Development of an Exploratory Heritage Educational Game Integrating SVVR Scenarios, Narrative Scripts, and Generative AI Characters

Ti-Chieh Lin, National Taiwan University of Science and Technology, Taiwan
Hung-Yu Chan, National Taiwan University of Science and Technology, Taiwan
Huei-Tse Hou, National Taiwan University of Science and Technology, Taiwan

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Abstract

Information integration and critical thinking skills are essential core competencies in cultural education. This study combines generative AI (GenAI) characters with Spherical Video-Based Virtual Reality (SVVR) technology to design a digital learning game that integrates knowledge of military dependents' village culture with puzzle-solving mechanisms. Players will assume the role of a grandson returning to the military village of Forty-Four South Village in Taipei City. By exploring the environment and objects within the SVVR military village and engaging in dialogue with the GenAI grandfather character, players can inquire about the grandfather's memories to compare information, piece together clues through reasoning, and recover the grandfather's lost videotape. This process enhances immersion and understanding of the culture of military villages. A total of 17 learners participated in the empirical evaluation of this study. The findings revealed that learners experienced a high level of flow (M = 4.10) and moderate anxiety (M = 2.01) while playing the game. extrinsic cognitive load was relatively low (M = 1.45), indicating that the interface design did not impose additional burdens; however, germane cognitive load was relatively high (M = 4.41), suggesting that learners were willing to invest extra effort in reasoning and integrating clues. Among them, 88.2% of learners believed that the game deepened their impression of the village and pointed out that AI grandfather clues played a key role in reasoning. Additionally, 76.5% of learners were willing to visit the village in person as a result. This study combines GenAI and SVVR to provide an innovative model for historical and cultural education.

Keywords: generative AI, spherical video-based virtual reality, cultural heritage education

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Introduction

Cultural heritage education plays a central role in preserving and transmitting a society's cultural identity, traditions, and history. It fosters individuals' sense of belonging and identity while promoting cross-cultural understanding and appreciation (Camuñas-García et al., 2024). In the cultural education context examined by this study, information integration and interpretation skills are regarded as vital core competencies. However, traditional cultural education approaches, particularly within museums or cultural heritage sites, face challenges related to insufficient visitor engagement. Conventional museum artifact presentations often lack detail or provide limited information, making it difficult for visitors to connect with the artifacts or discern their significance (Othman et al., 2021). This static exhibition model typically fails to fully engage visitors and achieve effective participation, necessitating innovative approaches to enhance public interest and understanding of cultural heritage (Camuñas-García et al., 2024).

To address the limitations of traditional education, Digital Game-Based Learning (DGBL) has been widely adopted (Camuñas-García et al., 2024). Technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) have proven to be powerful tools for cultural heritage preservation and education, enhancing the interactivity of cultural objects (Jiang et al., 2025). Jiang et al. (2025) noted that the application of these technologies is shifting from traditional static preservation methods toward dynamic, interactive approaches to foster public engagement and educational impact. VR provides fully immersive experiences, such as creating detailed digital replicas of endangered cultural monuments or virtual models of fragile heritage sites (e.g., the Lascaux caves in France), enabling interactive exploration without causing physical wear to artifacts (Jiang et al., 2025).

Serious games leverage technology in the cultural heritage sector to engage users in educational and immersive experiences. They integrate instructional content and practical knowledge into gameplay mechanics, aiming to achieve user satisfaction, engagement, immersion, and effective perception of educational content (Bontchev et al., 2024). Othman et al. (2021) developed a mobile gamified tour application using a treasure hunt game mechanism. They found that while the game enhanced children's cultural heritage experiences in living museums, differences in engagement, knowledge and learning, and meaningful experiences did not reach significant levels. Only the emotional connection dimension showed a significant effect. This also indicates that traditional game mechanisms still have limitations in comprehensively enhancing cognition and engagement.

This study selected the integration of SVVR (Spherical Video-Based Virtual Reality) and GenAI (Generative AI) to overcome the limitations of either technology alone and leverage their complementary characteristics. SVVR is a form of immersive VR that captures real environments through 360-degree video (or real-life footage), offering a low-cost, user-friendly immersive learning experience suitable for educational settings. Its interactivity is limited to viewpoint switching, lacking scaffolding support and assessment capabilities (Jong, 2023). GenAI delivers creative and randomized feedback, generating content from data to provide adaptive guidance and real-time feedback (Lau et al., 2024). GenAI exhibits bidirectional dynamism and explorability, guiding learners to instantly search for information, analyze situations, and strategize within games. It also features role-playing capabilities, enabling characters like “village grandfathers” in cultural education to create contextualized learning experiences (Chien et al., 2025). Therefore, this study employs SVVR to deliver immersive real-world settings and GenAI character interactions to address its interactive limitations.

Through real-time dialogue, role-based guidance, and cultural knowledge transmission, it realizes an immersive and interactive educational model for military dependents' villages, meeting educational design requirements. Consequently, this study focuses on the SVVR military dependents' village setting, cultural artifact interactions, and dialogues with the generative AI grandfather character. Presenting the game through a web interface and panoramic VR mode, it designs a historical-cultural educational game integrating cultural exploration and puzzle-solving. The AI dialogue within the story script incorporates multiple cultural clues. Learners must progressively deduce and integrate information through exploration and conversation to piece together the historical context of military dependents' village life.

Methods

Participants in this study were recruited voluntarily, comprising 17 individuals: 9 males and 8 females, aged between 22 and 77 years old, with a mean age of 32.1 years. To assess learners' flow states, this study adopted the Flow State Inventory developed by Kiili (2006), utilizing the Chinese version translated by Hou and Li (2014). In this study, the overall reliability of the Flow Scale was Cronbach's $\alpha = .882$, indicating high reliability. To assess learners' activity anxiety, this study adapted the activity anxiety Scale translated by Hung (2001). In this study, the overall reliability of the activity anxiety Scale was Cronbach's $\alpha = .596$. Future research could improve reliability by expanding the sample size. The cognitive load scale translated by Leppink et al. (2013) was adapted and adjusted based on Klepsch et al. (2017)'s differentiated cognitive load scale to assess learners' cognitive load. In this study, the overall reliability of the activity learning cognitive load scale was Cronbach's $\alpha = .769$, demonstrating high reliability. All questionnaires employed a five-point Likert scale, with 1 indicating strongly disagree and 5 indicating strongly agree. Additionally, to understand learners' impressions, emotions, and cultural understanding, this study incorporated open-ended questions to collect qualitative feedback.

This study designed the historical education game "Time Village" The game features a realistic storyline, generative AI-simulated character interactions, and allows players to explore environments and objects within the SVVR-created military dependents' village setting (Forty-Four South Village). Players assume the role of a young man who converses with a generative AI NPC (the protagonist's grandfather), whose character script was co-designed by the research team. Through information cross-referencing and clue deduction, players must find a lost videotape within a limited timeframe. Players can input questions in the left dialogue box to receive the grandfather's responses, as shown in Figure 1. Simultaneously, they can explore objects within the military dependents' village scene (Forty-Four South Village) created by SVVR through the right-side game interface, as shown in Figure 2.

Figure 1
Time Village-GenAI interaction

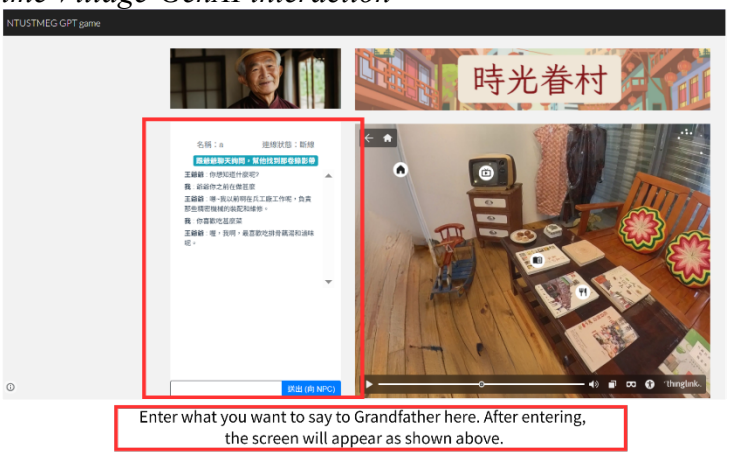


Figure 2
Time Village-SVVR Created Military Dependent Village Scene (Forty-Four South Village)

Results and Discussions

To examine learners' flow, this study employed a nonparametric one-sample Wilcoxon signed-rank test, comparing individual scores against the median (i.e., 3). Table 1 presents learners' flow states following the task. Overall flow ($M = 4.1$) was significantly higher than 3, and the subdimensions Flow antecedents ($M = 4.1$) and Flow experience ($M = 4.1$) were also significantly above 3. Results indicate that learners experienced high levels of flow ($M = 4.10$, $p < .001$) during gameplay. Among the sub-dimensions, Concentration ($M = 4.35$, $p < .001$) and Goals of an activity ($M = 4.50$, $p < .001$) stood out most prominently, showing that learners maintained focus and clearly understood task goals throughout the game. Additionally, high scores were observed for sense of Control ($M = 4.38$, $p < .01$) and Autotelic experience ($M = 4.18$, $p < .01$), showing the game's operability and provision of intrinsic feedback. The integration of SVVR scenarios with generative AI dialogue successfully created an immersive learning environment conducive to flow. This aligns with Fang (2024)'s findings that focus and control are key components of flow experiences within goal-directed training VR learning settings.

Table 1
The Mean and Standard Deviation of Learners' Flow

	(*N* = 17)			
	M	*SD*	*Z*	*Sig.*
Overall Flow	4.10	0.56	3.57***	.000
Flow antecedents	4.10	0.50	3.52***	.000
Challenge-skill balance	3.71	0.99	2.56*	.010
Goals of an activity	4.50	0.75	3.56***	.000
Unambiguous Feedback	3.76	0.99	2.64**	.008
Control	4.38	0.78	3.48**	.001
Playability	4.15	0.75	3.33**	.001
Flow experience	4.10	0.65	3.51***	.000
Concentration	4.35	0.78	3.50***	.000
Time distortion	3.91	1.08	2.65**	.008
Autotelic experience	4.18	0.83	3.35**	.001
Loss of self-consciousness	3.62	1.47	1.68	.093

*p < 0.05, **p < 0.01, *** p < 0.001

To examine learners' activity anxiety, this study employed a nonparametric one-sample Wilcoxon signed-rank test, comparing individual scores against the median. Table 2 presents the statistical results for activity anxiety. Overall anxiety (M = 2.01, p < .001) fell below 3, indicating that learners experienced low-to-moderate anxiety during gameplay. This finding also indicates that while the game provided cognitive challenges, it did not induce excessive stress, allowing learners to focus on exploration and reasoning tasks. Li et al. (2024) noted that the relationship between anxiety levels and student performance follows a fluctuating curve: low to moderate anxiety helps keep learning motivation, while excessive anxiety may negatively impact learning performance.

Table 2
The Mean and Standard Deviation of Learners' Activity Anxiety

	(*N* = 17)			
	M	*SD*	*Z*	*Sig.*
Activity anxiety	2.01	0.55	-3.52***	.000

***p < 0.001

To examine learners' cognitive load, this study employed a nonparametric one-sample Wilcoxon signed-rank test, comparing individual scores against 3. Table 3 presents the statistical results for cognitive load. Analysis indicates that intrinsic cognitive load was at a moderate level (M = 3.03, p = .740), showing no significant difference from 3. This suggests the cultural education task itself was neither excessively difficult nor overly simple. Extrinsic cognitive load was significantly low (M = 1.45, p < .001), showing significant difference from 3. This indicates that the SVVR interface and game mechanics did not impose additional burdens. Germane cognitive load was significantly high (M = 4.41, p < .001), showing significant difference from 3. This indicates that learners were willing to invest substantial effort in reasoning, integrating clues, and engaging with historical narratives. This outcome highlights how game design effectively minimizes unnecessary distractions while fostering meaningful cognitive engagement. Sevcenko et al. (2021) noted that in serious games,

appropriately managing learners' cognitive load through thoughtful design helps maintain optimal learning states, thereby promoting meaningful participation.

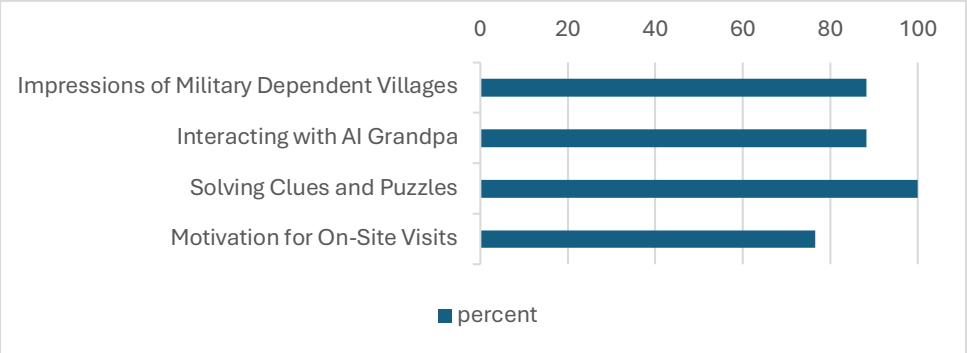
Table 3
The Mean and Standard Deviation of Learners' Cognitive Load

	(*N* = 17)			
	M	*SD*	*Z*	*Sig.*
Intrinsic cognitive load	3.03	0.69	0.33	.740
Extrinsic cognitive load	1.45	0.74	-3.82***	.000
Germane cognitive load	4.41	0.67	3.85***	.000

*p < 0.05, **p < 0.01, *** p < 0.001

Figure 3 presents learners' open-ended feedback and quantitative results. 88.2% of learners felt that the SVVR exploration deepened their impression of Forty-Four South Village. Similarly, 88.2% noted that conversations with AI Grandfather enhanced emotional engagement, with his authentic tone making memories of life in the munitions factory and neighborhood interactions feel more real and immersive. 100% of learners indicated that solving clues, such as flipping through recipes, reading bulletin boards, and listening to Grandfather's recollections, helped them deeply understand the culinary traditions and social interactions within military dependents' village culture. Furthermore, 76.5% of learners expressed that the SVVR experience sparked their curiosity, prompting them to visit Forty-Four South Village in person.

Figure 3
Results of the Open-Ended Questions on Military Dependent Villages



Conclusions and Limitations

This study confirms that integrating SVVR with GenAI characters in cultural education games effectively promotes learner flow, reduces activity anxiety, and enhances cultural understanding. Learners experience focus, immersion, and heightened presence during gameplay while mitigating task-induced learning anxiety, maintaining an optimal challenge level throughout exploration. Through a blend of exploratory interaction, puzzle-solving design, and contextual immersive scenarios, learners actively participate in clue collection and information inference. Simultaneously, they progressively construct cultural knowledge through dialogues with the AI Grandfather, deepening their understanding of military dependents' village history and cultural context. Research findings indicate that this gamified learning model not only enhances learner engagement and motivation but also sparks a desire to visit actual sites, bridging virtual learning with real-world cultural experiences. This achieves a connection between digital interactive education and cultural heritage preservation.

Beyond these findings, the study also identified limitations and future research directions. While AI Grandfather delivers culturally meaningful narratives, some learners suggested enriching dialogue content. Future research could enhance the contextual richness of AI dialogues and incorporate additional elements of military dependents' village knowledge—such as literature and music—to create a more comprehensive cultural learning experience.

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Contact email: hthou@mail.ntust.edu.tw