Enhancing Cultural Learning Through Innovative Technology: A VR Application for Museum Keris Nusantara

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Abstract

This study presents the design, implementation, and evaluation of an Android-based Virtual Reality (VR) application developed to enhance cultural learning at Museum Keris Nusantara, Surakarta. The application serves as an innovative educational tool that allows users to explore the museum in an immersive 3D environment, interact with virtual keris artifacts, and access detailed information through integrated visual and audio features. A Research and Development (R&D) approach was employed, guided by the Waterfall model, which includes five sequential phases: communication, planning, modeling, construction, and deployment. The resulting VR application includes a virtual walkthrough of the museum, interactive keris visualizations, and audio-narrated explanations to support user engagement and knowledge retention. Feasibility of the application was evaluated across five key dimensions: functional suitability, performance efficiency, portability, usability, and multimedia learning effectiveness. The results demonstrate high feasibility in all aspects: functional suitability scored 100%, performance efficiency showed smooth interaction and low latency, portability was confirmed through compatibility across various Android devices, usability yielded a strong satisfaction score of 84.25%, and multimedia effectiveness was rated highly, with media presentation scoring 94% and content accuracy 89%. These findings underscore the value of VR as an effective medium for informal cultural education. The study contributes to the growing body of research on the implementation of immersive technologies in educational settings, particularly in the context of cultural heritage preservation.

Keywords: virtual reality, Museum Keris, cultural learning

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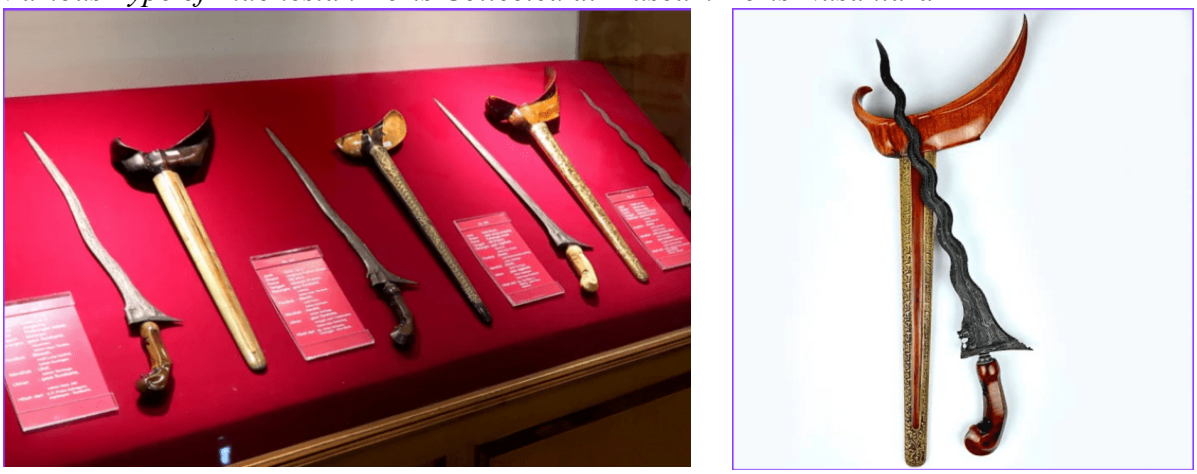
Introduction

Indonesia's rich cultural heritage is a source of national pride, with the *keris* standing out as a symbol of spiritual, historical, and artistic significance. As a UNESCO-recognized Masterpiece of the Oral and Intangible Heritage of Humanity, the keris is not merely a weapon, but an artifact that embodies cultural values, mythology, and craftsmanship unique to the Indonesian archipelago. Institutions like Museum Keris Nusantara in Surakarta play a vital role in preserving and educating the public about this heritage. However, traditional museum formats often fail to capture the attention of younger, tech-oriented generations, who tend to engage more with digital content than with conventional exhibits (Nurhadi et al., 2014).

Figure 1
Various Type of Indonesian Keris Collected at Museum Keris Nusantara



The core problem lies in the widening gap between traditional heritage education and modern learning preferences. Most keris-related learning is limited to static displays or textual descriptions, often presented in outdated formats (Marcellino et al., 2022). This limits experiential learning and fails to cultivate deep cultural appreciation among students and casual visitors. Virtual Reality (VR), with its immersive capabilities, has emerged as a promising solution. It offers a dynamic, interactive environment where users can explore artifacts up close, enhancing engagement, emotional connection, and knowledge retention (Sooai et al., 2017).

Recent research supports the use of VR to teach intangible heritage like the keris in ways that resonate with young learners. A VR training initiative in an elementary school in Semarang found that more than 80% of students reported increased interest and understanding after engaging with a keris-themed VR application (Naryanto et al., 2023). Similar applications have been developed in Malaysian museums focusing on traditional weapons such as the keris, proving effective in teaching through non-immersive VR formats (Samah et al., 2021). These findings reinforce the urgency to modernize museum learning through technological integration.

Additionally, the use of design thinking in virtual museum development offers user-centric innovation that meets the needs of modern learners. By focusing on empathy and iterative prototyping, VR-based learning experiences can be tailored for clarity, emotional engagement, and usability (Yudhanto et al., 2022). Projects like Museum Maya Indonesia, which integrates VR with 3D photogrammetry and interactive infographics, have shown high

appeal among students in rural areas with limited museum access (Noviana et al., 2024). Meanwhile, national-level projects such as ImersifA utilize 360-degree installations to deliver immersive narratives, increasing museum reach and educational effectiveness (Adiba et al., 2025).

Studies in other cultural domains, such as Batik and Ulos preservation, have also demonstrated the effectiveness of immersive learning tools. AR and mixed reality applications designed to teach Batik motifs and Ulos weaving traditions not only increased awareness but also drove public recognition and youth participation (Anshari, 2020; Halim et al., 2024). These successful case studies suggest that VR for keris education is not only viable but necessary to keep cultural learning relevant and engaging.

Figure 2

Museum Keris Nusantara Located in Surakarta, Indonesia

Given this context, the purpose of this study is to develop and assess a VR-based application tailored for Museum Keris Nusantara, aiming to enhance the educational experience for visitors—especially students and youth. The research seeks to (1) identify the specific challenges in keris education at the museum, (2) apply user-centered design principles to develop an immersive VR learning tool, and (3) evaluate its effectiveness in improving user engagement, cultural understanding, and learning outcomes. By addressing these aims, this study contributes to ongoing efforts in digital cultural preservation while offering a scalable model for VR-based heritage education. It is expected that such innovation will not only revitalize interest in traditional artifacts like the keris but also inspire broader use of immersive media in cultural institutions across Indonesia and beyond.

Literature Review

Virtual Reality (VR) has increasingly been recognized as a powerful educational tool, particularly in the context of cultural learning. Its immersive qualities allow users to engage deeply with intangible heritage, offering experiential learning opportunities that traditional museum formats often lack. Scholars have highlighted the potential of VR to present cultural artifacts in interactive, accessible, and emotionally resonant ways that enhance knowledge retention and visitor engagement (Rahman et al., 2024; Syahrial & Suparman, 2017).

In Indonesia, the keris serves not only as a traditional weapon but as a cultural symbol infused with historical and spiritual meaning. However, public understanding of the keris remains limited, largely due to its insufficient representation in formal education and

traditional museums. To bridge this gap, researchers have explored multimedia solutions such as Augmented Reality (AR) and VR. The "Keris Magic Book," for example, merges print media with AR to create interactive learning tools for teenagers (Nurhadi et al., 2014), while other studies focus on AR-based Android apps that bring keris models into users' physical environments (Marcellino et al., 2022).

A notable application of VR in keris education was developed by Universitas Negeri Semarang, where virtual environments were used to train elementary school students on keris culture. Post-intervention assessments revealed significant improvements in cultural knowledge and enthusiasm, with over 80% of students expressing positive reactions to the VR medium (Naryanto et al., 2023).Complementary research at Museum Keris Nusantara explores design thinking as a methodological approach for creating VR applications that respond to user needs through iterative development and empathy mapping (Yudhanto et al., 2022).

Beyond keris education, numerous Indonesian initiatives have demonstrated the impact of VR and AR in preserving broader cultural elements. "Museum Maya Indonesia" integrates 3D photogrammetry and immersive environments to support cultural learning, especially for students in remote areas (Noviana et al., 2024). Likewise, the "ImersifA" initiative employs video mapping and VR tours to enhance digital cultural memory in national museums (Adiba et al., 2025).

Other sectors have adopted similar techniques to preserve and teach traditional textiles and rituals. For instance, an interactive mixed-reality museum project focused on Ulos Batak demonstrated the effectiveness of immersive learning in promoting endangered cultural crafts (Halim et al., 2024), while AR apps were used to introduce Batik in museums, enhancing visitor interaction and motif recognition (Anshari, 2020).

Cross-comparative studies suggest that immersive museum installations significantly outperform traditional displays in visitor engagement, especially among youth and digital natives. The "Jelajah Bahari" VR game at Museum Bahari in Jakarta exemplifies how gamification in VR can drive curiosity and comprehension of maritime history (Arief et al., 2025). Moreover, museums in Malaysia have adopted non-immersive VR platforms to adapt to post-COVID tourism trends, showcasing how even limited forms of VR can support cultural education when physical access is restricted (Samah et al., 2021).

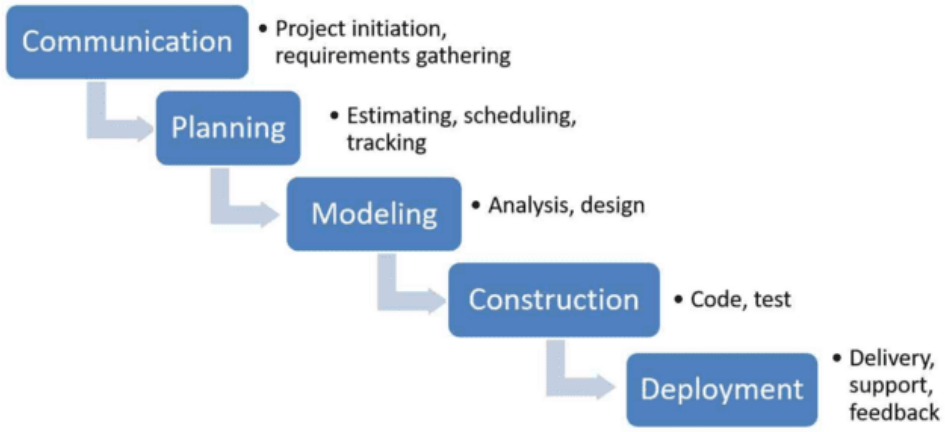
Even visitors' expectations for museum experiences are evolving. According to a survey on VR preferences among museum-goers in Indonesia, audiences now anticipate more interactive and immersive experiences in alignment with the global trend toward digital transformation in cultural institutions (Widharsyah et al., 2024). Complementary research affirms that educational VR environments not only improve memory and understanding but also increase motivation among students when cultural topics are integrated with local wisdom, such as among Baduy communities in Banten (Adiputra et al., 2024).

Together, these findings affirm the transformative potential of VR in the museum context. As museums evolve into learning spaces that emphasize interaction, personalization, and emotional engagement, VR-based applications emerge as indispensable tools in cultural education—especially in a country as diverse and tradition-rich as Indonesia.

Methodology

This study applied a Research and Development (R&D) approach to design, implement, and evaluate a Virtual Reality (VR) application for enhancing cultural learning at Museum Keris Nusantara in Surakarta. The development process followed the Waterfall model, a structured and sequential software engineering methodology. The Waterfall model was chosen for its linear flow and systematic phases, allowing each stage to be completed before moving on to the next. This ensured that the VR application could be built with clarity, consistent documentation, and stable integration of multimedia features. The process included five primary stages: communication, planning, modeling, construction, and deployment.

Figure 3
Waterfall Process Model (Pressman & Maxim, 2015)



In the communication phase, data was collected through informal interviews and consultations with cultural experts, museum curators, and educators. This stage aimed to define user needs and content requirements for representing the keris accurately and engagingly. These consultations also informed decisions about which types of keris to include, the level of historical detail to provide, and the educational goals of the application.

During the planning phase, the technical and functional design of the VR system was outlined. The team developed storyboards, navigation flowcharts, object interaction diagrams, and script outlines for bilingual audio narration. Planning also covered considerations for user interface (UI) clarity, mobile compatibility, and optimal user flow through the virtual museum environment.

In the modeling phase, visual and technical assets were created. 3D models of various keris artifacts were designed using Blender, while Unity was used to build the interactive virtual environment. Each model was linked to narration triggers, allowing users to receive historical and philosophical explanations in both Indonesian and English. Hotspots and guided paths were designed to simulate the natural flow of visiting the actual museum.

Figure 4

Unity 3D Software as the Main Development Engine

The construction phase the entire VR environment was developed using Unity 3D, a powerful and widely used game engine for immersive and interactive applications. Unity was selected for its flexibility, cross-platform deployment capabilities, and built-in support for stereoscopic rendering required for VR experiences. This phase also integrates all assets into a functioning VR application. This Android-based application featured immersive 360° walkthroughs, object manipulation (zoom, rotate), and contextual storytelling. The system was optimized for performance efficiency and low latency on various Android devices to ensure smooth interaction. Audio and visual content were embedded to support multimedia learning and improve cultural knowledge retention.

Finally, in the deployment phase, the VR application was tested and evaluated in real-world conditions. Field trials were conducted at Museum Keris Nusantara, where users interacted with the system using VR-compatible Android smartphones. These trials generated data for empirical analysis and iterative refinement of the application.

The feasibility and effectiveness of the VR application were evaluated using five key dimensions: functional suitability, performance efficiency, portability, usability, and multimedia learning effectiveness. These criteria were adapted from ISO/IEC 25010 software quality standards and multimedia learning frameworks.

Participants in the study included subject matter experts, developers, and general users. Purposive sampling was used to recruit 5 cultural and technical experts for expert validation, 10 multimedia developers for internal testing, and 30 museum visitors between ages 15 and 25 for field testing and survey completion. This range of participants ensured both content accuracy and user-centered design effectiveness.

Data collection methods included expert validation forms, performance logs, cross-device compatibility testing matrices, and structured questionnaires. The questionnaires consisted of Likert-scale items adapted from existing VR usability research, alongside open-ended prompts to gather user feedback. Quantitative data from these instruments were analyzed using descriptive statistics, including mean scores and percentage ratings, while qualitative responses were thematically analyzed to identify areas for content improvement and interface refinement.

Through this structured R&D process and comprehensive evaluation, the study was able to assess the feasibility of VR as a medium for informal cultural education in a museum context.

The findings support the continued development of immersive technology for heritage learning, particularly in regions with rich, underrepresented cultural assets such as the keris.

Results and Discussion

The evaluation of the Android-based Virtual Reality (VR) application for Museum Keris Nusantara was conducted across five key dimensions: functional suitability, performance efficiency, portability, usability, and multimedia learning effectiveness. In addition to these formal measurements, this section presents an in-depth overview of the main features integrated into the application, including immersive navigation, keris artifact interaction, audio narration, and video documentation of traditional keris ceremonies. These features are central to the success of the application in delivering an engaging and educational virtual museum experience.

Figure 5
The Affordable Hardware for the VR Using VR-Box

The application was built to closely simulate the spatial layout of the actual Museum Keris Nusantara in Surakarta. Upon launching the app, users enter a stylized VR lobby displaying a virtual banner that reads “Museum Keris Nusantara,” along with a “Mulai Tour” (Start Tour) button. Navigation inside the app uses a guided pathway system designed to mimic the visitor flow through the museum’s exhibition halls. Using head movement and simple controls via the VR-Box controller, users can move between rooms and exhibits. The immersive design replicates the real museum layout, including virtual showcases, wall texts, wooden structures, and display glass cases, giving users the sense of being physically present in the gallery.

Figure 6
Main Menu and Short Description for Each Keris

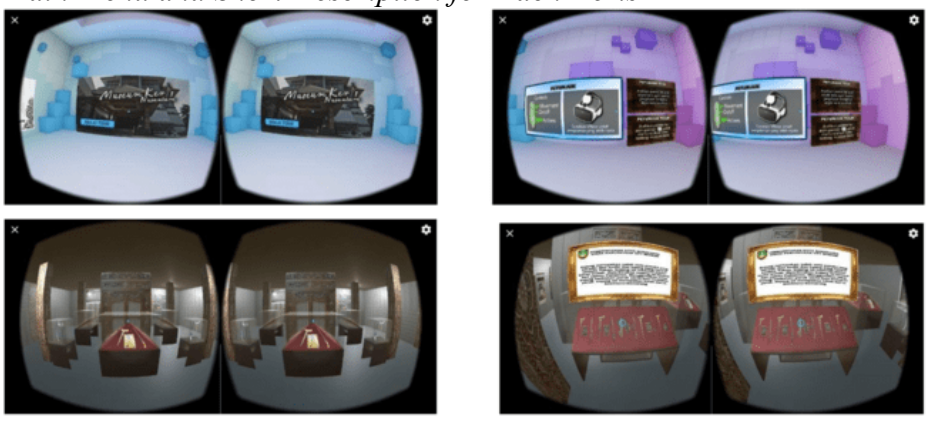
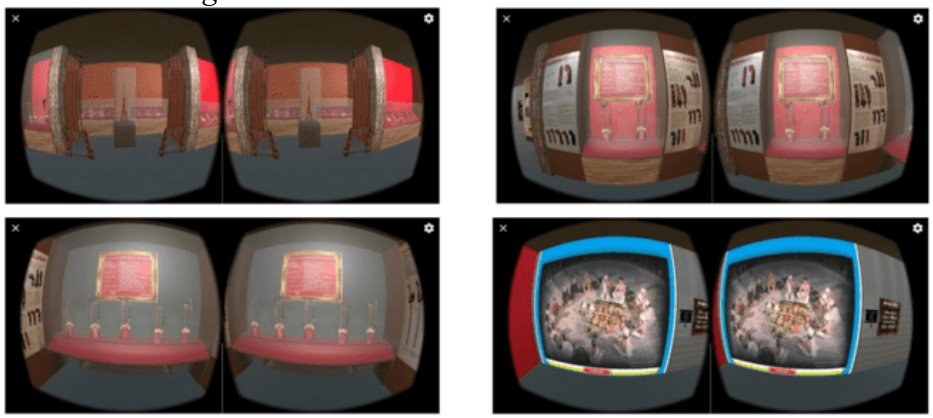


Figure 7

Immersive Design as Close as Possible With the Real Museum and Video Explanation



Each exhibit within the virtual museum features detailed 3D models of keris artifacts, arranged according to real curatorial displays. When users hover over or gaze at an object, interactive panels appear, presenting descriptions of the keris's origin, function, symbolism, and regional variation. These descriptions are presented in both visual text and bilingual audio narration, providing multimodal support for learning. The narration was developed in collaboration with museum experts to ensure historical and philosophical accuracy. This allows users not only to see and read about the keris but also to hear context-rich stories that reinforce cultural understanding.

Another key component is the video integration feature, which plays traditional documentation of keris-related ceremonies from different Indonesian regions. For instance, one immersive video showcases the Jamasan (ritual cleansing of keris) performed in Central Java, while another presents a Bugis ritual where the keris is used during sacred communal events. These video features are embedded inside virtual media screens placed within exhibition rooms, allowing users to sit, watch, and absorb ceremonial practices as if attending an in-person museum screening. The videos further deepen user appreciation of how the keris continues to play a role in cultural rituals today.

All features were designed to operate through a simple, low-cost VR-Box headset, which makes the experience accessible to a wide audience, including schools and communities with limited access to high-end VR systems. The headset allows smartphones ranging from 3.5" to 6" to be inserted into the device and aligns the display into stereoscopic view. The system supports interaction via Bluetooth controller or gaze-based input, ensuring that even users with no prior VR experience can navigate easily. The use of VR-Box emphasizes scalability and affordability, making it suitable for educational deployment on a national level.

In terms of empirical results, the application achieved 100% functional suitability, with all intended features running as planned during evaluation. Performance efficiency was validated through smooth scene transitions, quick object loading, and low system latency. Portability was proven through compatibility testing across various Android smartphones. Usability, measured through a System Usability Scale (SUS) questionnaire, yielded an average satisfaction score of 84.25%, confirming ease of use, intuitive interaction, and visual clarity. The multimedia learning effectiveness component also performed highly, with expert ratings of 94% for media presentation and 89% for cultural content accuracy.

These findings strongly support the conclusion that the VR application not only meets technical and educational benchmarks but also provides an immersive, accessible, and meaningful tool for informal cultural education. The combined presence of interactive keris models, narrated explanations, immersive museum navigation, and ceremonial video viewing makes the experience both comprehensive and culturally rich. It also demonstrates that heritage learning can be democratized through simple, cost-effective technologies like VR-Box—offering a model for other museums and educational institutions to follow.

Conclusion

This study aimed to design, implement, and evaluate an Android-based Virtual Reality (VR) application to enhance cultural learning experiences at Museum Keris Nusantara, Surakarta. The development followed a structured Research and Development (R&D) process using the Waterfall model, with clearly defined stages: communication, planning, modeling, construction, and deployment. Through this process, a functional and immersive VR museum application was successfully created using Unity 3D, featuring interactive keris models, guided narration, traditional ceremony videos, and a spatial navigation system that closely replicates the layout of the physical museum.

The evaluation results showed that the application performed highly across all feasibility dimensions. Functional suitability scored 100%, with all planned features implemented as intended. Performance efficiency was validated through low-latency interaction and smooth rendering on Android smartphones. The system demonstrated strong portability, operating reliably on multiple devices and screen sizes. Usability, based on participant feedback, achieved a satisfaction score of 84.25%, while multimedia learning effectiveness scored 94% in media presentation and 89% in content accuracy. These results confirm that the application is both technically sound and pedagogically effective as a tool for informal cultural education.

The inclusion of immersive features such as 3D walkthroughs, object interactivity, audio narration, and culturally contextual videos enhances engagement, understanding, and memory retention. Importantly, the use of low-cost VR-Box headsets ensures that the experience is accessible to a wide audience, including schools, cultural institutions, and rural communities. This approach demonstrates how immersive technology can democratize access to heritage learning and play a significant role in preserving and promoting Indonesia’s cultural identity.

Recommendation

To further improve the VR application for Museum Keris Nusantara, several recommendations are proposed. First, the content can be expanded by including other traditional Indonesian artifacts to provide a more comprehensive cultural experience. Adding more language options, such as local dialects or subtitles, would increase accessibility and inclusivity for diverse users. Integrating Augmented Reality (AR) features could also make the app more flexible for use without a VR headset, particularly in classroom settings.

Gamification elements—such as quizzes or interactive challenges—are recommended to boost user engagement, especially among younger audiences. An offline version of the app would be valuable for areas with limited internet access, ensuring broader usability. Collaborating with schools to integrate the application into cultural education curricula would

enhance its educational impact. Finally, this model could be adapted for other museums across Indonesia, forming a network of virtual heritage experiences to promote national cultural preservation through digital innovation.

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