman, 1989; Collins, 2006) originated from traditional craft apprenticeships; it posits that tacit and embodied craft knowledge can be transformed into learnable cognitive processes through six instructional methods: modeling, coaching, scaffolding, articulation, reflection, and exploration. The traditional methods of transmitting cloisonné craftsmanship align closely with this theoretical framework. Moreover, Prawang et al. (2024) have validated the continued relevance of simulation-based learning models grounded in Cognitive Apprenticeship within contemporary educational contexts. The S-O-R framework (Mehrabian and Russell, 1974; Jacoby, 2002) offers a complementary perspective by examining how environmental stimuli within a mediated experience influences a player's response via their internal cognitive and emotional states. This framework has previously been validated within the context of cultural heritage studies; for instance, Jiang et al. (2024), in their research on virtual cultural heritage tourism, identified cultural identity as a key predictor of a player's willingness to engage continuously. Wang and Men (2025) further substantiated the explanatory power of this framework regarding player engagement in ICH-related games. In this study, the two frameworks serve distinct functions: Cognitive Apprenticeship prescribes the specific actions the "AI Master" should undertake (i.e., modeling, coaching, scaffolding, and reflection). Conversely, the S-O-R framework explains how the AI's dynamically generated

content (S), by shaping the player's cognitive and emotional states (O), influences their learning behaviors and cultural engagement (R). Together, the two frameworks position generative AI as a pedagogical scaffold that mediates between craft knowledge and player experience.

3. Game Design and AI Master Instructor

3.1 Game Overview and Craft Workflow

This AI Master Cloisonné simulation game gamifies four core stages of the traditional cloisonné process introduced above: body forming, wire inlaying, enamel filling, and firing. Specifically, body forming is presented as a Quick Time Event rhythm puzzle; wire inlaying as a path-drawing puzzle; enamel filling as a coloring puzzle; and firing as a temperature-control puzzle. Guided by an AI Master or by consulting static encyclopedic text, players complete the levels corresponding to these four craft steps to ultimately create a digital cloisonné artwork. A single playthrough takes approximately 40–60 minutes, with each individual level simulating a duration of about 8–13 minutes.



Figure 1: Overview of the cloisonné serious game

3.2 AI Master Artist: Cognitive Apprenticeship in Practice

Table 1 summarizes the four cognitive apprenticeship instructional methods implemented by the AI Master within the game. Among these, Coaching serves as the AI Master's primary mode of intervention, extending throughout the entire gameplay experience. Scaffolding is dynamically triggered based on score thresholds, thereby embodying the principle of on-demand support. Modeling is activated at the start of the game to assist players in establishing conceptual understanding, in accordance with theoretical frameworks. Reflection is situated at critical junctures marking the conclusion of specific steps. The remaining two methods (Articulation and Exploration) have not yet been implemented in this pilot version and are reserved for future implementation attempts.

Table 1: Overview of AI Master

Method	Trigger Timing	Form of Intervention	Example
Modeling	Game start	The AI Master briefly outlines the cloisonné production process and the expected objectives for the task.	"Today, I want you to cast aside all those restless thoughts; approach this plate with absolute diligence, starting right from the initial shaping of the clay body. To begin with, the thickness must be locked down precisely at..."
Coaching	Throughout each step (every 30s)	Incorporates real-time prompts featuring specialized terminology, dynamically adjusting based on the player's current performance.	The thickness of the copper body should be maintained between 1.2 and 1.5 mm; do not hammer it too thin, otherwise the vessel will deform during firing.
Scaffolding	When step score < 60%	With increased prompting frequency, the AI tutor provides more instructive guidance.	The time interval for triggering hints will be reduced by 10 seconds.
Reflection	End of each step + end of game	A production evaluation based on player performance. Upon completion of the game, the work will undergo an additional comparison against classic cloisonné enamel pieces of a similar genre to identify any shortcomings.	"If I had to say what truly stood out about your work today, it would be your mastery of the clay body—you didn't end up with one of those 'river-drifters' that warp the moment they hit the heat..."

3.3 Technical Implementation

The "AI Master" functionality is primarily implemented via a Python proxy. This proxy captures the player's current progress, score, and dynastic context in real-time. Based on this data, it retrieves relevant entries from a manually curated JSON knowledge base; these entries—combined with a prompt-engineered persona description for the master—are then fed into the Gemini-3-flash-preview model. The generated dialogue is instantly transmitted back to the game's user interface. The knowledge base is structured around four top-level stages of the crafting process, with each stage encompassing four categories: terminology, technical essentials, methods of appreciation, and historical context. The content of the knowledge base was compiled based on Gold and Silver Filigree Craftsmanship and Cloisonné (Tang, 2004)—a seminal monograph in the study of cloisonné—to ensure the accuracy of all cultural and technical information.

3.4 Static-Text Control Condition Design

To enable a qualitative and quantitative comparison of the effectiveness of the in-game "AI Master," we developed a second version of the game. Using "The Fifth Great Invention"—the game mentioned previously—as a template, we replaced all narrative content delivered by the AI Master with a static-text presentation format. Table 2 summarizes the key differences between the two versions. With the exception of the instructional medium and feedback mechanisms, all other game elements were kept consistent to ensure that any observed differences in test results could be attributed, to the greatest extent possible, to the instructional approach itself. The presentation format for the static text adhered to the conventions established in The Fifth Great Invention (2020), thereby ensuring alignment with current mainstream practices in the field of ICH-themed serious games.

Table 2: Comparison of AI Version vs. Fixed-text Version Overview

Dimension	AI Master Condition	Static-Text Condition
Game mechanics (4 craft puzzles)	Identical	Identical
Visual presentation	Identical	Identical
Difficulty and scoring	Identical	Identical
Knowledge source	Curated JSON Knowledge Base (Based on Professional Literature)	4 Fixed Encyclopedic Text Segments (Based on the Same Specialized Book)
Pedagogical method	Cognitive apprenticeship -based (Modeling, Coaching, Scaffolding, Reflection)	Encyclopedia Entry (Referencing "The Fifth Great Invention")
Trigger timing	Continuous, performance-adaptive (~every 30 s)	Fixed, at start of each step only
Length per intervention	40–60 words, dynamically generated	About 80 words, pre-written
Post-step feedback	Performance-Based Assessment	Only provide the score.

4. Method

The game testing was conducted in February 2026, involving a total of 12 participants aged 21 to 30 (comprising a control group and an experimental group, with 6 individuals in each); participation was entirely voluntary and based on informed consent. Given that the game's primary objective is to disseminate the culture of traditional Chinese craftsmanship among a younger demographic, most of the subjects were recruited from a single art and design institution in the United States. The participants were randomly assigned to either an AI-assisted instruction group (n=6) or a static-text control group (n=6). We observed the subjects' complete interaction processes and collected questionnaire data via pre-tests and post-tests to assess the educational impact and effectiveness of the game. Additionally, brief semi-structured interviews were conducted with the 6 subjects in the AI-assisted instruction group to gain insight into the players' perceptions of the "AI Master" and their attitudes toward learning.

The entire testing process is divided into three stages: (1) Pre-test (~10 minutes): Participants in both groups complete a questionnaire covering their knowledge of Cloisonné, gaming experience, interest in Intangible Cultural Heritage (ICH), and attitudes toward AI-assisted learning; (2) Gaming Session (~40 minutes): Participants, assigned to groups randomly, play their respective versions of the game while verbally narrating their operational experiences using a "think-aloud" protocol, with the entire session being audio-recorded; (3) Post-test (~10–15 minutes): Participants in both groups complete a knowledge test, a Social Presence Scale, and a Learning Experience Scale; additionally, the experimental group undergoes a semi-structured interview (consisting of three questions) regarding the "AI Master."

The knowledge test consists of four multiple-choice questions covering four core themes—body forming, wire inlaying, firing, and connoisseurship—with both questions and answers drawn from the monograph Gold and Silver Filigree Craftsmanship and Cloisonné (Tang, 2004). Identical questions were used in the pre-test and post-test; each correct answer scored one point (0 to 4 total). The Social Presence Scale was adapted from Biocca et al. (2003) and comprises seven items—covering the perceived presence of the master, personalization of feedback, the facilitative role of feedback, preference for qualitative evaluation, narrative engagement, the sense of accomplishment from the concluding remarks, and overall attitude toward the virtual apprenticeship system—on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree), with good internal consistency (Cronbach's $\alpha = .88$). The Learning Experience Scale, custom-developed for this study, consists of seven items on a 4-point Likert scale (1 = Low, 4 = High) across four dimensions: subjective knowledge growth, helpfulness of feedback, willingness to continue learning, and willingness to explore further. Semi-structured interviews with the AI group centered on three questions: overall impressions of the AI master, whether the feedback influenced learning engagement, and suggestions for future AI-driven educational games.

Quantitative data were analyzed using JASP; however, given the small sample size of the pilot study ($n = 6$ per group), the results should be interpreted with caution. Considering this limitation, this study invited a domain expert in Cloisonné craftsmanship with extensive professional and educational experience in the field to evaluate the game. After fully experiencing the "AI Master" version of the game, the expert provided an assessment through a combination of semi-structured interviews and multi-dimensional Likert-scale ratings. The evaluation focused primarily on four aspects: (1) The accuracy of the gamified representation of the craft. (2) The potential for instruction and cultural dissemination. (3) The plausibility and cultural authenticity of the AI-generated content. (4) Suggestions for Improvement and Extended Applications

5. Preliminary Findings

Table 3 presents the scores of the two groups on the knowledge component of both the pre-test and post-test. The pre-test scores for both groups were close to zero ($M_{AI} = 0.50$; $M_{Control} = 0.00$), indicating that the participants possessed limited knowledge regarding the cloisonné craft prior to the game. In the post-test, both groups demonstrated an increase in knowledge, with only a minor difference between the groups ($M_{AI} = 2.17$, $SD = 0.98$; $M_{Control} = 2.33$, $SD = 1.03$). This result suggests that—given identical game mechanics, visual presentation, and knowledge sources—an "AI Master," when regulated by a knowledge base and instructional framework, can facilitate a level of knowledge acquisition comparable to that of a static text-based instructional medium.

Table 3: Knowledge Test Descriptive Statistics by Group

	Group	N	Mean	SD	SE
Total knowledge (pre-test)	AI	6	0.500	0.837	0.342
	Control	6	0.000	0.000	0.000
Total knowledge (post-test)	AI	6	2.167	0.983	0.401
	Control	6	2.333	1.033	0.422

In terms of experiential metrics, the AI Master group scored higher than the Static Text group across three dimensions: perceived social presence, learning experience, and cultural identity (Figure 2). Observations of the participants corroborated this finding. Most players in the Static Text group—unaware that the informational text could not be skipped—repeatedly clicked their mice to bypass the text, relying on their habitual gaming behaviors. In contrast, players in the AI group generally chose to pause and actively read the feedback provided

by the AI Master. This disparity was echoed in the scale data (Figure 2): the AI group achieved higher scores than the control group on two specific items "the extent to which the Master's feedback facilitates learning" and "attitudes toward the virtual mentorship system"—with the most significant difference observed in the dimension of cultural identity.

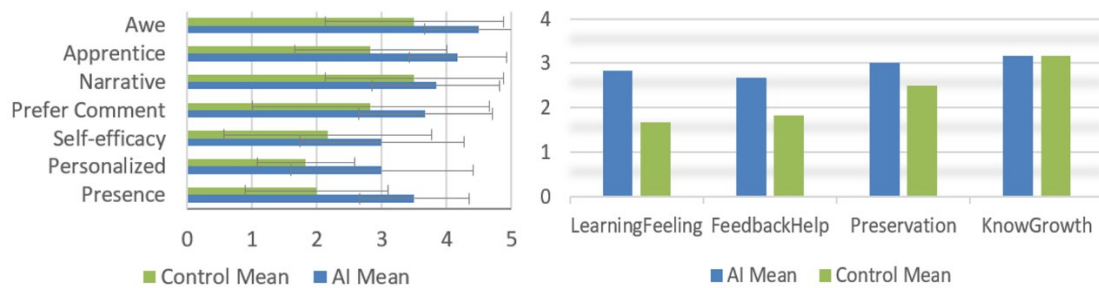


Figure 2: Results of the Social Presence Scale and Learning Experience Scale

Think-aloud protocols and interview data provided further support for these findings. One participant in the AI group remarked, "I can sense that the AI Master adjusts its attitude based on my actions," a sentiment that directly corresponds to an enhanced sense of perceived presence. Another participant stated, "I prefer reading professional jargon rather than general explanatory text," reflecting how dynamic, contextualized feedback is more effective than static encyclopedic text in sustaining a sense of cultural immersion. Additionally, some participants suggested that they "would like a more concrete avatar for the Master," pointing toward a future direction for improvement involving the visual concretization of the AI Master's persona.

Professor Shen provided a positive evaluation of the "AI Master" version of the game across four core dimensions (refer to Figure 3 for specific Likert scale ratings). The expert explicitly affirmed the technical accuracy of the content generated in real-time by the AI Master: "The snippets of technical terminology observed so far are accurate." This assessment validates the study's design strategy, which employs a manually curated knowledge base to govern the generative output.

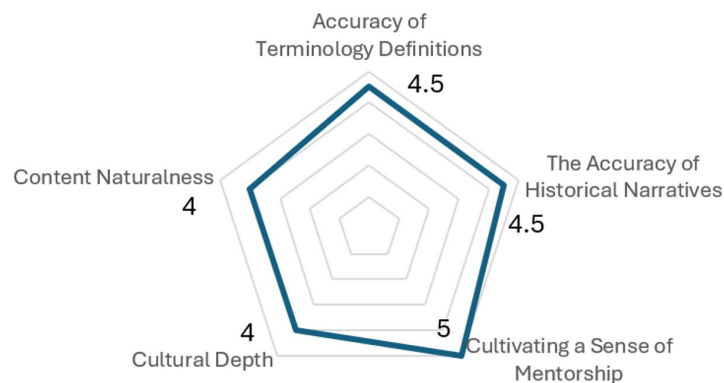


Figure 3: Professor Shen's Multi-Dimensional Likert-Scale Evaluation of AI Master's Performance

When comparing the two instructional media, the AI Master and static encyclopedic text, the expert's assessment corroborated the experiential data collected in this study. The expert noted: "The AI Master is more effective; static explanatory text is easily overlooked or skipped by players, whereas the guidance provided by the AI Master is far more successful at satisfying players' curiosity." This observation aligns closely with the player behavioral patterns observed during the pilot testing (where the static group repeatedly clicked to skip the content, while the AI group actively paused to read it).

At the same time, the expert pointed out that the current AI Master remains deficient in the "Modeling" dimension: "A real-world master provides operational demonstrations and offers critiques. In the game segment presented here, the critique is present, but the operational demonstration is missing." The expert recommended that future iterations incorporate visual operational demonstrations to more fully realize the "Modeling" component of the Cognitive Apprenticeship framework.

6. Discussion and Conclusion

Through a between-subjects pilot study, this research investigated whether an "AI Master" instructional approach—theoretically grounded in cognitive apprenticeship—within a cloisonné-themed serious game could yield distinctively more vivid learning outcomes and experiences compared to static encyclopedic text. Synthesizing quantitative data, observations of player behavior, and expert evaluations, the study revealed that while the educational efficacy of the AI Master and static encyclopedic text differed negligibly regarding short-term factual knowledge acquisition, the AI Master-guided condition significantly outperformed the static text condition across various experiential metrics (perceived social presence, learning engagement, and cultural identity).

This finding can be interpreted through two lenses. At the knowledge level, the minimal difference in instructional efficacy between the AI Master and static text likely stems from a cognitive-load trade-off between the two media. The static-text group received roughly 80 words of dense encyclopedic content per step—high in information density but low in frequency—whereas the AI group received dynamic 40–60-word prompts every 30 seconds, whose greater cumulative volume required players to divide attention between reading and gameplay. As one AI-group participant noted, "The text updates quite rapidly, making it difficult to notice the annotations tucked away in the corner." At the experiential level, the AI Master's advantage is more readily explained through cognitive apprenticeship: its performance-adaptive modeling, coaching, scaffolding, and reflection provided a quality of mentor-apprentice interaction that static text cannot replicate. This aligns with Wouters et al. (2013), whose meta-analysis of serious games found that when content coverage and gameplay structure are held constant, the critical difference often lies not in what learners know but in how they feel about it and their willingness to remain engaged. Most importantly, the AI group's superior outcomes in cultural identity offer a concrete mechanism for the open question posed by Wang and Men (2025)—how the vividness and interactivity of ICH games can enhance cultural appreciation: by deploying generative AI as an instructional agent within a cognitive apprenticeship framework.

This study contributes in three key areas. Theoretically, it extends cognitive apprenticeship—traditionally applied in classroom and simulation-based training—to AI-driven learning for Intangible Cultural Heritage (ICH), validating the feasibility of embedding its core components (modeling, coaching, scaffolding, and reflection) into the output mechanisms of Large Language Models (LLMs); using the Stimulus-Organism-Response (S-O-R) framework, it further clarifies the pathways through which this pedagogical medium shapes players' experiential outcomes. Methodologically, it demonstrates a practical approach for grounding generative AI outputs in a manually curated, domain-specific knowledge base, enabling dynamic, contextualized feedback while maintaining the accuracy of cultural and technical content (as verified by domain experts)—a reusable design strategy for future ICH research concerned with the authenticity of AI-generated content. Practically, the findings guide designers of AI-assisted serious games, curators of interactive museum learning programs, and developers of digital craft education: in AI-driven cultural education, the primary value may lie not in accelerating immediate knowledge acquisition but in fostering deeper engagement and strengthening cultural identity through the contextualized, mentorship-like companionship the AI provides.

This study has several limitations. First, the sample is small and drawn predominantly from a single institution ($N = 12$; most participants were recruited from one art and design institution in the United States), a pool likely more artistically sensitive and receptive to ICH than the general youth population, which may limit generalizability. Second, both knowledge and experiential outcomes were assessed immediately after the game, so the long-term efficacy of the AI Master approach for knowledge retention and sustained engagement remains unknown. Finally, the knowledge base was curated specifically for cloisonné; extending the framework to other ICH forms—such as performing arts or oral traditions—would require re-validating both the knowledge base and the framework's pedagogical effectiveness in those contexts.

Future work will address these limitations through larger and more diverse samples, delayed post-tests, and the extension of this knowledge-base-grounded framework to other ICH domains.

Ethics Declaration: This study followed institutional ethical guidelines, formal ethics was not required. All participants provided informed consent, no sensitive data were collected during the process.

AI Declaration: In this study, the real-time text generated by the AI master (the research subject) was achieved using Gemini3-flash-preview. The content of this article was written entirely by the author. Upon completion, Claude was used to assist with language polishing and grammar checking.

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