Research Article

Developments of Virtual Museums in China's Educational Sector

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Abstract:

To address current challenges in education, art educators need to innovatively integrate the rich resources of virtual museums with online teaching platforms, designing courses that engage students and enhance their artistic literacy. However, the development of virtual museums in China is currently disappointing, facing issues such as subpar virtual presentations, a lack of interactivity, and low online traffic. This paper adopts Robert K. Yin's case study methodology to analyze several Chinese virtual museums and examines three major issues related to their public art education function: lack of interactivity, a monotonous user experience, and insufficient technological innovation. The study analyzes museum cases based on uniform criteria, including user engagement, technology application, and educational functionality. Through the "Data Collection" and "Analysis" phases in Yin's model, the study gathered feedback on aspects such as immersion, interactivity, and technical quality, leading to improvement recommendations in the "Share" phase. The findings in Tables 2 and 3 reveal that virtual museums should shift from knowledge dissemination to emphasizing interactivity and user experience, move beyond merely replicating physical museums to creating more innovative designs, and transition from focusing on artistic skills to fostering individual creativity and artistic literacy.

1. Introduction

According to a survey by the International Council of Museums (ICOM), following the outbreak of COVID-19, nearly 80% of museums in 106 countries reduced their operations, with approximately 12.8% of these museums possibly facing permanent closure. In 2020, the number of exhibitions and visitors in Chinese museums decreased by 56% (Gao, 2023). This highlights the limitations of physical museums in fulfilling their social roles during unexpected public events.

Since their inception, museums have played an important educational role (Hein, 2002). However, despite the potential of museums to help children learn humanitarian principles and enhance their self-worth through historical exhibits, their educational function has not been fully realized in practice (Daniela, 2020; Atamuratov, 2020).

As a product of digital technology, virtual museums provide rich educational resources for students, teachers, and researchers. Compared to physical exhibitions, the digital and interactive nature of virtual museums makes them more appealing to learners, enhancing their collaboration, critical thinking, and research depth (Islek & Danju, 2019). Through virtual learning technologies, students can explore exhibits at their own pace, engage in deep reflection, and thus achieve a more enriched learning experience (Wu, 2021).

However, the design of many virtual museums in China primarily relies on panoramic modeling to simply replicate the

experience of physical museums. While this approach can offer a close-to-real museum experience, it fails to fully leverage the innovative potential of digital environments, resulting in a monotonous user experience that struggles to engage and retain users. Virtual museums need to adopt innovative interactive designs to guide users from passive viewing to active exploration (Yang & Zhang, 2021).

Furthermore, the traditional methods of disseminating historical, artistic, and scientific knowledge can be too complex or dull for audiences with different levels of cognitive understanding. Exhibition design should consider the characteristics and interests of different groups, offering dynamic, interactive, and engaging experiences to attract a broader audience, thereby enhancing their engagement and understanding of the content (Huang, 2003).

2. Literature Review

Introduction

Museums, as an important carrier of culture and education, have traditionally played an indispensable role in social education. On the basis of traditional museums, virtual museums have emerged with the advancement of science and technology and have rapidly become an emerging platform for art education. Virtual museums not only extend the educational function of museums, but also change the way the public interacts with cultural heritage. In this context, this paper analyses the role and differences between traditional and virtual museums in public art education by comparing them.

Traditional Museums

During the ongoing COVID-19 pandemic, social distancing restrictions have prohibited schools from conducting field trips to public places where large gatherings occur. Additionally, the traditional learning methods adopted by many museums have not been appealing to learners and educators alike (Ostrowska-Tryzno & Pawlikowska-Piechotka, 2022).

Traditional museums generally consist of three fundamental components: "artifacts," "space," and "individuals." "Artifacts" refer to the numerous materials or relics that make up the museum's collection. On the other hand, "space" includes the museum's physical location, architectural features, and amenities (Kamal Mahmoud et al., 2022; Morishita, 2003). Individuals in museums are not only recipients of culture, but also facilitators of cultural transmission and exchange (Yang & Zhang, 2011; Meier et al., 2021). Their interaction and participation are central to the realisation of the museum's social and educational functions.

Virtual Museum

A virtual museum is a digital entity that extends, supplements, or enhances the museum experience through personalized, interactive content that features characteristics of actual museums (Kersten et al., 2017; Sin, 2007). A virtual platform known as a virtual museum replicates a real museum, allowing people to explore and study artworks from home (Goulding, 2020). The four main categories of virtual museums are Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and Metaspace (MS) (Gao, 2011; Maas & Hughes, 2020).

The Impact of Museums in Art Education

As early as the mid-1990s, most researchers began to focus on the educational potential of museums and their significance for students' cognitive, emotional, and social development. The creation of "virtual museums" stemmed from technological advancements. Pescarin (2013) explains that a "virtual museum" refers to a permanent or temporary virtual creation organized for society and its development, accessible to the public, where the tangible and intangible heritage of humanity and the environment is preserved, researched, shared, and displayed. Educational experts believe that learning in museums, whether actual or virtual, is not just a cognitive process. It is also the result of interaction between social and cultural groups. This is

because student visitors can explore and interact with various objects in an environment free from classroom constraints, forming new cognitive patterns based on their prior experiences and knowledge (Anderson et al.). Kisiel (2003) points out that virtual museums provide insights and information, are interactive, rely on stakeholders' free will, and offer students educational experiences that enhance their abilities and skills. Thus, virtual museums can act as catalysts, changing the behavior of visitors or students, as they serve as spaces for learning, communication, and enjoyment.

Table 1. Synthesis of Traditional Museums and Virtual Museums

Category	Traditional Museum	Virtual Museum
Artifacts	Physical collections: actual artefacts and objects in museums	Digitised objects: displaying digitised artefacts through virtual display technology
Behavior/Interaction	Physical interaction: Visitors physically touch and observe the exhibits at close range	Virtual interaction: interaction through virtual reality, augmented reality and other technologies
Elements	Artefacts, space, visitors (individuals): core elements of a museum	Virtual displays, virtual spaces, users: digital technology-enabled museum experiences
Reason/this for what	Cultural preservation, collection, education and research: the core functions of traditional museums	Enhancing interactivity and broadening audiences: virtual museums enhance participation through technology

This table synthesizes the main differences and connections between virtual museums and traditional museums, referencing specific literature. It outlines how these two types of museums utilize artifacts, space, and personnel as fundamental components. Despite fundamentally different approaches, both reflect the unique experiences they offer. The introduction of virtual technology in virtual museums enables immersive and interactive experiences, highlighting the technological divide between virtual and traditional environments. The functional roles of both platforms remain consistent, with a focus on research, collection, preservation, exhibition, and education, underscoring the shared mission of museums to preserve and disseminate cultural heritage. However, the nature of visitor interaction and public experience differs significantly, with traditional museums offering physical engagement and virtual museums providing digital interaction. This comparison indicates that while virtual and traditional museums serve similar educational and cultural preservation roles, the methods and experiences they offer reflect the evolving nature of museum interaction, driven by technological advancements and changing visitor expectations.

3. Research Methodology

This study adopts the case study method proposed by Robert K. Yin (2009) and follows a structured approach, as illustrated

in Figure 1, to conduct an in-depth analysis of multiple virtual museum cases in the educational field. In the initial stage, the research objectives and problems were clearly identified, focusing on evaluating the strengths and limitations of virtual museums concerning technology application and user experience. The research design ensures a diverse data set by selecting virtual museum cases from different regions across China, thereby enhancing the comprehensiveness and representativeness of the findings.

During the data collection phase, as shown in Figure 1, researchers adhered to the sequence of Planning, Design, Prepare, Collect, Analyze, and Share phases based on Yin's case study model. User feedback was gathered through multiple channels, such as platform visit counts, likes, and comments, alongside observational analyses of the technological applications and interactive design within each virtual museum. The diversity in data sources builds a solid foundation for the study's analytical rigor, ensuring completeness and consistency in the findings.

Finally, during the analysis phase, the data gathered from various cases were compared to identify primary issues and develop recommendations for improvements in interactive design, user engagement, and technological presentation. Based on these analyses, the study provides practical suggestions for optimizing virtual museums in the educational context, ensuring that the research findings not only hold academic significance but also offer valuable references for real-world application.
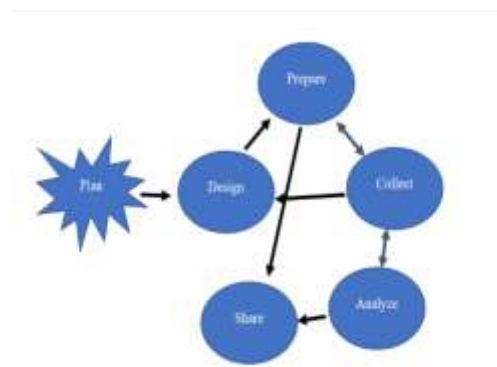

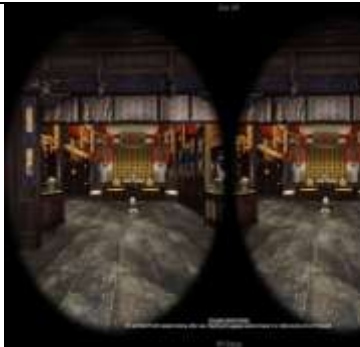*Figure 1. Robert K. Yin (2018) Case study model*

Case Analysis

Virtual museums represent the digital evolution of cultural institutions, leveraging the power of the internet and virtual reality technology to enable people to browse and interact with artworks, historical artifacts, and various exhibitions from around the world online. While these virtual museum applications can provide educational and cultural experiences similar to those of traditional museums, they also possess their own unique features and advantages. Virtual museums in different regions showcase distinct characteristics. Below is a comparative analysis of some existing virtual museum applications.

Discussion

The advent of virtual museums represents a transformative approach to cultural preservation and education, leveraging digital technologies such as virtual reality (VR) and augmented reality (AR) to enhance user experiences. However, creating immersive, interactive, and user-friendly virtual environments demands a robust technical framework. The VR Museum Conceptual Model (Figure 1) organizes this infrastructure into three interconnected layers: the Equipment Layer (hardware, e.g., VR headsets and controllers), the Technical Layer (software, rendering engines, and user interface frameworks), and the Project Layer (application-specific functionalities, e.g., interactive exhibits and social features). Grounded in user-centered design principles, this model provides a systematic lens for evaluating and enhancing virtual museum experiences. By integrating insights from Table 2's case studies and Table 3's recommendations within Robert K. Yin's case study framework, this study identifies deficiencies in immersion, interactivity, educational value, technical quality, and user-friendliness, proposing targeted strategies to transform virtual museums into dynamic, engaging platforms for art education.

Table 2. Summarizes the comparative analysis of virtual museums on different platforms

Museum Name	Museum category	immersive	interactive	user reviews	comment	platforms	illustrations
The Palace Museum	Architecture	full immersion and half immersion	Controller Interaction	There is no feedback channel, and after browsing, there is no real-time presentation.	The Palace Museum (Forbidden City) has introduced a panoramic Forbidden City program using full-view VR technology, allowing visitors and viewers to immerse themselves in a 360° virtual tour of the Forbidden City. In addition to the areas that are already open to the public, users can explore areas that are temporarily closed in VR. During the pandemic, it has gained popularity among a large number of users, with daily average visits exceeding 300,000, 275,831 likes. However, the online virtual scenes lack essential interactive and feedback mechanisms.	webvr	
Henan Museum	Historical	Full immersion and half immersion	Minimal Interactivity	No user feedback available	Visits are unknown (the platform has statistics on visits, but they don't work), 0 likes, 0 comments. Interactivity is almost nil, with no visible signs of user engagement and a lack of basic user feedback and interaction mechanisms.	webvr	
Hunan Museum	Historical	Full immersion and half immersion	isual Interaction, no comment functionality	No comment feedback	365,270 visits, 5,500+ likes, no comments section. Users actively participate in liking the exhibition, but the lack of a comment feedback feature prevents users from providing more detailed opinions about the exhibition.	webvr	
Xi'an Museum	Historical	Full immersion and half immersion	Minimal Interactivity	No user feedback available	Visits unknown, 0 likes, 0 comments. Live replica of the virtual pavilion, but with low quality images and lack of user feedback and interactive features to enhance the user experience.	webvr	

Hangzhou Liangzhu Museum	Art	half immersion	Controller Interaction、Visual Interaction	There is no feedback channel, and after browsing, there is no real-time presentation.	At the entrance of the Liangzhu Museum in Hangzhou, AR-guided glasses equipped with an AR smart guide application offer visitors a mixed-reality experience. These glasses provide features such as AR special effects, digital sand tables, AR map navigation, and virtual tour guides. By wearing these AR glasses, visitors can observe intricate details on artifacts that have been weathered by time, immersing themselves in the museum's collection of precious artifacts. This allows for a deep historical understanding within a mixed-reality visual environment. However, throughout the entire experience, the interactive elements are limited, with more emphasis on explanatory presentations. Additionally, the museum has not designed an online virtual platform, so the experience needs to be enjoyed within the physical museum.	AR	
Virtual Art Museum of Nanjing Museum	Art	full immersion and half immersion	Visual Interaction	There is no feedback channel, and after browsing, there is no real-time presentation.	The virtual exhibition hall at the Nanjing Museum features exquisite scene modeling and high-definition display images, with well-designed lighting that enhances the overall experience. However, in the actual experience, the movement within the scenes may feel overly fixed, and there is a lack of interaction with the exhibited items.	webvr	
Zhejiang Art Museum	Art	full immersion and half immersion	Minimal Interactivity	There is no feedback channel, and after browsing, there is no real-	The virtual venue at the Zhejiang Art Museum utilizes real-world photography, achieving a very high level of scene realism. It also provides four different viewing perspectives (normal, little planet, fisheye, crystal ball). However, a drawback is that during use, it only offers traditional viewing	AR	

				time presentation.	functionality and lacks interactive and feedback experiences.		
Guangdong Art Museum	Art	full immersion and half immersion	Visual Interaction、Social Interaction	It has features similar to TikTok, such as liking, commenting, and providing feedback.	60,000+ visits, 97 likes, 15 comments (86.67% positive, 13.33% negative). Overall user feedback was positive, but weaknesses of lack of interactivity were noted.The venue's design is not based on real-world virtual scenes but rather modeled scenes. The displayed items have a considerably high resolution, but what's most impressive is the user interface design. It provides real-time data display, showing the number of views, likes, and comments. Additionally, it offers clear usage instructions. However, a drawback is that the material textures in the scenes appear somewhat rough.	webvr	
Jiangxi Art Museum.	Art	full immersion and half immersion	Visual Interaction、Social Interaction	You can leave simple messages, like, and share.	5,934 visits, 18 likes, 0 comments. User interaction is low, relying mainly on simple like and share functions, lacking more in-depth feedback channels and interactive sessions.It features super high-resolution real-world images, and the exhibition's fidelity is high. However, one drawback in the user experience is that upon entering the interface, you can see an advertisement for the company that created this virtual venue, which can be considered a downside.And, apart from browsing the exhibition information, there are no more interactive sessions.	AR	
Quanzhou Overseas Traffic History Museum	Historical	full immersion and half immersion	Minimal Interactivity	Showing information about the museum from the entrance to	The virtual exhibits function more as an introduction to the museum, providing comprehensive information about the institution. They can be considered detailed recreations of the physical museum. However, during use, the experience primarily revolves around information dissemination,	AR	

				the exhibition halls.	with minimal opportunities for personalized interaction.		
Gansu Provincial Museum	Art	full immersion and half immersion	Minimal Interactivity	Musems have rich collections for historical reasons, but access to information about the collections is difficult	This virtual museum is also a simple replica of the real one, so much so that you remain at a distance from the actual collection as you browse through it, with no way of getting information about the exhibits through interaction, but only being satisfied with simple viewing.	AR	
Sichuan Museum	Art	half immersion	Minimal Interactivity	The Sichuan Provincial Museum is a large comprehensive museum, but the online virtual museum is too simple	The virtual museum is presented with only ordinary panoramic views, no actual modelling or fully immersive viewing experience, simple functionality, and no interactive experience or other forms of interaction.	AR	

Henan Provincial Museum	Art	full immersion and half immersion	Minimal Interactivity	The virtual pavilion of Henan Provincial Museum is large in size and rich in collections.	The virtual pavilion is rich in content, simple in operation interface, and all of them show the necessary key information. However, the interactivity of the virtual pavilion is poor, and the dissemination of knowledge information is dominated by a lack of interest.	AR	
Guangxi Museum of Nationalities	Art	half immersion	Minimal Interactivity	The virtual museum interface is not user-friendly	The production of this virtual museum is so simple that it is not possible to get the first information on how to operate it when going in, and the process of using it is less experiential and does not have any form of interaction	AR	

Figure 2. VR Museum Conceptual Model. The model structures virtual museum technology into the Equipment Layer (hardware enabling VR experiences), the Technical Layer (software and rendering for seamless performance), and the Project Layer (user-driven functionalities like interactivity and social engagement).

Table 2 illustrates variations in immersion, interactivity, and user engagement across virtual museums, highlighting both strengths and limitations. The Palace Museum, for instance, utilizes VR technology to deliver an immersive panoramic experience, allowing users to explore restricted areas. This capability is enabled by the Equipment Layer's high-fidelity VR headsets and controllers, which create realistic virtual environments, as shown in Figure 1. However, the absence of real-time interaction, as identified in the "Data Collection" phase of Yin's model, restricts user engagement. In contrast, the Guangdong Museum of Art enhances user engagement through social features like likes and comments, fostering a positive interaction loop. This success aligns with the Project Layer's focus on community-driven functionalities and the "Share" phase of Yin's model, where user feedback drives satisfaction and community building. These case studies underscore the need for a balanced approach that combines immersion with interactivity, a goal that Table 3 addresses through technically grounded recommendations.
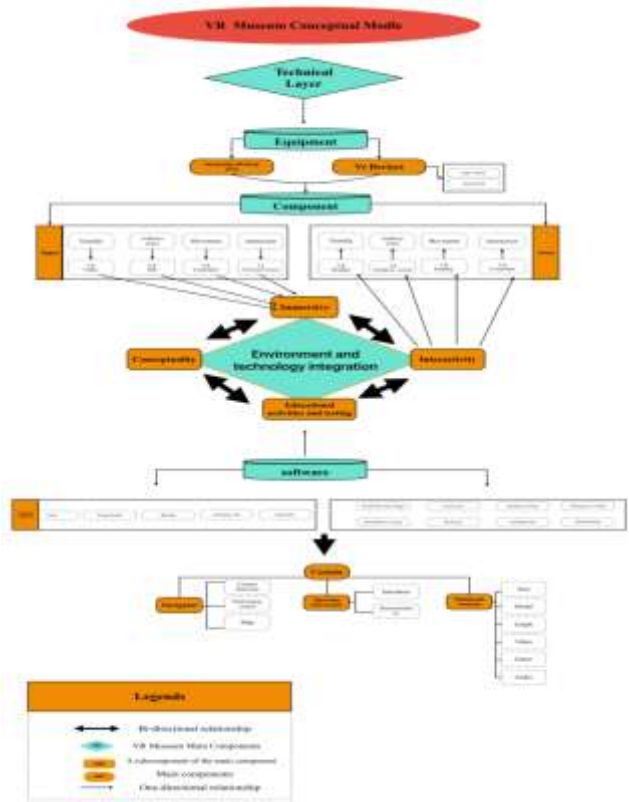
Table 3. *Observations and Improvement Recommendations for Virtual Museum Experiences*

Aspect	paulObservation	Suggested Improvements
Immersion & Interactivity	Full immersion with controller interaction is highly valued, leading to better user satisfaction. As seen in The Palace Museum, users appreciate immersive environments, but desire more interaction.	Enhance interactivity and immersion by leveraging the Equipment Layer (e.g., advanced VR controllers) and Technical Layer (e.g., real-time rendering) to support dynamic interactions. Incorporate Project Layer features like gesture-based controls or interactive virtual tours to deepen user engagement, addressing user demands from the Data Collection phase of Yin's model.
Educational Value	High-resolution artworks and detailed explanations are well received, but can become monotonous without engagement. Seen in Henan Provincial Museum and Zhejiang Art Museum.	Balance educational content with interactivity by integrating Project Layer features, such as gamified learning modules or interactive storytelling, supported by the Technical Layer's high-quality rendering. This aligns with the Data Collection phase's call for engaging educational experiences to maintain user interest.
Technical Quality & Realism	The realism of artworks and the quality of the virtual environment are crucial for user satisfaction, especially in museums like Jiangxi Art Museum.	Improve technical execution by optimizing the Technical Layer for high-resolution textures and realistic lighting, supported by the Equipment Layer (e.g., advanced GPUs). Ensure seamless, convincing virtual environments, aligning with the Preparation and Design phases of Yin's model for enhanced user satisfaction.
User Feedback Mechanisms	Museums with social interaction features, like Guangdong Art Museum, foster community engagement through likes and comments.	Incorporate Project Layer feedback channels (e.g., likes, comments, surveys) supported by the Technical Layer's cloud-based platforms or APIs for real-time interaction. This enhances user involvement and personalizes experiences, aligning with the
Accessibility & User-Friendliness	The absence of feedback channels and poor user interface design, as seen in Guangxi Museum of Nationalities, indicates a need for improvement in accessibility and usability.	Minimize technical barriers by enhancing Technical Layer user interface frameworks for intuitive designs and ensuring Equipment Layer compatibility with diverse devices. Integrate Project Layer accessible feedback mechanisms, aligning with the Preparation and Design phases to broaden access and improve usability.

Table 3 summarizes observations from virtual museum case studies and proposes improvements

that leverage the VR Museum Conceptual Model's layers to address identified deficiencies. For instance, while Henan Provincial Museum and Zhejiang Art Museum excel in delivering high-quality exhibit information through the Technical Layer's rendering capabilities, their lack of interactive design results in a one-dimensional experience. The "Data Collection" phase of Yin's model reveals user demand for greater interactivity, which Table 3 addresses by recommending Project Layer features like gamified learning modules and interactive storytelling. These enhancements, supported by the Technical Layer's high-resolution rendering, ensure educational content remains engaging, aligning with the model's user-centric focus.

Technical quality and realism are critical for user satisfaction, as demonstrated by Jiangxi Art Museum's high-resolution virtual environment, which benefits from the Technical Layer's advanced rendering techniques and the Equipment Layer's robust hardware (Figure 1). Conversely, low-quality visuals and unfriendly interfaces at Gansu Provincial Museum and Guangxi Museum of Nationalities detract from the user experience, highlighting deficiencies in the Technical Layer's execution and Project Layer's usability features. The "Preparation and Design" phases of Yin's model emphasize the importance of interface design and technical quality, which Table 3 addresses by recommending optimizations in rendering pipelines and intuitive UI frameworks. These improvements ensure seamless, immersive experiences that meet user expectations.

User feedback mechanisms, as exemplified by the Guangdong Museum of Art's social features, are pivotal for fostering community engagement. The Project Layer's support for likes and comments, combined with the Technical Layer's cloud-based platforms, enables real-time interaction that aligns with the "Share" phase of Yin's model. Table 3 extends this approach by recommending feedback channels like surveys and comment systems across virtual museums, enhancing personalization and user involvement. Similarly, accessibility and user-friendliness, critical for broadening access, are hindered by poor interface design in cases like Guangxi Museum of Nationalities. Table 3's suggestions to enhance Technical Layer UI frameworks and ensure Equipment Layer device compatibility address these issues, aligning with Yin's "Preparation and Design" phases to create inclusive, intuitive experiences.

By synthesizing insights from Table 2 and Table 3 within the VR Museum Conceptual Model and Yin's framework, this study systematically addresses deficiencies in virtual museum experiences. The model's layered structure—Equipment Layer for hardware accessibility, Technical Layer for rendering and interface quality, and Project Layer for interactive and social functionalities—provides a roadmap for transforming passive information displays into dynamic, user-centric platforms. For example, combining high-resolution rendering (Technical Layer) with gesture-based interactive exhibits (Project Layer) and advanced VR hardware (Equipment Layer) creates immersive, engaging experiences that meet modern educational needs. These enhancements, as depicted in Figure 1, position virtual museums to fulfill their potential as innovative tools for cultural engagement and learning.

4. Conclusions

This study analyzes several Chinese virtual museums, identifying key challenges in their educational functionality, including limited interactivity, low user engagement, and inconsistent technical quality. While virtual museums demonstrate some potential for immersive experiences, the findings reveal that their educational impact is restricted by a lack of interactive design, feedback mechanisms, and technical standards.

The study recommends that future development of virtual museums shift from a primary focus on knowledge dissemination to emphasizing user interaction and immersive experiences, with a focus on introducing feedback mechanisms and improving technical quality. By systematically addressing these areas, virtual museums could become more engaging and educationally effective, offering a richer artistic learning experience and fostering both artistic literacy and creativity.

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request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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