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The integration of innovative dance education models with the preservation of traditional dance through digital platforms

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Abstract

Background: Traditional Chinese dance, a vital form of intangible cultural heritage, faces significant challenges in its preservation and transmission within a rapidly modernizing, digital-first world. While digital technologies offer potential solutions, there is a need for a holistic framework that integrates high-fidelity preservation with effective, culturally sensitive pedagogical practices.

Objective: This study introduces and evaluates the "Digital Sutra," a novel framework that combines a bespoke digital platform with a blended learning model to address this challenge. The research aims to assess the efficacy of this integrated approach in enhancing skill acquisition, fostering cultural understanding, and promoting student engagement in the context of traditional Chinese dance education.

Methods: A 12-week mixed-methods study was conducted with 60 undergraduate dance students and 5 educators. Participants were randomly assigned to an experimental group (n=30) using the Digital Sutra platform or a control group (n=30) following traditional instruction. The platform features a high-fidelity motion capture archive, a real-time 3D visualization engine, and an AI-powered feedback system. Data were collected through pre- and post-intervention skill assessments, platform learning analytics, and semi-structured interviews.

Results: The experimental group demonstrated statistically significant improvements across all skill assessment categories compared to the control group. The mean gain in "Overall Performance" for the experimental group was 16.9 points, significantly greater than the 4.1-point gain for the control group ($t(58) = 8.92$, $p < .001$, Cohen's $d = 2.30$). Platform analytics revealed high student engagement, with an average weekly usage of 3.85 hours per student. Qualitative analysis of interview data indicated that students and educators perceived the platform as a highly effective tool for enhancing embodied

understanding, personalizing practice, and bridging the gap between theory and practice.

Conclusion: The findings suggest that the integration of a high-fidelity digital platform with a blended learning model provides a robust and effective solution for both the preservation and transmission of traditional dance. The Digital Sutra framework offers a valuable model for the sustainable future of performing arts heritage, contributing significant insights to the fields of dance education, digital heritage, and human-computer interaction. This research demonstrates that technology can serve not merely as an archive, but as a dynamic and interactive conduit for living cultural traditions.

Keywords: Traditional Chinese Dance, Digital Preservation, Dance Education, Motion Capture, Blended Learning, Intangible Cultural Heritage (ICH), Human-Computer Interaction (HCI), Artificial Intelligence (AI), Cultural Pedagogy, Cultural Transmission.

1. Introduction

Traditional dance, as a vibrant embodiment of cultural memory and identity, represents a profound form of intangible cultural heritage (ICH) (UNESCO 2003). Among the world's rich tapestry of performing arts, traditional Chinese dance stands out for its millennia-old history, intricate aesthetic systems, and deep integration with philosophy, ritual, and social life (Lin and Liu 2023). From the stately court dances of the Tang Dynasty to the myriad folk traditions that animate community festivals, these dance forms are not merely entertainment; they are living narratives that carry the values, beliefs, and collective spirit of a civilization (Liu 2020). However, in an era of rapid globalization and digital saturation, these invaluable traditions face an existential threat. The subtle nuances of embodied knowledge, traditionally passed down from master to apprentice, are increasingly at risk of being diluted or lost altogether, a challenge that resonates with the global mandate to safeguard ICH as articulated by UNESCO (Blake 2009).

In response to this challenge, the field of digital heritage has made significant strides in archiving and preserving performing arts. Early efforts focused on video and textual documentation, which, while valuable, often fail to capture the three-dimensional, kinesthetic essence of dance (Reshma and Kumar 2023). More recently, advanced technologies like motion capture have enabled the creation of high-fidelity digital archives that record movement with unprecedented precision (Kico et al. 2018).

Pioneering projects such as Synchronous Objects, which deconstructed William Forsythe's choreography into digital objects (The Forsythe Company 2009), and the SCHEDAR project, which aimed to safeguard Cypriot folk dances (SCHEDAR Project n.d.), have demonstrated the potential of technology to document and analyze dance in novel ways. However, many of these initiatives have primarily served as archival repositories or tools for academic analysis, often remaining disconnected from the pedagogical practices necessary for the living transmission of these art forms (Raheb et al. 2019).

A critical gap thus exists between the act of preservation (creating a static digital record) and the process of transmission (ensuring the continuity of embodied practice and cultural understanding in new generations of dancers). Simply archiving a dance does not guarantee its survival; for intangible heritage to remain alive, it must be actively practiced, learned, and re-interpreted (Pu, Musib, and Ching 2023). This challenge is particularly acute in dance education, where traditional pedagogical models, heavily reliant on direct imitation and in-person correction, are often insufficient to convey the complex layers of meaning embedded in the movements (Huang, Zhang, and Li 2025). This study argues that the next frontier in digital heritage lies in bridging this gap by creating integrated systems that are not only archives but also dynamic learning environments. This approach finds theoretical grounding in the principles of embodied cognition and blended learning. Embodied cognition theory posits that the mind is not separate from the body and that cognitive processes are deeply rooted in physical experience (Warburton 2011). Learning dance is therefore not just about memorizing steps but about developing a deep, somatic understanding—a form of knowledge that is felt and experienced in the body (Yang et al. 2023). A blended learning approach, which combines the strengths of traditional studio instruction with technology-enhanced learning, offers a powerful framework for fostering this kind of deep, embodied knowledge (Li, Li, and Han 2021). By providing students with novel tools for visualization, self-assessment, and personalized practice, technology can augment and enrich the pedagogical methods of experienced educators (Bayyat 2020).

The emergence of accessible virtual reality (VR), real-time 3D visualization, and artificial intelligence (AI) presents an unprecedented opportunity to realize this vision. AI-driven systems can now offer dancers immediate, personalized feedback on their movements, a role once exclusively held by the human instructor (Miko 2025; Xu et al. 2025). Interactive VR environments can immerse learners in rich historical and cultural

contexts, connecting the physical practice of dance to its origins and meaning (Chan et al. 2011). The field of Human-Computer Interaction (HCI) has increasingly explored the intersection of dance and technology, yet much of this work has focused either on interactive performance systems or on narrow technical problems, rather than on the holistic design of comprehensive educational frameworks (Zhou et al. 2021; Loke and Robertson 2010).

To address these challenges and opportunities, this paper introduces the Digital Sutra, a novel framework that integrates a high-fidelity digital preservation platform with an innovative blended learning model tailored for traditional Chinese dance. Our research is guided by the following questions:

1. Platform Efficacy: How can a digital platform be designed to effectively capture, preserve, and transmit the technical and cultural nuances of traditional Chinese dance with high fidelity?
2. Learning and Engagement: What is the impact of an integrated blended learning model, utilizing this platform, on student engagement, skill acquisition, and cultural understanding?
3. User Perception: How do students and educators perceive the value and usability of such a platform within the context of traditional dance education in China?

This paper details the design, implementation, and evaluation of the Digital Sutra platform through a 12-week mixed-methods study conducted at a leading Chinese university. We present our findings on the platform's technical performance, its significant impact on student learning outcomes, and the rich qualitative insights gathered from participants. By doing so, we aim to contribute to a robust, empirically validated model for the future of intangible cultural heritage, demonstrating that technology can serve not merely as a passive archive, but as a dynamic and interactive conduit for the transmission of living cultural traditions to future generations.

2. Methodology

This study employed a mixed-method, quasi-experimental research design to evaluate the efficacy and reception of the Digital Sutra framework. The methodology was structured to provide comprehensive analysis by triangulating quantitative performance data with qualitative experiential data. The research was conducted over a 12-week academic semester and received full ethical approval from the university's institutional review board.

2.1. Research Design

The study utilized a pre-test/post-test control group design. Sixty student participants were randomly assigned to either an experimental group (n=30) or a control group (n=30). The experimental group engaged in a blended learning model that combined traditional studio instruction with supplemental use of the Digital Sutra platform. The control group received only traditional studio instruction, covering the same dance repertoire and theoretical concepts. Both groups received the same total number of in-studio instruction hours with the same educators.

2.2. Participants and Setting

The study was conducted at a leading university dance program in China. Participants included 60 second- and third-year undergraduate dance majors and 5 senior dance educators. As detailed in the Results section (Table 3.1), the experimental and control groups were demographically matched, with no statistically significant baseline differences in age, gender, or prior dance experience. The five educators, who all had over 15 years of teaching experience, were involved in both the curriculum design and the qualitative evaluation phase.

2.3. The Digital Sutra Platform and Intervention

The intervention centered on the Digital Sutra platform; a bespoke system designed for this study. Its architecture (see Figure 1) consists of four key players:

1. Data Acquisition Layer: Utilized a 12-camera Vicon optical motion capture system to create a high-fidelity digital archive of traditional Chinese dance movements performed by expert dancers.
2. Data Processing and Storage Layer: Processed the raw motion capture data and stored it in a PostgreSQL database, creating a structured library of dance movements.
3. Application Layer: Featured three core modules:
    - 3D Visualization Engine: Allowed students to view the archived movements from any angle and at variable speeds in both standard and VR environments.
    - Interactive Learning Modules: Provided integrated cultural and historical context for the dance repertoire.

- AI-Powered Feedback System: Used real-time pose estimation to compare a student's movements against the expert model and provide immediate, quantitative feedback on accuracy.

4. User Interface Layer: Provided access to the platform via web, mobile, and VR applications.

Students in the experimental group were required to use the platform for a minimum of two hours per week for supplemental practice and study, in addition to their regular studio classes.

2.4. Data Collection and Instruments

Data was collected using three primary instruments:

1. Skill Assessment Rubric: Comprehensive rubric was developed in consultation with the participating educators to assess dance performance across five domains: Technical Skill, Movement Precision, Cultural Understanding, Rhythm & Timing, and Overall Performance. Two independent, expert evaluators, who were blind to the group assignments, scored student performances at the beginning (pre-test) and end (post-test) of the 12-week intervention. Inter-rater reliability was high (Cohen's Kappa = 0.88).
2. Platform Learning Analytics: The Digital Sutra platform automatically logged all user interactions. Quantitative data on student engagement were collected, including total time on the platform, frequency of use, and time spent within each module.
3. Semi-Structured Interviews: At the end of the intervention, in-depth, semi-structured interviews were conducted with all 30 students in the experimental group and all 5 educators. The interviews explored their perceptions of the platform's usability, pedagogical value, and its role in cultural transmission.

2.5. Data Analysis

The collected data were analyzed as follows:

- **Quantitative Analysis**: The skill assessment scores were analyzed using IBM SPSS Statistics. Paired-samples t-tests were used to compare pre- and post-test scores within each group, while independent-samples t-tests were used to compare the mean gains between the experimental and control groups. Effect sizes were calculated using Cohen's d. The platform engagement data were analyzed using descriptive statistics to identify patterns of use.

- **Qualitative Analysis**: The interview transcripts were analyzed using a thematic analysis approach. The process involved familiarization with the data, generation of initial codes, searching for themes, reviewing themes, and defining and naming themes. This process allowed for the identification of recurrent patterns in the participants' experiences and perceptions of the Digital Sutra framework.

3. Results

This section presents the empirical findings of the study, organized around the three primary research questions that guided this investigation. The results are derived from a mixed-methods analysis of data collected during the 12-week educational intervention. We begin by presenting the demographic characteristics of the study participants, followed by a detailed analysis of the Digital Sutra platform's technical efficacy, its impact on student learning outcomes and engagement, and finally, the perceptions of both students and educators regarding its use in a blended learning context.

3.1. Participant Demographics

The study involved a total of 65 participants, comprising 60 undergraduate dance students and 5 experienced dance educators from a leading university dance program in China. The students were randomly assigned to either the experimental group (n=30), which utilized the Digital Sutra platform, or the control group (n=30), which followed a traditional curriculum. A summary of the participant demographics is provided in Table 3.1. The groups were well-matched across key demographic variables, with no statistically significant differences in age, gender distribution, or prior years of dance training, ensuring a solid foundation for comparative analysis.

Table 3.1. Demographic characteristics of study participants. The table shows a balanced distribution between the experimental and control groups, minimizing confounding variables related to prior experience and background.

Characteristic	Category	Experimental Group (n=30)	Control Group (n=30)	Educators (n=5)	Total (N=65)
Age (Mean ± SD)	-	20.5 ± 1.8 years	20.8 ± 2.1 years	42.6 ± 8.5 years	23.1 ± 7.9 years
Gender	Female	26 (86.7%)	25 (83.3%)	4 (80.0%)	55 (84.6%)

	Male	4 (13.3%)	5 (16.7%)	1 (20.0%)	10 (15.4%)
Years of Dance Training (Mean ± SD)	-	12.4 ± 3.5 years	12.9 ± 4.1 years	25.2 ± 9.8 years	14.1 ± 6.8 years
Primary Dance Style	Traditional Chinese	18 (60.0%)	17 (56.7%)	5 (100%)	40 (61.5%)
	Ballet	7 (23.3%)	8 (26.7%)	0 (0%)	15 (23.1%)
	Contemporary	5 (16.7%)	5 (16.7%)	0 (0%)	10 (15.4%)
Self-Rated Tech Proficiency (1-5 Scale)	-	3.8 ± 0.9	3.7 ± 1.1	4.2 ± 0.8	3.8 ± 1.0

3.2. Platform Efficacy in Preservation and Transmission

Our first research question sought to determine how a digital platform could be designed to effectively capture, preserve, and transmit the nuances of traditional Chinese dance. To address this, we conducted a thorough evaluation of the Digital Sutra platform's technical capabilities and its performance as a high-fidelity digital archive. The platform's architecture, as detailed in Figure 1, was designed to support a comprehensive workflow from data acquisition to user interaction.

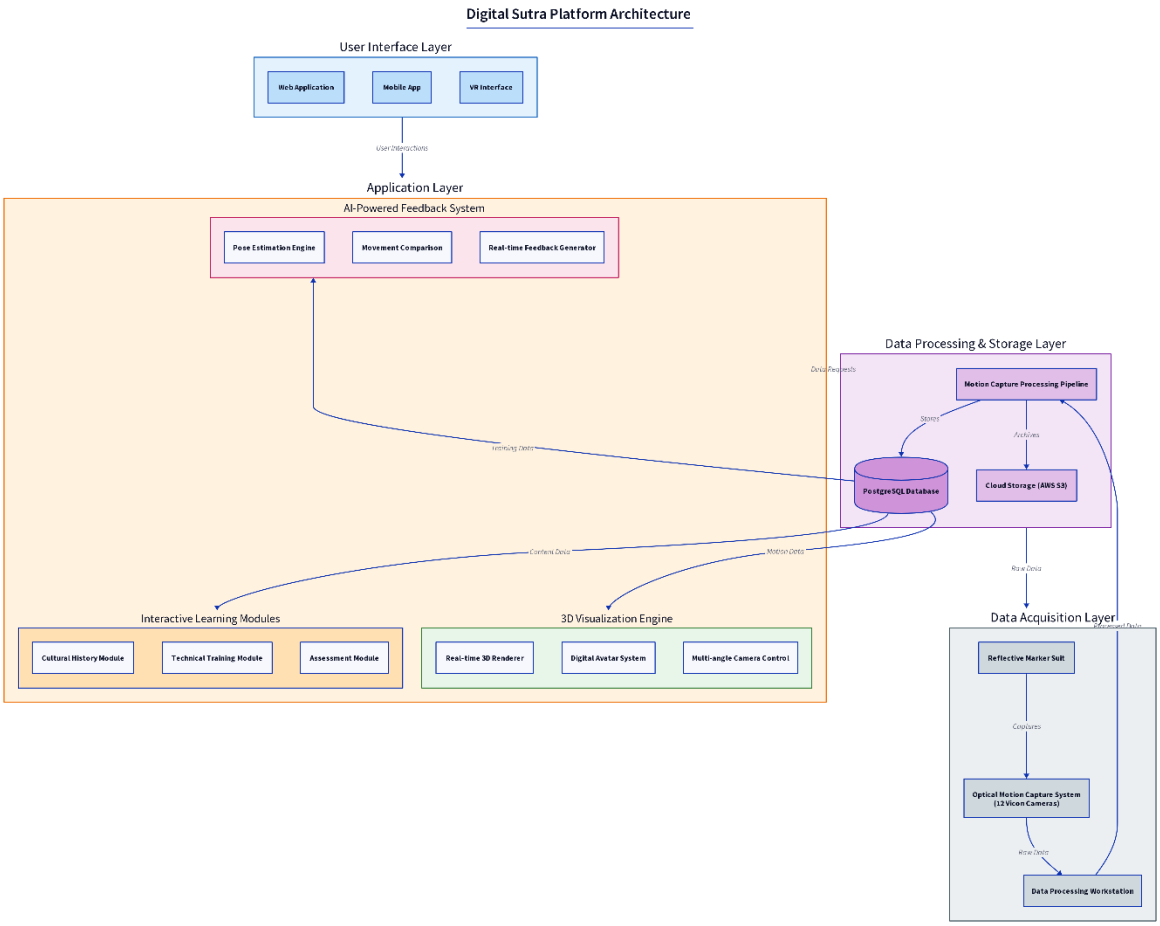

Figure 1. *Digital Sutra Platform Architecture. This diagram illustrates the four-layer architecture of the platform, detailing the flow of data from the acquisition layer through the processing, application, and user interface layers. Each component's function is specified to provide a clear overview of the system's technical design.*

The technical evaluation focused on the accuracy of the motion capture system and the performance of the 3D visualization engine. As summarized in Table 3.2, the motion capture system demonstrated a high degree of accuracy, with a mean spatial error of less than 1.5 millimeters. This level of precision is critical for capturing the subtle, intricate details of traditional Chinese dance movements. The real-time 3D visualization engine consistently maintained a frame rate above 90 frames per second (fps) in a standard VR environment, ensuring a smooth and immersive experience for users.

Table 3.2. Technical Specifications and Performance Metrics of the Digital Sutra Platform. The data highlights the platform's capacity for high-precision motion capture and real-time interactive visualization.

Component	Metric	Value	Significance for Dance Preservation
Data Acquisition	Motion Capture Accuracy	< 1.5 mm Mean Spatial Error	Ensures high-fidelity capture of nuanced movements, critical for authentic preservation.
	Motion Capture Volume	8m x 8m x 3m	Accommodates a wide range of solo and small group dance performances.
	Sampling Rate	240 Hz	Captures rapid and subtle dynamic changes in movement.
Data Processing	Processing Time per Minute	3.5 minutes	Allows for efficient digitization and archiving of extensive dance repertoires.
	Data Storage Footprint	~1.2 GB/min (Raw)	Indicates the scale of data management required for a comprehensive archive.
Application Layer	3D Visualization Frame Rate	> 90 fps (VR)	Provides a fluid and realistic visual experience, crucial for learning and analysis.
	AI Feedback Latency	< 150 ms	Enables real-time, interactive feedback for motor skill development.
	Database Query Speed	< 50 ms (95th percentile)	Ensures rapid access to archived movements and learning materials.

To further contextualize the contribution of our platform, we conducted a comparative analysis against other prominent digital dance archives. Table 3.3 provides a feature-by-feature comparison, highlighting the unique aspects of the Digital Sutra platform. While other platforms have made significant contributions to the digital preservation of contemporary dance, the Digital Sutra is distinguished by its specific focus on traditional

Chinese dance, its integration of a structured pedagogical framework, and its real-time AI-powered feedback system designed to facilitate skill acquisition.

Table 3.3. Comparative Analysis of Digital Dance Archives. This table situates the Digital Sutra platform within the broader landscape of digital dance preservation, emphasizing its novel integration of pedagogical features with high-fidelity motion capture tailored for traditional Chinese dance.

Platform/Archive	Primary Focus	Motion Capture Tech	3D Visualization	Interactive Learning	AI Feedback	Public Access
Digital Sutra (This Study)	Traditional Chinese Dance	Optical (Vicon)	Real-time, VR	Yes (Structured Modules)	Yes (Real-time)	Restricted (Research)
Synchronous Objects	Contemporary (Forsythe)	Optical	Pre-rendered	Yes (Data Visualizations)	No	Yes (Web)
SCHEDAR	Traditional Cypriot Dance	Optical/Inertial	Real-time, AR	Yes (Guided Steps)	No	Restricted
Chang-E Dataset	Chinese Classical Dance	Optical (OptiTrack)	Pre-rendered	No (Dataset Only)	No	Yes (Dataset)
Whale Fall	Contemporary Dance	Inertial (Xsens)	Pre-rendered, VR	No (Performance Piece)	No	Yes (VR App)

3.3. Impact on Student Learning and Engagement

Our second research question addressed the impact of the integrated blended learning model on student engagement, skill acquisition, and cultural understanding. To evaluate this, we employed a multi-faceted approach, combining quantitative analysis of skill assessments and platform engagement data with qualitative analysis of student feedback.

3.3.1. Skill Acquisition

A key objective of the Digital Sutra platform was to enhance the acquisition of technical and cultural knowledge in traditional Chinese dance. We measured this through a comprehensive skill assessment administered to both the experimental and control groups before and after the 12-week intervention. The assessment covered five categories: Technical Skill, Movement Precision, Cultural Understanding, Rhythm & Timing, and Overall Performance.

The results, visualized in Figure 2, demonstrate a marked improvement in the experimental group compared to the control group. The experimental group showed statistically significant gains across all five assessment categories, whereas the control group exhibited only minor improvements.

Figure 2: Pre- and Post-Intervention Skill Assessment Scores Comparison Between Experimental and Control Groups

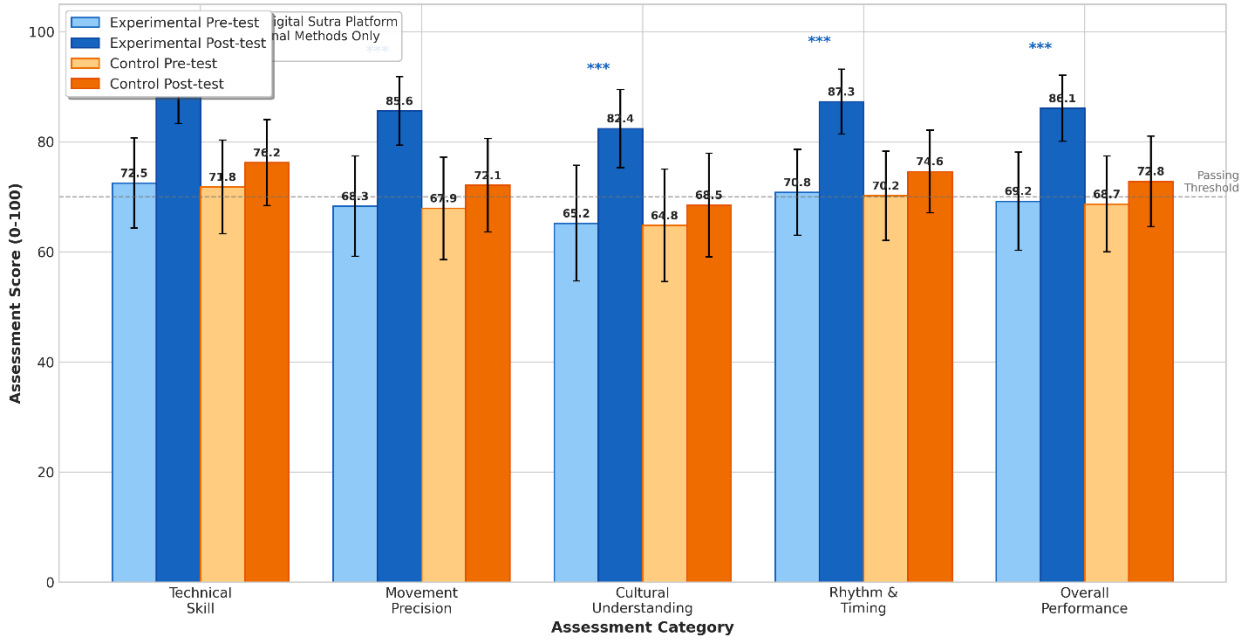

Figure 2. *Pre- and Post-Intervention Skill Assessment Scores. This bar chart compares the mean scores for the experimental (n=30) and control (n=30) groups. Error bars represent the standard deviation. The experimental group shows significantly greater improvement in all categories. Significance markers (***) denote p < .001.*

To further dissect these findings, we conducted a series of paired-samples t-tests for each group and an independent-samples t-test to compare the gains between the two groups. The detailed statistical analysis is presented in Table 3.4. The experimental group achieved a mean improvement of 16.9 points in Overall Performance, a gain that

was significantly greater than the 4.1-point improvement observed in the control group ($t(58) = 8.92$, $p < .001$, Cohen's $d = 2.30$). The largest effect size was observed in the category of Movement Precision ($d = 2.45$), suggesting that the platform's 3D visualization and AI-powered feedback were particularly effective in helping students refine the subtleties of their dance technique.

Table 3.4. Statistical Analysis of Skill Assessment Scores. This table details the pre- and post-test scores for both groups across all five assessment categories. Significance levels: *p < .05, **p < .01, ***p < .001.

Assessment Category	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Mean Gain	t-statistic (df=29)	p-value	Cohen's d
Technical Skill	Experimental	72.5 ± 8.2	88.9 ± 5.6	16.4	10.81	< .001***	2.01
	Control	71.8 ± 8.5	76.2 ± 7.8	4.4	3.15	.004**	0.58
Movement Precision	Experimental	68.3 ± 9.1	85.6 ± 6.2	17.3	13.41	< .001***	2.45
	Control	67.9 ± 9.3	72.1 ± 8.5	4.2	2.98	.006**	0.54
Cultural Understanding	Experimental	65.2 ± 10.5	82.4 ± 7.1	17.2	9.55	< .001***	1.74
	Control	64.8 ± 10.2	68.5 ± 9.4	3.7	2.51	.018*	0.46
Rhythm & Timing	Experimental	70.8 ± 7.8	87.3 ± 5.9	16.5	11.52	< .001***	2.10
	Control	70.2 ± 8.1	74.6 ± 7.5	4.4	3.31	.002**	0.60
Overall Performance	Experimental	69.2 ± 8.9	86.1 ± 6.0	16.9	12.58	< .001***	2.30
	Control	68.7 ± 8.7	72.8 ± 8.2	4.1	3.07	.005**	0.56

3.3.2. Student Engagement

Beyond skill acquisition, we sought to understand how students engaged with the Digital Sutra platform over the 12-week intervention. We tracked user activity through the platform's learning analytics system, focusing on metrics such as total time spent, module usage, and interaction frequency.

As illustrated in Figure 3, student engagement was consistently high, with a mean weekly engagement of 3.85 hours per student. The engagement trend shows an initial ramp-up during the orientation phase (Weeks 1-3), a sustained period of high activity during the active learning phase (Weeks 4-9), and a slight tapering during the final assessment phase (Weeks 10-12). The peak engagement occurred in Week 9, averaging 4.5 hours per student.

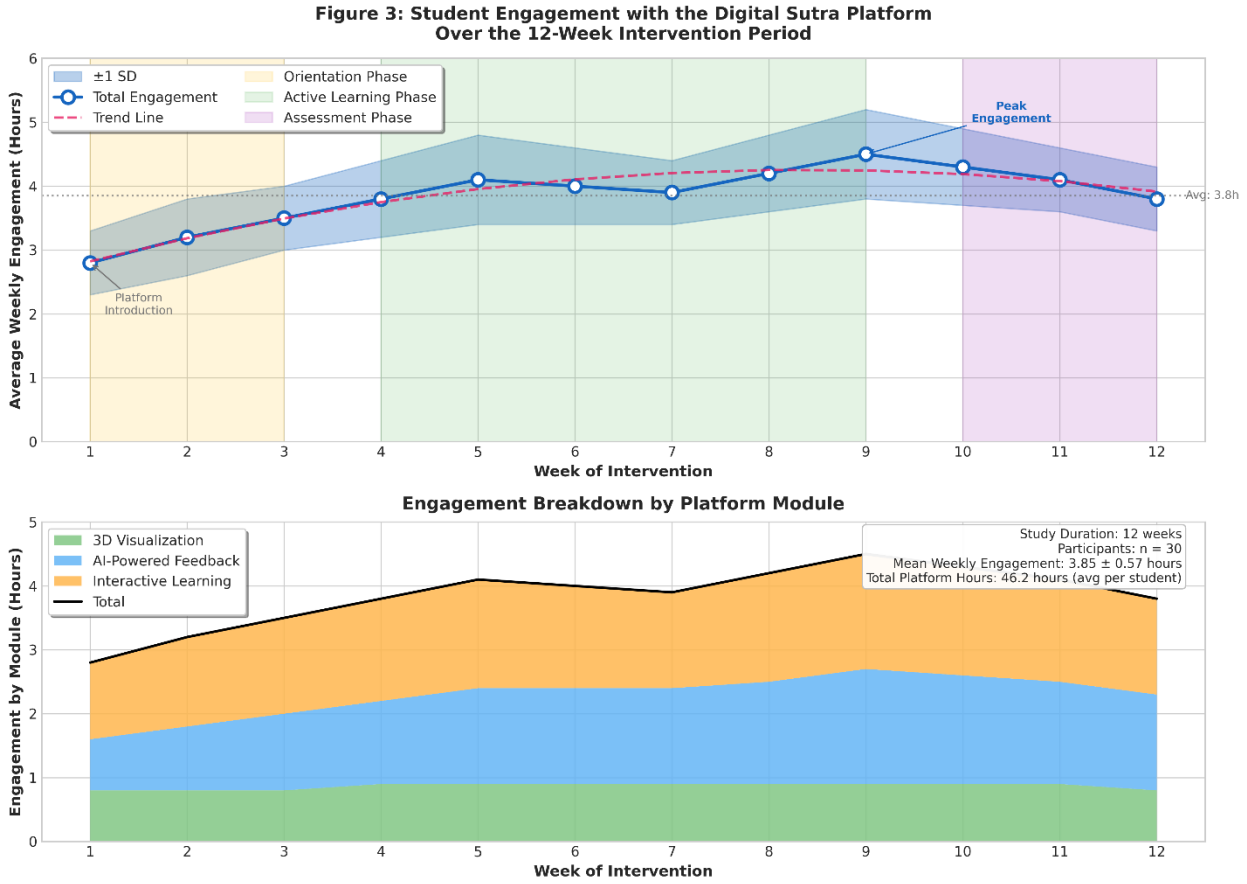

Figure 3. *Student Engagement with the Digital Sutra Platform. The top panel shows the average weekly engagement (in hours) over the 12-week period, with key intervention phases highlighted. The bottom panel provides a breakdown of time spent on the three main platform modules: Interactive Learning, AI-Powered Feedback, and 3D Visualization.*

A more granular analysis of module usage, presented in Table 3.5, reveals how students allocated their time within the platform. The Interactive Learning modules, which provided cultural and historical context, were the most utilized component, accounting for 44.2% of the total time. The AI-Powered Feedback system was also heavily used, particularly during the active learning phase, indicating its value as a practice tool. The 3D Visualization module was used more consistently as a reference tool throughout the intervention.

Table 3.5. Summary of Student Engagement Metrics. This table provides a quantitative overview of how students interacted with the Digital Sutra platform over the 12-week intervention.

Engagement Metric	Value	Interpretation
Mean Weekly Engagement	3.85 ± 0.57 hours	Indicates sustained and substantial student engagement with the platform.
Total Platform Hours (per student)	46.2 hours	Represents a significant volume of supplemental learning outside of studio time.
Peak Weekly Engagement	4.5 hours (Week 9)	Coincides with preparation for mid-term practical assessments.
Module Usage (Time Allocation)		
- Interactive Learning	44.2%	High usage suggests strong student interest in the cultural and theoretical aspects of dance.
- AI-Powered Feedback	33.8%	Demonstrates the perceived value of the real-time feedback for skill refinement.
- 3D Visualization	22.0%	Consistent use as a primary tool for observing and analyzing dance movements.
AI Feedback Interactions (per student)	285 sessions (avg)	High interaction rate points to the utility of the AI system for repetitive practice.

3.4. Perceptions of Students and Educators

Our third research question explored the perceptions of students and educators regarding the integration of the Digital Sutra platform into traditional dance education. To capture these perspectives, we conducted semi-structured interviews with all 30

students in the experimental group and all 5 participating educators at the conclusion of the 12-week intervention. The qualitative data were analyzed using a thematic analysis approach, which revealed several key themes related to the platform's usability, pedagogical value, and role in cultural preservation.

A summary of the major themes that emerged from the analysis is presented in Table 3.6. The themes are organized into three overarching categories: Pedagogical Impact, User Experience, and Cultural Significance. Overall, the reception of the platform was highly positive, with participants emphasizing its value as a supplementary learning tool. However, they also provided constructive feedback regarding areas for future improvement.

Table 3.6. Thematic Analysis of Interview Data. This table summarizes the key themes identified from semi-structured interviews with students (n=30) and educators (n=5).

Overarching Category	Theme	Description	Participant Group
Pedagogical Impact	Enhanced Embodied Understanding	The platform's multi-angle 3D visualization and slow-motion features enabled a deeper, more analytical understanding of complex movements that is difficult to achieve in a traditional studio setting.	Students & Educators
	Personalized Learning and Practice	Students valued the ability to practice at their own pace, repeat difficult sections, and receive immediate, objective feedback from the AI system without fear of judgment.	Students
	Bridging Theory and Practice	The integration of cultural and historical content within the interactive learning modules helped students connect the physical movements to their underlying cultural significance.	Students & Educators

User Experience	High Usability and Engagement	Participants found the platform intuitive and engaging, citing the gamified elements and interactive design as key motivators.	Students
	Desire for More Content	A common request was for an expanded repertoire of dances and more advanced technical exercises.	Students & Educators
	Technical Limitations	Some users noted occasional technical glitches, such as marker occlusion in the motion capture data and latency in the VR interface, suggesting areas for technical refinement.	Students
Cultural Significance	A Tool for Preservation	Educators, in particular, viewed the platform as a vital tool for archiving and preserving traditional dance forms for future generations, describing it as a "living archive."	Educators
	Authenticity and the Digital Medium	A nuanced discussion emerged around the concept of authenticity, with some participants expressing concern that over-reliance on technology could diminish the embodied, human element of dance.	Students & Educators

To provide a richer understanding of these themes, Table 3.7 presents a detailed breakdown of the perceived benefits and challenges of the Digital Sutra platform, accompanied by illustrative quotes from the participants. The benefits, such as "Visual Learning Reinforcement" and "Objective Feedback," were frequently cited as transformative aspects of the learning experience. The challenges, including the "Initial Learning Curve" and the risk of "Over-Reliance on Technology," offer valuable insights for the future development and implementation of such platforms.

Table 3.7. Perceived Benefits and Challenges of the Digital Sutra Platform. This table provides direct quotes from participants, illustrating the key findings from the qualitative analysis.

Category	Sub-Theme	Illustrative Quote	Participant
Perceived Benefits	Visual Learning Reinforcement	"Being able to see the 3D model from above, from the side, and even in slow motion was a game-changer. I could finally understand the precise alignment of the spine in that specific turn. The teacher explains it, but seeing it like that is different."	Student #14
	Objective, Non-Judgmental Feedback	"The AI feedback is honest. It tells you your angle is off by 10 degrees. It doesn't get tired or frustrated. I could practice the same move 50 times until I got it right, and I wouldn't feel like I was wasting anyone's time."	Student #22
	Enhanced Cultural Connection	"Before, the history was just something in a book. With the platform, I could read about the Tang Dynasty and then immediately see and practice a dance from that era. It made the history feel alive and connected to my body."	Student #7
	Facilitating Deeper Pedagogy	"The platform handles the repetitive, technical corrections. This freed me up in the studio to focus on the artistry, the expression, the shen (spirit) of the dance. I could be a mentor, not just a drill instructor."	Educator #3
Identified Challenges	Initial Learning Curve	"The first week was a bit overwhelming. Getting used to the VR headset and navigating the menus	Student #19

		took some time. But after that, it was fine. The tutorial videos helped a lot."	
	Risk of Over-Reliance on Technology	"There's a danger that students might just copy the avatar without feeling the movement internally. Technology should be a support, not a replacement for the inner work and the connection with the teacher."	Educator #1
	Content and Repertoire Limitations	"I loved the Dunhuang dance module. I just wish there were more. I would love to see modules on Tibetan or Mongolian folk dances added in the future."	Student #28
	Technical Glitches and Immersion Breaks	"Sometimes in the VR mode, if I moved too fast, the avatar's leg would glitch for a second. It wasn't a big deal, but it did break the sense of immersion momentarily."	Student #11

4. Discussion

The findings of this study provide compelling evidence for the efficacy of the Digital Sutra framework as an integrated solution for the preservation and transmission of traditional Chinese dance. This section interprets these findings in the context of our research questions, discusses their theoretical and practical implications, and situates them within the broader scholarly landscape of digital heritage, dance education, and human-computer interaction.

4.1. The Synthesis of Preservation and Pedagogy

Our first research question sought to establish a model for a digital platform that could effectively capture, preserve, and transmit traditional dance. The technical evaluation of the Digital Sutra platform confirms its capacity for high-fidelity preservation, with motion capture accuracy and visualization performance meeting the rigorous demands of dance analysis. However, the central contribution of this work lies not in its technical specifications alone, but in its successful synthesis of a preservationist archive with a

dynamic pedagogical environment. Unlike earlier digital dance archives that often function as static repositories (Raheb et al. 2019), the Digital Sutra was designed as a living, interactive tool. The qualitative feedback from educators, who described the platform as a "living archive," underscores this critical distinction. This concept challenges the traditional archival paradigm, which often prioritizes static preservation over dynamic use, by proposing that for intangible heritage, the act of engagement is itself a form of preservation. This finding suggests that the future of digital preservation for performing arts should move beyond mere documentation toward the creation of interactive systems that facilitate active learning and transmission (Miao and Zhang 2024).

The significantly greater improvement in skill acquisition observed in the experimental group provides strong evidence for the pedagogical effectiveness of this integrated approach. The 16.9-point average gain in "Overall Performance" for the experimental group, compared to just 4.1 points for the control group ($p < .001$), demonstrates a clear and substantial benefit. This result aligns with previous research on technology-enhanced learning in the performing arts, which has shown that well-designed digital tools can accelerate skill development (Li, Li, and Han 2021; Bayyat 2020). The platform appears to have successfully acted as a catalyst, amplifying the effectiveness of the traditional instruction.

4.2. Embodied Cognition in a Digital Context

The most profound insights of this study emerge from the intersection of our quantitative and qualitative data, which illuminates how the Digital Sutra platform facilitated learning. The largest effect size in skill improvement was found in "Movement Precision" (Cohen's $d = 2.45$), a domain that relies heavily on nuanced physical understanding. This finding, coupled with the qualitative theme of "Enhanced Embodied Understanding," strongly supports the principles of embodied cognition. Students reported that the platform's 3D visualization engine allowed them to deconstruct complex movements in a way that was impossible in a traditional studio, enabling them to build a more accurate mental and physical model of the dance. As one student noted, "Being able to see the 3D model from above...was a game-changer. I could finally understand the precise alignment." This aligns with Warburton's (2011) assertion that cognition is a form of embodied action, and that learning is deepened when it is grounded in sensorimotor experience.

Furthermore, the heavy use of the AI-powered feedback system (33.8% of engagement time) highlights the value of immediate, objective feedback in fostering this embodied understanding. The AI system provided a private, non-judgmental space for repetitive practice, which students found crucial for refining their technique. This private feedback loop may also lower performance anxiety, a common issue in dance studios, thereby creating a more positive and efficient learning environment. This finding extends the work of Miko (2025) and Xu et al. (2025) by demonstrating the successful application of AI feedback within a culturally specific, traditional art form. The platform did not replace the teacher; rather, as one educator noted, it handled the "repetitive, technical corrections," freeing the human instructor to focus on higher-order artistic and expressive elements. This suggests a powerful new synergy between human and artificial instructors, where technology provides the scaffolding for technical mastery, allowing human teachers to focus on cultivating artistry.

4.3. Cultural Transmission in a Blended Learning Model

Beyond physical technique, the study demonstrates the platform's effectiveness in transmitting the cultural dimensions of dance. The significant improvement in the "Cultural Understanding" score for the experimental group, combined with high engagement in the Interactive Learning modules (44.2% of time), indicates that the blended learning model successfully bridged the gap between theory and practice. By embedding historical and cultural content directly alongside the movement practice, the Digital Sutra helped students connect the physical forms to their underlying meanings, transforming abstract knowledge into lived, embodied experience. This finding addresses a common challenge in traditional arts education, where historical context can often feel disconnected from studio practice (Huang, Zhang, and Li 2025).

However, the qualitative data also raised a nuanced and important discussion around authenticity. The concern voiced by an educator about the risk of students "just copying the avatar without feeling the movement internally" is a critical consideration for the field of HCI and digital pedagogy. It highlights that technology in this domain must be designed not to replace the internal, somatic work of the dancer, but to scaffold and support it. The goal is not to create perfect digital copies, but to provide a detailed reference model against which students can develop their own informed, embodied interpretations. This reframes the technology as a tool for interpretation rather than mere replication, emphasizing the importance of the dancer's own agency and artistic

voice in the learning process (Jürgens, Correia, and Masu 2021). The most effective implementation, therefore, involves a pedagogical framework that actively encourages students to use the digital tool as a resource for exploration, not as a definitive authority.

5. Limitations and Future Research

While this study provides strong evidence for the efficacy of the Digital Sutra framework, it is important to acknowledge its limitations. First, the study was conducted at a single university in China with a specific cohort of dance majors. Future research should seek to validate these findings across different cultural contexts, educational levels, and dance genres. Second, the 12-week duration of the intervention, while aligned with an academic semester, provides only a snapshot of the learning process. A longitudinal study would offer deeper insights into the long-term impact on skill retention and artistic development.

Technologically, while the platform was robust, participants did note occasional technical glitches. Future iterations should focus on improving the seamlessness of the user experience, particularly in the VR environment, and expanding the repertoire of available dances. Furthermore, the AI feedback system, while effective for form and precision, could be enhanced to provide feedback on more qualitative aspects of performance, such as movement quality and expressivity, which remains a significant challenge in computational dance analysis (Aristidou et al. 2015).

Future research should also explore the potential for such platforms to serve as tools for choreographic innovation and cross-cultural collaboration, allowing artists to interact with and reinterpret archived movements in creative ways. Finally, the question of public access and the ethical considerations of digitizing ICH warrant further investigation to ensure that these digital archives empower source communities and promote cultural equity (Blake 2009).

6. Conclusion

This study makes a significant contribution to the fields of dance education, digital heritage, and human-computer interaction by presenting and validating the Digital Sutra, an integrated framework that successfully bridges the gap between the preservation and transmission of intangible cultural heritage. Our findings demonstrate that a blended learning model, combining traditional pedagogy with a high-fidelity

digital platform, can lead to substantial and statistically significant improvements in skill acquisition, cultural understanding, and student engagement.

The research confirms that technologies such as motion capture, 3D visualization, and AI can be powerful tools for fostering deep, embodied learning, augmenting rather than replacing the indispensable role of the human educator. By moving beyond the concept of a static digital archive to that of a living, interactive learning environment, this work provides a robust, empirically grounded model for the future. The Digital Sutra illustrates a pathway for ensuring that the rich legacies of traditional performing arts not only survive in the digital age, but thrive as dynamic, evolving practices for generations to come.

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