eISSN: 2654-4687
pISSN: 2654-3894
jithor@upi.edu
http://ejournal.upi.edu/index.php/Jithor
Vol. 9, No. 2, October 2026

Journal Of Indonesian Tourism, Hospitality and Recreation

Developing bilingual Augmented Reality (AR) to enhance visitor experience at Brawijaya Museum

Novitasari[1*], Tri Astuti Handayani, Candrika Citra Sari, Dhimas Dwi Nugraha Hadistya, Yanik Lailinas Sakinah, Noverita Wahyuningsih

[*]Politeknik Negeri Malang, Indonesia

novitasari@polinema.ac.id[1] , triastuti30@polinema.ac.id , candrika.citra@polinema.ac.id, dhimasdwinugraha@polinema.ac.id, yanik.lailinas@polinema.ac.id, noverita@polinema.ac.id

Article Info

Submitted,
24 Januari 2026
Revised,
30April 2026
Accepted,
1 October 2026

Keywords:
Augemnted reality;
Brawijaya Museum;
Death Carriage;
Visitor Experience

ABSTRACT

Museums play a pivotal role as centers for preserving regional history and culture. Museum Brawijaya, one of the local museums in Malang City, houses a rich collection with significant historical value related to the nation's struggle. Although the collections are appealing, the presentation and delivery of collection still rely on traditional methods, such as static labels and guide explanations, which are less effective in engaging younger visitors who are familiar with digital technology. Moreover, the presence of international visitors highlights the importance of providing museum information in more than one language. Therefore, this study aims to develop a bilingual Augmented Reality (AR) as an interactive educational tool at Museum Brawijaya, focusing on the Gerbong Maut collection to enhance both domestic and international visitors' experiences. This study employed a Research and Development (R&D) approach with ADDIE model, encompassing the stages of Analysis, Design, Development, Implementation, and Evaluation. Field testing involving 132 visitors demonstrated improved visitor understanding (mean = 4.30), enhanced visitor experience (mean = 4.26), and high overall usability. Although the bilingual AR media received positive responses, further technical refinements are recommended to enhance device compatibility and system stability.

Kata Kunci:
Augmented reality;
Museum Brawijaya;
Gerbong Maut;
Pengalaman Pengunjung

ABSTRAK

Museum memiliki peran penting sebagai pusat pelestarian sejarah dan budaya suatu daerah. Museum Brawijaya, sebagai salah satu museum lokal di Kota Malang, memiliki koleksi yang kaya dengan nilai sejarah yang signifikan terkait perjuangan bangsa. Meskipun koleksinya menarik, penyajian dan penyampaian informasi koleksi masih bergantung pada metode tradisional, seperti label statis dan penjelasan pemandu, yang dinilai kurang efektif dalam melibatkan pengunjung muda yang akrab dengan teknologi digital. Selain itu, keberadaan pengunjung mancanegara menegaskan pentingnya penyediaan informasi museum dalam lebih dari satu bahasa. Oleh karena itu, penelitian ini bertujuan untuk mengembangkan Augmented Reality (AR) dwibahasa sebagai media edukasi interaktif di Museum Brawijaya, dengan fokus pada koleksi Gerbong Maut guna meningkatkan pengalaman pengunjung domestik maupun mancanegara. Penelitian ini menggunakan pendekatan Research and Development (R&D) dengan model ADDIE yang mencakup tahap Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi. Uji lapangan yang melibatkan 132 pengunjung menunjukkan peningkatan pemahaman pengunjung (rerata = 4,30), peningkatan pengalaman kunjungan (rerata = 4,26), serta tingkat kemudahan penggunaan yang tinggi. Meskipun media AR dwibahasa mendapatkan respons positif, penyempurnaan teknis lebih lanjut masih diperlukan untuk meningkatkan kompatibilitas perangkat dan stabilitas sistem.

D.O.I:
https://doi.org/10.17509/jithor.v9i2.96405

INTRODUCTION

Museums play a crucial role in preserving culture and informal community education. As explained by the Ministry of Education and Culture of the Republic of Indonesia (Kemendikbud), museums are not only repositories for ancient and historical artifacts but also fundamental learning resources for the community. This function provides visitors, especially students, with the opportunity to directly understand history and culture through interaction with the artifact collections (Peraturan Pemerintah (PP) Tentang Museum No. 66 Tahun 2015, 2015). This informal educational function also includes developing creative, logical, critical, and appreciative thinking skills for the nation's cultural heritage. Museums also serve as arenas for history learning, where the historical value of the artifacts on display can motivate visitors to explore unique concepts through digital-based approaches such as Augmented Reality (Chen & Lai, 2021).

Despite their crucial role in education, museums have seen a decline in their appeal. Indonesia hosts numerous museums; however, public interest in visiting them has decreased in recent years (Ristawati et al., 2025). Younger generations often perceive museums as irrelevant and boring. Younger generations are less interested in visiting museums due to their dull displays and the lack of innovation in presenting the information (Patricia & Soeprapto, 2023). Furthermore, most museums in Indonesia have not yet adopted engaging and interactive digital technology, leading to a monotonous experience for visitors (Fattah et al., 2021). These museums often display artifacts and objects in traditional ways, which are considered less engaging for visitors accustomed to digital and interactive experiences in their daily lives.

Similar challenges are faced by several museums in Indonesia, including Brawijaya Museum. This museum is a historic museum that houses important collections related to the Indonesian independence struggle and is a destination for educational and historical tourism in the city of Malang. The museum houses a large collection of weapons and war transportation rich in the heroic history of the heroes during the Indonesian independence era. However, like most other museums, Brawijaya Museum faces various obstacles and has not fully adopted modern technology. Based on interviews with museum managers, not all museum collections have descriptions containing information related to the collection. Collection descriptions available in the museum are also only posted and still use one language, Indonesian or English. Some collections also provide QR codes that can be scanned and visitors can access audio containing descriptions of the collection; unfortunately, the audio descriptions are only in one language, English. Furthermore, Brawijaya Museum has not yet utilized AR technology, which provides audiovisuals in three-dimensional form and is also presented in bilingual, thus enhancing the visitor experience, for both local and international tourists. Therefore, it can be concluded that Brawijaya Museum requires significant updates, both in terms of its appearance, information delivery media, and language accessibility.

To address this issue, Augmented Reality (AR) technology can be considered as a solution. AR is a technology that enables the integration of virtual objects into the real world, providing an immersive and interactive experience for users (Perra et al., 2019). In the context of museums, AR allows visitors to view museum collections in 3D and obtain additional information through engaging visual displays. In addition to visual

displays, visitors can also listen to information from AR technology accessed through their devices. Besides being engaging, technology can provide a complete and detailed picture of museum objects, especially for museum objects that are no longer intact. In the last ten thousand years, more than 90% of cultural heritage objects have disappeared, and many of those found are damaged and incomplete (Boboc et al., 2022). Therefore, by using AR technology, objects that are no longer intact can be reconstructed and visitors can see them in their intact state.

Furthermore, this technology provides greater opportunities to enhance museum appeal and attract visitors, especially younger generations such as Generation Z and Alpha, who are more interested in digital approaches. AR in museums can enhance the learning experience, attract more visitors, and extend the duration of their visits (Boboc et al., 2022). Mubarok et al. (2023) also stated in his research that AR provides an immersive and interactive learning experience, so that students are more engaged and motivated compared to traditional methods. Innovations based on Augmented Reality (AR) technology can increase the appeal and effectiveness of learning in museums, especially in the current digital era. This research aligns with the principles of Tourism 5.0, which not only prioritize the use of technology but also emphasize meaningful tourism experiences (Vujičić et al., 2024). The use of bilingual AR at the Brawijaya Museum is a concrete application of the principles of Tourism 5.0, which integrate technology to create an inclusive, humanistic, and interactive tourism experience.

Based on visitor data in 2024, the Brawijaya Museum received approximately 14,947 visitors. The majority of visitors were students, university students, and study tour groups from various educational institutions. In 2024, there were 195 international visitors, the majority of whom were from the Netherlands. Interviews with museum guides revealed that museum guides lacked strong foreign language skills, thus preventing them from providing optimal assistance. It can be concluded that language barriers are also a significant issue that must be addressed, as the Brawijaya Museum is also visited by international tourists. Providing information in multiple languages to facilitate understanding for foreign visitors is essential. In this regard, the application of AR technology with bilingual features can be a very effective solution.

AR technology allows museums to provide information in both Indonesian and English, allowing international visitors to enjoy a more inclusive visiting experience. This bilingual feature not only helps visitors understand the museum's collections but also broadens the museum's appeal to a wider audience, including younger generations who are more accustomed to technological approaches. By integrating AR technology that supports bilingual features, museums can become more inclusive and relevant to the needs of modern society. Therefore, this study aims to develop bilingual AR to enhance the visitor experience at the Brawijaya Museum, making it more interactive. By integrating AR, the Brawijaya Museum has a significant opportunity to increase its appeal, not only to local but also to international tourists.

In the development of museums in Indonesia, the implementation of bilingual AR is still very limited, so this study offers an innovation that not only increases accessibility for domestic and international visitors, but also positions the Brawijaya Museum as a museum that implements immersive technology. Most AR applications in Indonesia only use one

language, namely Indonesian. However, this study offers a bilingual feature (Indonesian and English), which allows the museum to reach international visitors, while providing a broader educational experience for domestic visitors. The research on the development of bilingual AR at the Brawijaya Museum is in line with the vision of Society 5.0, namely utilizing digital technology to increase the relevance of museums in the modern era (Nabillah et al., 2024). By integrating bilingual AR, this study offers an innovative solution to address the challenges of changing interests of the younger generation, increase accessibility, enrich the visitor experience, and support cultural preservation in the era of globalization.

Bilingual AR can provide an interactive and enjoyable learning experience, bridging the gap between physical cultural heritage and the digital world. This research supports the transformation of museums in Tourism 5.0 and in the era of Society 5.0, where technology is used to address the needs of the digital generation, while expanding the function of museums as modern and inclusive centers for education and cultural preservation. The application of AR in museums such as the Brawijaya Museum is expected to increase the number of visitors, extend the duration of visits, and strengthen the role of museums as centers for learning and cultural preservation that are relevant in this digital era. This is in line with the Ministry of Education and Culture's vision to make museums dynamic, interactive, and inclusive learning facilities (Peraturan Pemerintah (PP) Tentang Museum No. 66 Tahun 2015, 2015).

Based on the research background, the research questions are as follows:

1. What are the needs and challenges related to the presentation of collection information at Museum Brawijaya?
2. How is bilingual Augmented Reality (AR) media developed based on the ADDIE model?
3. What are the feasibility results and visitor responses to the developed bilingual Augmented Reality (AR) media?

LITERATURE REVIEW

Augmented Reality (AR) technology has developed rapidly and is being utilized in various fields, including tourism and museum education. Kolstee (2011) emphasized that this method is highly effective in enhancing experiences with cultural heritage. The interactive experience offered is a smart solution for visitors to easily enjoy all the information available in the museum. Language barriers for both local and international visitors are a major challenge in utilizing AR in museums. Therefore, the use of bilingual AR development is a potential solution to increase visitor engagement and understanding at the Brawijaya Museum.

Several studies have examined the role of AR in enhancing visitor experiences in various museums. Djamil & Sulistyo, (2023), Saputra et al. (2022); Solechan et al. (2024), Horhoruw et al., 2023; Cibilić et al., 2021; Fitriani et al. (2022), Jiman & Kulal (2023), Bernarduzzi et al. (2021), and Khan et al. (2021) have developed AR as a technology-based tool that complements the real world with computer-generated virtual objects, appearing in the same space as the real world. From these studies, it can be concluded that this new technology is very useful in sharing content and context efficiently and effectively with visitors in museums.

The interpretation of the development of AR as a medium to

enhance the visitor experience has also been successful in improving tourism marketing. The current generation is highly dependent on technology and the internet, making AR capable of becoming a new breakthrough for developing museums and improving marketing (Istina, 2022). Jung et al. (2016) revealed that there are social and economic impacts when applying technology-based media such as AR. The most significant social impacts are on educational experiences, entertainment experiences, escape experiences, and aesthetic experiences.

According to Bernarduzzi et al. (2021), the use of digital technology has proven crucial for both external and internal communication. AR applications also create a more lively and active museum experience, making it more engaging for museum visitors. Khan et al. (2021) conducted a study entitled "Using augmented reality and deep learning to enhance the Taxila Museum experience." This study integrated AR to bridge the gap between the museum's historical collections and the visitor experience. The results of Khan et al.'s study indicate that digitization in modern museums, particularly the use of AR applications, has successfully bridged the gap between visitors and museum collections. The use of AR applications significantly increased engagement, meaningful experiences, and emotional connections compared to museum visits without AR applications. Unfortunately, this study did not address the use of language in AR applications at the Taxila Museum. This study focused solely on integrating museum artifacts into multimedia content accessible to museum visitors.

Although several research have been conducted on the development and implementation of AR in museums, few have focused on developing AR that supports more than one language. The use of more than one language will accommodate international visitors. Furthermore, previous research has focused more on interactive experiences without considering linguistic factors as a key factor in conveying historical information. Therefore, based on the great potential of AR technology in increasing museum visitors, the current research will combine it with bilingual features in museums. This research is expected to make a significant contribution to the field of technology-based museum education.

RESEARCH METHOD

This study employs Research and Development (R&D) using the ADDIE model by Branch (2009) which consists of several phases: Analyze, Design, Develop, Implement, and Evaluate. Research and Development (R&D) was selected because this study aimed to develop a product and evaluate its feasibility rather than merely examine existing phenomena. In addition, The ADDIE model was chosen because it provides a systematic and flexible framework for developing educational and digital media, allowing continuous revision at each stage.

The product developed in this study was a bilingual Augmented Reality (AR) application for Brawijaya Museum. The research procedure is briefly depicted in the following figure:

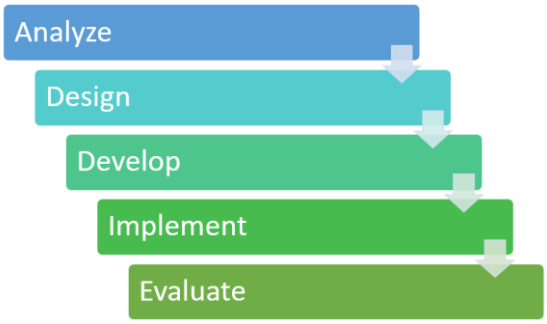

Figure 1. Research Procedure

In the analyze phase, the problem and the need were identified through interview with the museum staff. This

phase aimed to understand the existing condition of information delivery and the expectations of the target users. The results of this analysis served as the basis for designing the bilingual product in the design phase.

Based on the results obtained in the analyze phase, a storyboard design was created by presenting visuals accompanied by explanations related to the visuals. In addition, an explanatory script or information related to the museum collection used to provide voiceovers in the AR being developed will also be written in the storyboard.

In the develop phase, the prototype of Augmented Reality was developed. The voice over with bilingual audios (Indonesian and English) was integrated in the system. After the product had been developed, while still in the development stage, it was evaluated by three experts from two different disciplines: (1) a language expert, who reviewed the linguistic aspects, particularly the bilingual narratives related to the collections as well as the quality and clarity of the oral narration; and (2) an IT expert, who assessed the visual appropriateness and the practicality of accessing the AR. Following the expert validation, revisions were made based on the feedback provided.

After going through the development phase, the product was implemented directly. QR codes was placed in museum collections, then museum staff and several visitors will be asked to scan the QR code to access the AR related to the collection. In the final phase, the visitors were asked to give some feedback on AR performance. An evaluation is carried out based on the implementation results.

Data were collected through interview to identify the museum needs based on the perspective of museum staff, expert validation to assess the quality of the AR, both in terms of verbal narrative information and design, and user-friendliness in accessing information from the AR (Augmented Reality) being developed, and survey through questionnaire which was distributed to visitors to determine user assessments regarding the ease of accessing and understanding the information within the AR.

This study employed a mixed-methods approach, in which both qualitative and quantitative data were collected and analyzed to obtain a comprehensive understanding of the research findings. Qualitative data were analyzed descriptively, while quantitative data were analyzed using descriptive statistics. Qualitative data obtained through interviews and open ended questionnaire were analyzed using thematic analysis theory (Clarke & Braun, 2017). In this theory, qualitative data is analyzed to identify keywords, then themes are developed based on these keywords. The keywords are then grouped into themes. Finally, the data is interpreted to develop and improve the product based on feedback.

Quantitative data obtained through expert validation and survey were analyzed using descriptive statistics to summarize the data in the form of a mean or average. This analysis is used to determine whether the product is feasible for implementation. If the score is greater than 75%, then, following the revisions provided by the experts, the product is considered suitable for user trials to obtain further feedback.

RESULT AND DISCUSSION

The findings of this study are presented and discussed based on the development phases.

Analyze

In the analyze stage, a direct visit to the Brawijaya Museum and interview with museum staff to obtain information regarding visitor profiles was conducted. Based on the summary document of tourist visits throughout 2024, the Brawijaya Museum received many visits from the public, especially students from kindergarten to university level. Although the number of foreign tourists was not as high as domestic tourists, their visits were observed to be quite consistent. Only in March were there no domestic tourist visits recorded. presents a summary of museum visitors throughout 2024.



Figure 2. Museum visitors throughout 2024

Through the interview with two staffs in the museum, the core problem of the museum was identified, namely the lack of human resource skills in communicating using foreign languages, especially English to facilitate international tourists. In addition, the lack of human resources and the continued increase in collections also mean that not all collections can be labeled with information. Then, the museum also identified the importance of the existence of technology that can be directly used by visitors to study the museum's collections independently. Based on these three problems and based on the results of previous research in which Novitasari et al. (2025) found that the existence of technology is important to improve the experience of museum visitors, the author created Augmented Reality to reconstruct the collection and provide bilingual audio, Indonesian and English so that domestic and international tourists can study the collection independently. In this study, based on the request from the museum, the procurement of AR media will focus on the Gerbong Maut collection which is one of the icons of Brawijaya Museum that has been approved by the BPCB (Cultural Heritage Preservation Agency).

Design

After conducting interviews with the guide and the head of Brawijaya Museum, it was agreed that the death carriage was the main icon representing the museum and was chosen as an AR object. In the design phase, bilingual narration scripts and AR concept were prepared. It includes designing the user interface and interaction flow, selecting appropriate visual representations of objects, and preparing bilingual textual and audio narration in Indonesian and English. In addition, instructional strategies, storytelling structure, and usability considerations are established to support an engaging, immersive, and educational AR experience, particularly in a museum context.

For the AR design of the death carriage, based on the results of the need analysis and the limitations of AR projection, it was decided to create three freight carriages, one of which is the death carriage with the number GR 19152.

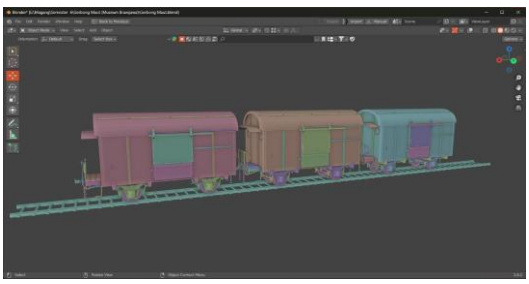

Figure 3. Three carriages design

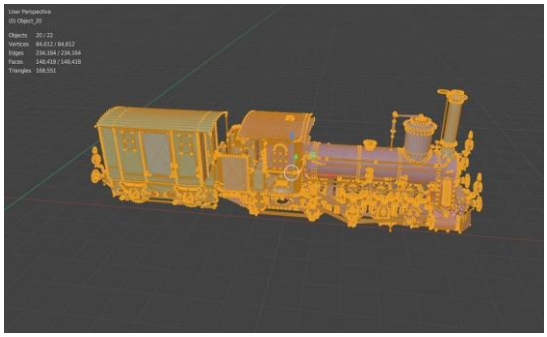

Figure 4. Locomotive design



Figure 5. The death carriage design

The next design is a tour guide, depicted as a woman and featuring a voiceover by a voice talent. The tour guide's movements are simple, consisting of hand gestures appearing on the screen. Visitors can choose to view the tour guide or the death train by tapping the screen in the app.



Figure 6.Tour guide design

A bilingual narrative script for the voice-over was also prepared. Relevant historical information was collected from several references from books and also from curator explanations. The content was first written in Indonesian to ensure accuracy and alignment with local historical context. The Indonesian script was then translated into English, focusing on clarity, cultural appropriateness, and accessibility for international visitors. Both versions were adjusted to maintain equivalent meaning, tone, and length to support effective voice-over delivery. The scripts were subsequently reviewed by expert in translation to ensure linguistic accuracy and suitability for audio narration.

Develop

This stage focuses on the development of interactive AR multimedia by integrating 3D visual representations of historical objects with audio narration to support experiential learning in museum contexts. After the script was ready, the bilingual voice-over audio was recorded and integrated into the system. For the voiceover, it has two recorded audios with the help of voice talent from the research team. The voiceover was designed in two versions, one for Indonesian and one for English, to reach both Indonesian-speaking and international visitors.

After the voice recording is completed, the recording is edited to improve clarity and a more rounded sound, allowing users to more easily hear the VO's explanations. The editing process itself is performed using the voice.ai website. The next step is embedding voice-over (VO) audio into the AR system. The research team has previously compiled and edited the audio narrative to reflect the historical context of the Death Carriage. The VO integration is designed so that visitors can hear it automatically when they scan the provided Quick Response (QR) code.

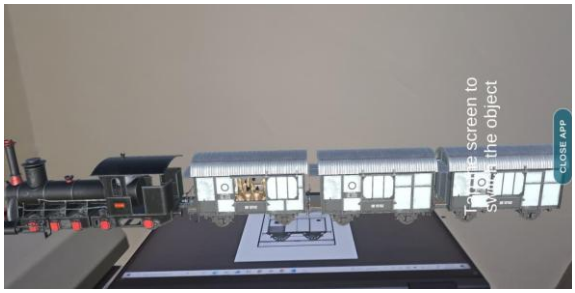

Figure 7. An AR image depicting one locomotive and three freight carriages carrying political prisoners inside.

The final stage was creating markers.

AR marker has function as markers to display AR objects. After visitors download the AR app, they can point their phone cameras at the provided markers, which will display the death train in AR format. The markers are designed with images of the death train, and there are two types: one for the Indonesian voiceover version and one for the English voiceover version.

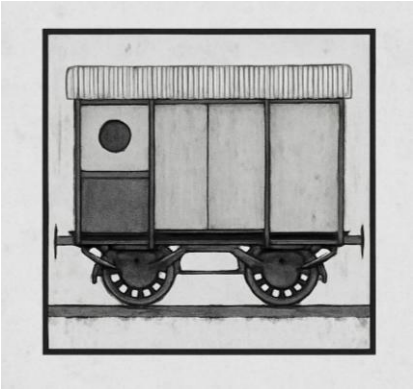

Figure 8. AR marker design: Indonesian version

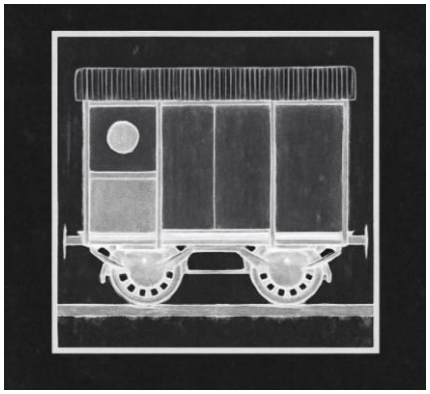

Figure 9. AR marker design: English version

To access the AR, visitors had to scan the provided marker. The marker itself was designed to resemble a train car, and there were two markers to differentiate between the Indonesian and English audio versions of the AR. After all stages were completed, the final product was handled by AR team to create an application integrating the design, voiceover, and markers for potential visitors to access.

Products that have been developed are then validated by two experts: a language expert and a media expert. Input from the experts is used to make revisions before the implementation stage. Based on validation result from the language expert, the language used in the AR product Gerbong Maut received a positive response from language expert. Out of 10 statements, the language validator gave a score of 4, indicating that the assessed aspects were in the appropriate category. However, the expert provided feedback indicating that the background music volume was too high and interfered with the clarity of the voice-over. Therefore, revisions were made to adjust the background music volume to ensure that the voice-over was clearly audible.

Based on the validation result from media expert, the developed AR demonstrated a positive response. Based on an assessment of 10 aspects, the validator awarded a score of 4 for all aspects, reflecting high validity across all

indicators. In addition, the media expert suggested adding an exit point to improve usability. Therefore, a revision was made by incorporating an exit feature into the application.

Implement

After making some revisions in previous phase, the product was implemented. The purpose of this implementation phase is to ensure that the product can be used according to its function, runs smoothly, and is easily accessible to target users.

The implementation took place near the location of the Death Carriage collection. First, a socialization session was conducted to demonstrate how to use the AR application to guides and museum staff. The session included installing the AR application, scanning markers, and displaying a 3D Death Carriage object accompanied by voice-over narration.

Museum guides and staff were asked to direct visitors to use the AR application according to the instructions. Each visitor was asked to try scanning the marker directly using a mobile device, observing the visual display, and listening to the resulting narration. Throughout the process, guides and staff observed the application's use to ensure all elements were working properly, including scanning stability, narration clarity, and visual accuracy.

The entire implementation process is documented through photos/videos and technical field observation notes, which include notes on any technical challenges that may arise during implementation. Through this implementation, a clear picture of how the product used in a real-world environment and the extent to which it performs as designed were obtained. The findings from this stage serve as the basis for further reflection and refinement if necessary.

Evaluate

The evaluation was conducted by distributing questionnaires to AR users at the Brawijaya Museum. There were two user questionnaire formats: a Google form and a printed form. Both had the same rating scale. Responses were measured using a five-point Likert scale, consisting of five rating categories: 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), and 5 (Strongly Agree). This scale was used to systematically evaluate respondents' perceptions and levels of agreement toward the statements presented in the questionnaire.

A total of 132 respondents provided ratings based on their experience using AR for the Death Carriage at the Brawijaya Museum. Of these, 120 were Indonesian citizens and 12 were foreign citizens. Based on age distribution, the 15–19 age group dominated, accounting for 78 of the total respondents.

Table 1. The Survey result

	Statements	1	2	3	4	5	mean
1.	The information in the AR helps visitors better understand Gerbong Maut collection.	2.27%	1.51%	6.06%	43.93%	46.21%	4.30
2.	The AR content provides additional information which is not available on the physical information boards.	11.36%	3.03%	15.90%	28.78%	40.90%	3.85
3.	Gerbong Maut AR enhances the museum visitor experience.	3.03%	1.15%	9.84%	38.63%	47.73%	4.26
4.	The instructions for using the AR are clear and easy to follow.	3.78%	2.27%	15.15%	37.12%	41.67%	4.11
5.	The instructions for using the AR are clear and easy to follow.	6.06%	17.42%	14.40%	34.84%	27.27%	3.60
6.	The AR installation/activation process is easy to carry out.	4.54%	14.40%	25%	31%	25%	3.58
7.	The AR application runs smoothly and does not experience significant technical issues during use.	5.30%	10.60%	18.93%	37.87%	27.27%	3.71
8.	The animation quality in the AR is very good.	0.75%	6.06%	18.93%	41.67%	32.57%	3.99
9.	The language used in the narration of the video/animation is clear and easy to understand.	3.78%	1.51%	9.09%	35.60%	50%	4.27
10.	The narration (voice over) sounds clear.	3.03%	2.27%	7.57%	38.60%	48.48%	4.27
	Total mean						39.94

Table 2. The mean range

Mean Range	Category	Interpretation
1.00 – 1.80	Strongly Disagree	Strong negative perception
1.81 – 2.60	Disagree	Moderately negative perception
2.61 – 3.40	Neutral	Moderate perception
3.41 – 4.20	Agree	Positive perception
4.21 – 5.00	Strongly Agree	Very positive perception

Based on the survey result above, it can be concluded that the majority of respondents gave positive assessments to almost all aspects measured. The mean values ranged from 3.58 to 4.30, with an overall average mean score of 4.00. Overall, these results indicate that most respondents agreed with the assessed aspects of the developed Augmented Reality (AR) application.

The highest mean score was obtained for the first item (mean= 4.30), which related to the compatibility of the AR application with users' devices. This finding suggests that the majority of respondents perceived the application to function well on their devices without significant issues. High mean scores were also observed for the ninth item (mean = 4.27) and the tenth item (mean= 4.27), which were related to the clarity of language and narration audio. This indicates that most respondents considered the narration language to be clear and easy to understand, and that the voice-over audio was audible and supportive of effective content comprehension.

Meanwhile, the lowest mean score was found for the sixth item (mean = 3.58), which assessed the ease of application installation or activation. Although this score still fell within the "agree" category, it suggests that a small number of respondents may have experienced minor difficulties during the installation or activation process, possibly due to variations in device types or specifications. Similarly, the fifth item (mean = 3.60) and the seventh item (mean= 3.71) showed comparable trends, indicating that while the application generally functioned well, improvements were still needed in terms of technical stability and ease of use. Overall, the mean analysis demonstrates that the AR application achieved a high level of acceptance among respondents.

The majority of respondents expressed satisfaction with the content, media quality, and its usefulness in enhancing understanding and the visitor experience. Most respondents gave positive responses to the app's appearance and concept. Many found the animations excellent and provided a unique experience during their visit.

"The animation is very good!" (R1)
"It enhances the visiting experience." (R21)
"The animation audio is clear. The narration is easy to understand, and the animation is not excessive, effectively conveying the story of the Death Carriage collection." (R34)
"The storytelling is very easy to understand, and the animation is also well designed." (R44)
"The AR is well developed and easy to understand." (R97)
"This AR can also attract more visitors to come directly to the museum, and it also increases knowledge." (R116)

Several foreign users also noted that the voice and use of English in the app sounded clear and easy to understand, helping them understand the information presented. Overall, many comments included "very good," "perfect," "very clear voice and easy-to-understand sentences," and "the animation and sound are very good, adding a new experience to my life that I have never encountered before," indicating that users are quite satisfied with the quality of the app.

Respondents also experienced several challenges when using AR. These challenges were relatively minor and primarily related to compatibility, app stability, and technical aspects that could be improved through further development. The most common issue was difficulty installing the app because the users' smartphones did not meet the required system specifications. Many users reported that the app was difficult to install or even impossible to install at all, especially on devices with low specifications. This highlights the need to optimize app size and performance to ensure smooth operation on a variety of phones, including those with limited RAM or processors.

In addition, several users reported that the application interface and usage procedures were still perceived as complicated. They expected the application to be simpler and more user-friendly, particularly for novice users. There were also notes indicating that the image and animation quality was occasionally unstable or unclear, which affected user comfort when using the application. Finally, users suggested adding more visual object variations to make the application more engaging and interactive.

Some suggestions and feedback from Indonesian visitors included the following:

"More animation elements should be added." (R5)
"The application should be made easier to download." (R6)
"I suggest improving the visual quality to enhance the user experience and adding more interactive features." (R36)
"The images are not very clear, and additional objects could be added to make it more interesting." (R86)
"The animation should include a pause feature so users do not need to repeat it from the beginning." (R120)

Meanwhile, international visitors provided the following feedback:

"I couldn't scan the QR code because my phone was not compatible. I use a Samsung A14. I could open the application, but it could not detect the camera." (R13)
"The application could not be installed." (R78)
"The image was unstable." (R40)

Nevertheless, not all suggestions and feedback from visitors could be accommodated in the final product. This limitation was due to several factors, including budget constraints and the

complexity of the Augmented Reality (AR) system used. Some suggestions required fundamental changes to the AR system structure, which would have necessitated restarting the development process from the beginning. Therefore, this study maintains elements that were already functional and effective while prioritizing feasible improvements within the available resources. However, suggestions that could not be implemented were documented as important considerations for future development.

The findings of this study indicated that the use of bilingual Augmented Reality (AR) was able to enhance visitors' interest and engagement, particularly among younger generations, through a more interactive and immersive learning experience. These findings are in line with Yuliantri et al. (2022), who emphasized the importance of the "museum for community" concept, which involves community participation in museum cultural activities to create a lively and participatory cultural space. Accordingly, the development of bilingual AR can be viewed as a digital strategy to realize the "museum for community" concept in the modern era. This result also supports the findings of Novitasari et al. (2025), which demonstrated that digital technology in museums plays a significant role in enhancing visitor engagement and experience, especially among younger generations who tend to be more responsive to visually interactive and digital-based media.

The development of bilingual AR media at Brawijaya Museum was not only intended to enhance learning experiences and attract younger generations' interest in national history, but also to establish a tangible form of collaboration between university academics and museums as part of a mutually supportive educational ecosystem. In this regard, the present study aligns with the research conducted by Soto-González et al. (2025) which highlighted the importance of collaboration among educational institutions such as museums, schools, and universities in fostering mutually reinforcing relationships with broader educational impacts. Through the development of bilingual Augmented Reality media, Brawijaya Museum is expected to function not only as a site for preserving historical collections, but also as a collaborative learning space that engages students, lecturers, and the wider community in more contextual and participatory learning processes.

Overall, the findings demonstrated that the integration of Augmented Reality (AR) technology in the form of a mobile-based application provided a more engaging and interactive experience for visitors to Brawijaya Museum. This finding aligns with Ifeanyi (2024) who states that augmented reality enhances visitor engagement and learning by providing interactive and personalized experiences, as evidenced in this study through the use of bilingual AR features and 3D visualizations that transformed conventional museum information delivery into a more dynamic educational experience. Moreover, by presenting information in two languages, Indonesian and English, this medium not only enhanced comprehension among local visitors but also improved accessibility for international tourists.

The results further indicated that the implementation of bilingual AR media in museums holds significant potential for increasing visitor engagement and interest, particularly among younger audiences. Based on the field testing results, most respondents reported greater interest and improved understanding of the historical context of the collections when information was presented through an interactive combination of visual elements and audio narration. This finding

reinforces the perspective that immersive media such as AR can enrich visitors' social and educational experiences by facilitating more meaningful encounters with cultural heritage (Illsley et al., 2025).

This study also identified several challenges related to technological readiness and user accessibility. The literature suggests that museums often face obstacles in implementing immersive media because they rely heavily on visitors' personal devices as the primary means of digital access. The findings of this study support this view, as not all visitors possessed compatible devices, stable internet connections, or sufficient storage capacity to download AR applications. These conditions created barriers to entry that limited the potential for an optimal immersive experience.

Several visitors continued to experience technical issues, such as device compatibility problems and application instability. Similar challenges have been reported in previous studies (Marques & Costello, 2018; Hasibuan et al., 2025; Wijaya et al., 2025). These issues indicate opportunities for further improvement of the product, particularly in terms of technical optimization through future development research.

In addition, visitors provided constructive suggestions for enhancing features and user experience, including the addition of animations, improvements in visual quality, and simplification of the application installation process. However, AR differs from conventional animation in that adding more objects increases system capacity demands, making the application heavier and more difficult to access. Limitations of visitors' smart devices pose a significant challenge (Laswi & Aman, 2018; Karayilanoğlu, 2020). Therefore, Lin et al. (2019) recommended providing on-site devices that visitors can directly use to access AR content. AR applications are also highly dependent on internet connectivity, particularly when users are required to download the application individually. In line with Ariza-Colpas (2024) improving on-site Wi-Fi infrastructure is essential to support AR performance (as cited in Hasibuan et al., 2025). In other words, the effectiveness of AR is not determined solely by the technology itself, but also by the readiness of the destination to facilitate visitor access to the developed AR system.

Given the limitations of this study, not all suggestions could be accommodated, as some proposed improvements would have required fundamental and complex system reconstruction. Despite these limitations, the findings underscore that while AR technology holds substantial potential for museum applications, successful implementation depends heavily on usability factors that influence visitor comfort, satisfaction, and the speed with which users can achieve their objectives. If access to AR content is overly time-consuming or complicated, users may lose interest.

CONCLUSION

The application of Augmented Reality (AR) technology with bilingual features (Indonesian and English) is a potential solution to address the challenges facing museums. This technology not only enables interactive and immersive presentation of collection information but also expands accessibility for both local and international visitors. This innovation creates a more meaningful tourism and learning experience.

Based on the result in evaluation phase, AR product is considered effective in helping visitors understand history in a more engaging and realistic way through visualizations of museum collection objects. However, several minor issues were encountered related to compatibility,

application stability, and several technical aspects. Therefore, future research and development should focus on refining AR usability and integration strategies to enhance the quality and atmosphere of museum exhibitions without compromising the overall visitor experience.

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