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Research Article

Exp AR Malacca: A Self-Guided Learning of Malacca's Malay Traditional Houses using Augmented Reality Technology and Physical Map

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Abstract

As a UNESCO World Heritage Site in Malaysia, Malacca is known for its traditions and historical treasures, notably traditional Malay houses. These houses are architectural jewels that represent the multiracialism and historical evolution of the Malay community, but major challenges such as urbanization, reduced accessibility, and a lack of public awareness make preserving them more challenging. Hence, this study employs the ADDIE model to develop the Exp AR: Malacca, an augmented reality (AR) application in an attempt to promote Malacca's traditional Malay houses to tourists and to preserve its cultural and historical significance. The app bridges the gap between modern technology and heritage preservation by overlaying interactive 3D models of traditional Malay houses, historical insights, and immersive features. Through interviews and observations, the research incorporates feedback from two industry experts, two residents, and five tourists. The result shows a high rate of satisfaction regarding the users' experience and engagement, with some recommendations for improvement. Using AR and a physical map as tools, this project proposes how technology could reshape cultural tourism by making tourism to heritage sites more engaging while fostering a deeper appreciation for Malacca's legacy. The contribution of this research is to provide insights for sustainable tourism development and the adoption of digital technologies in cultural heritage management, ensuring traditional Malay houses in Malacca continue to be appreciated and preserved for future generations.

Keywords: augmented reality, Malay traditional house, Malacca, self-guided learning.

INTRODUCTION

Tourism is the crucial sector of any country's economy; for Malacca and its deeply rooted cultural heritage, it plays an indispensable role in attracting tourists. Its prides include traditional Malay houses, which reflect the architectural skills and history of the Malay community. These traditional houses speak stories from the past and represent special evidence of the intermixing between Malay, Chinese, and European influences. However, many visitors are not aware of these gems as modern buildings and limited access make them a bit less noticeable.

Such potential for promotion and preservation may be attained with the aid of augmented reality (AR). AR permits tourists to interact with the 3D models, historical insights, and architectural details of the houses by overlaying digital content on physical reality (Unal et al., 2021). This creates an engaging, immersive experience and makes learning about the value of these traditional houses easier.

The study introduces Exp AR: Malacca, an AR application developed specially to showcase the beauty and significance of traditional Malay houses. The application combines education and entertainment, providing tourists with an exciting way to explore Malacca's heritage. As stated by Saari et al. (2021), education is important to help gain knowledge and skills. It not only raises awareness about these houses but also encourages greater appreciation for their role in Malaysia's cultural identity.

With AR, traditional Malay houses could be brought to life in new ways, ensuring that their stories are not lost to time. By bridging technology and history, this approach could help preserve Malacca's legacy for future generations while enhancing its appeal as a cultural tourism destination.

LITERATURE REVIEW

Tourism

Tourism plays an important role in the development of the economy and culture, especially in those states that are rich in heritage sites, such as Malacca. Being recognized as a UNESCO World Heritage Site, Malacca receives millions of visitors annually because of its famous landmarks such as Jonker Street, Stadthuys, and A Famosa, which are usually highlighted during tourism campaigns. Less prominence, however, is accorded to equally important but lesser-known cultural treasures, such as traditional Malay houses.

Traditional Malay houses are marvellous architectural manifestations that reflect the lifestyle, history, and identity of the Malay community. However, such houses also face several challenges related to urbanization, visibility, and public interest (Sevim & Çalışkan, 2021; Saedon, 2022). Indeed, modern building structures often make these old homes invisible; sometimes these homes are out of the way, and hence, tourism access is more difficult. Besides, traditional methods for promoting a cultural site to tourists using brochures or simple signs are usually less suitable in this modern digital era.

These are issues that need to be overcome by making cultural tourism more interactive and accessible. The promotion of less-recognized cultural tourist attractions, such as the traditional Malay houses, could help balance the distribution of tourists at a destination. This spreads the pressure from the congested areas and enhances the overall experience of the tourists (Ibrahim et al., 2023). Innovative approaches, using technology among others, become very important in enhancing the popularity of such less-recognized cultural attractions (UNESCO, 2023).

Cultural Heritage

Cultural heritage includes physical and intangible assets passed down from one generation to the next, such as traditions, stories, art, and architecture. Malacca's traditional Malay houses are perfect examples of tangible cultural heritage. These houses showcase a distinctive blend of architectural influences, combining Malay craftsmanship with elements borrowed from Chinese, Indian, and European cultures. Key features such as steep roofs for efficient rainwater drainage, intricate wood carvings, and elevated floors designed to prevent flooding highlight the resourcefulness and creativity of their builders (Aisyah & Siregar, 2024).

Despite their cultural importance, these traditional Malay houses are facing the critical possibility of disappearing entirely (Suaib et al., 2020). Many houses have gone into disrepair and have fallen to demolition for new development; further, environmental challenges like humidity and floods contribute to the organic decay of these structures. A general lack of awareness and appreciation by tourists and locals is further accelerating this loss, with many of these houses remaining hidden or under-promoted (Azzran, 2021).

Cultural heritage is very significant in retaining the identity and history of a community. The process of preserving traditional Malay houses involves two approaches: physical restoration and public education. The historical value and cultural significance of the houses need to be brought to the attention of the public for their survival (Ramele & Wongso, 2021). According to Han et al. (2021), preservation strategies could incorporate modern technology, such as augmented reality, to document, showcase, and celebrate these architectural treasures for future generations.

Augmented Reality

AR is the latest technology developed to layer digital elements — such as images, animations, or text- onto real-world settings. In contrast to the Virtual Reality (VR) method, which tries to fully plunge users into virtual worlds, the method of AR only extends reality by adding the ability for users to gain interactive and additional information from what is seen (Berriel et al., 2023). This latter aspect makes AR very popular in the tourism domain.

Recent studies have verified the effectiveness of AR in maximizing the visitor experience of cultural heritage sites. Hussein and Ali (2025), for example, verified that AR applications substantially enhance the perception of authenticity in heritage sites, which equates to higher levels of visitor satisfaction. Tatić and Stanković (2024) also illustrated how AR software is a contemporary method of presenting cultural and historic heritage in the sense of providing interactive and engaging experiences for the end-users.

These allow the visitor to experience a historical site in a new and different way within the context of cultural tourism. Examples are AR applications that could show 3D reconstructions of heritage buildings, virtual guides with additional information on historical facts, or point out architectural features in more detail. Such information could be accessed via smartphones, tablets, or AR headsets, which dynamically and interactively support learning (Richardson, 2024). Research evidence indicates that AR enhances engagement and learning outcomes since education and entertainment are combined innovatively (Fadli et al., 2022).

In this respect, AR would work for traditional Malay houses in Malacca, where limited visibility and accessibility have so far posed quite a few problems. There are two types of AR: marker-based AR and location-based AR (Mokmin et al., 2022). Both AR applications could show the tourist these houses digitally, showing every nook and corner with fine 2D or 3D details. For sure, immersiveness combined with interactive visuals could provide great appeal and make it all the more memorable (Fauzi et al., 2022; Yusof et al., 2024).

AR has more uses than improving the visitors' experiences: it could contribute much to the preservation of cultural heritage. In documenting minute details of traditional Malay houses, AR preserves the design and story of each for the ages. It is even an enabling technology for global audiences who could not visit Malacca to appreciate its rich heritage (Elshahawy et al., 2023). The AR is much more impressive,

accessible, and appealing for the contemporary tourist than any of the traditional promotional tools like guidebooks.

Recent studies have also explored the cognitive and psychological impact of AR among users from a cultural heritage tourism perspective. Zhu et al. (2024), for instance, examined AR's effect on the perceived authenticity of World Heritage sites by tourists, and object-based and existential authenticity were said to have a significant effect on tourists' sense of presence and behavioral intentions. In the same way, research by Prabuddha et al. (2024) explored AR's impact on destination satisfaction in Sri Lanka's heritage tourism and took into account the mediating effects of immersive experience and perceived value on tourist satisfaction.

There has also been a comparative analysis in assessing the efficacy of AR in comparison to other digital technologies in cultural heritage environments. Zaifri et al. (2023) compared mobile AR apps and conventional media in crowded tourist areas and concluded that AR enhanced user experience as it made visitation more enjoyable and engaging. In addition, research conducted by Pinto and Huertas (2025) compared the emotional influence of VR and AR applications on tourists at cultural heritage sites and concluded that the greater sense of immersion in VR resulted in a greater positive emotional influence than AR.

METHODOLOGY

The Exp AR: Malacca application was developed using the ADDIE model (see Figure 1), ensuring a systematic approach to creating an engaging AR experience. The model was used in this research as it is simple and suitable for application developments (Soraya, 2022; Alazzawi et al., 2023). The development process included the following five phases:

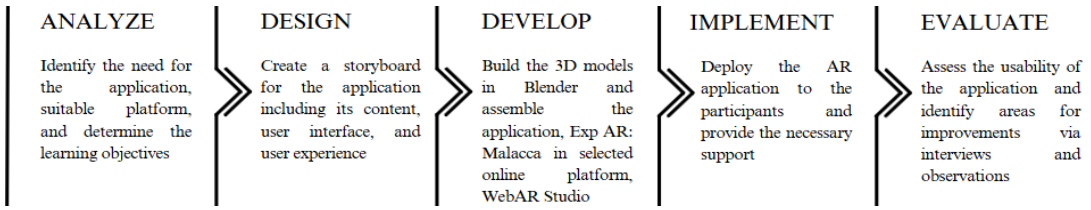

Figure 1: The ADDIE model used to develop Exp AR: Malacca application

Analysis Phase

During the analysis phase, the main objectives of the study were to promote and preserve the traditional Malay houses in Malacca by enhancing the experience for tourism. The target users identified included five domestic and international tourists, two industry experts, and two residents. The user needs, technological limitations, and possible sources of the contents were analyzed, including the architectural details and historical narratives of the Malay houses. Site visits to places such as Kampung Morten, the museums (see Figure 2), and other villages provided context for the creation of culturally accurate 3D models of the traditional houses.

Design Phase

The focus of the design here is on devising an easily usable but interactively engaging user interface. After analyzing and comparing various online AR platforms in the market, WebAR Studio was chosen as the most beneficial for the research. Using the provided interface from the platform, a storyboard (see Figure

3) was then developed which would chalk out in sequence how a user will navigate through the app in a friendly process.

Figure 2: The Malacca Sultanate Palace Museum, Malacca

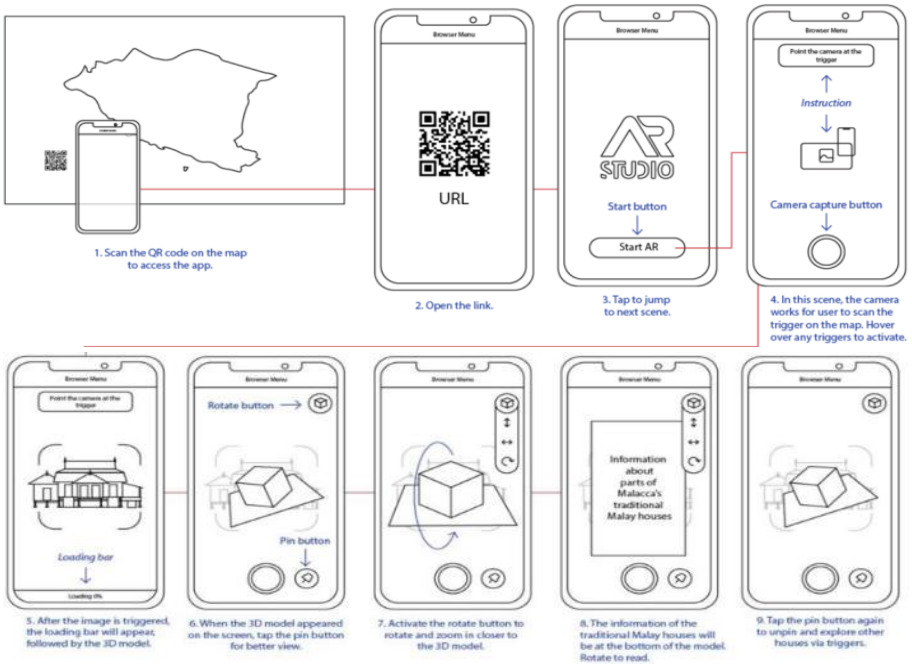

Figure 3: The wireframe storyboard of Exp AR: Malacca application

Some of the other main key features of the app are 3D models of the traditional Malay houses, an interactive map showing, and historical insights into all these places. The design for access and representation allows the image-based tracking to move closer to the detailed 3D model. Four types of traditional Malay houses were considered to optimize the space for markers on the physical map. Designs for the map and other assets were created in Adobe Illustrator (see Figure 4).

Figure 4: The design for the physical map to complement the application

Development Phase

The 3D models of the traditional Malay houses, culturally correct, were constructed during the development phase using Blender. The models featured unique elements, among which are the raised floors, steep roofs, and the wood carvings, showing the authenticity of these house types (see Figure 5). These then have visual info cards attached to them in order to describe them historically and culturally.

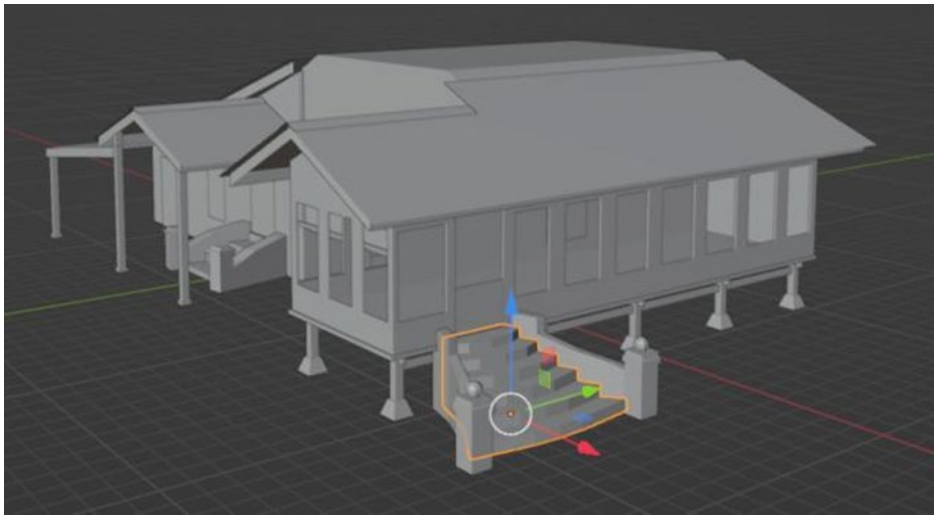

Figure 5: The 3D model development for one of the traditional Malay houses

After all the 3D models of Malacca's traditional houses were done, the exported models were then uploaded and set up in WebAR Studio. However, the models should be optimized beforehand in Blender as the platform provides a gallery with a limited upload size. Setting up the 3D models along with their marker images comes before publishing, and they then generate a QR code for access to the application.

Implementation Phase

The major tool used in the research is the Exp AR: Malacca application (see Figure 6), an AR platform of the traditional Malay houses through 3D models in an interactive manner. The application was utilized together with a physical map (see Figure 7) that had embedded AR markers that let users visualize the details of traditional Malay houses and their historical and cultural stories.

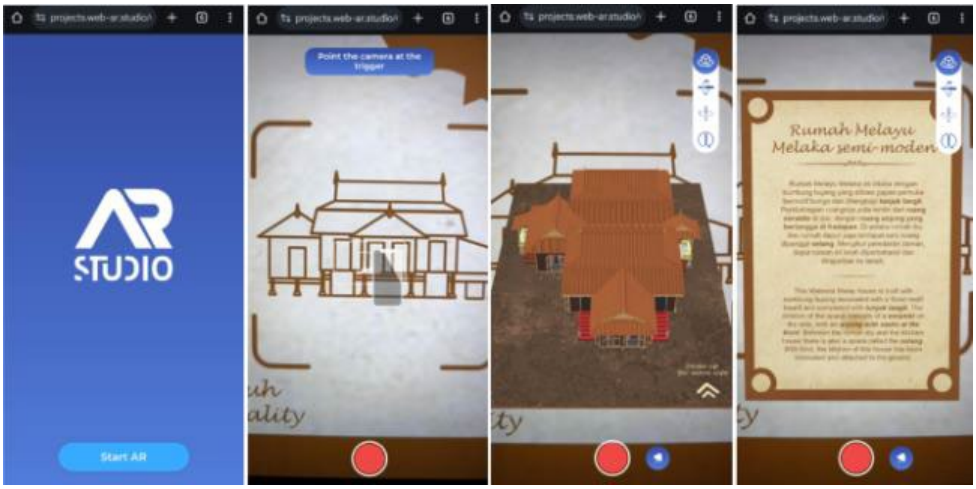

Figure 6: The interface of the Exp AR: Malacca application

Figure 7: The physical map embedded with the AR Markers

The functional testing of this application was executed on mobile devices for tourists. The implementation involved the deployment of the Exp AR: Malacca application to tourists visiting some historical sites, including the Stadthuys and Jonker Street. To locals, they were approached to see the application in their neighborhoods, while tourists were those who were engaging in the application for cultural landmarks.

Markers were interactive such that users could access digital content in an immersive way that linked their exploration and digital learning. Finally, data collection was done through interviews and observations (see Figure 8). Thematic analysis by Braun and Clarke (2006) was used to highlight the strengths and areas for further development.

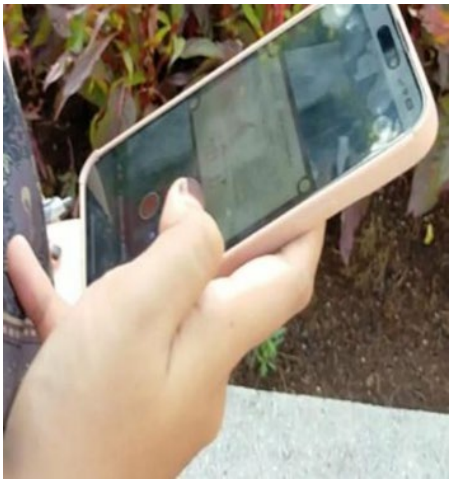

Figure 8: A tourist using the Exp AR: Malacca application

Evaluation Phase

This study used a qualitative research design to better understand how users engaged with the Exp AR: Malacca application to improve their tourism experience. Semi-structured interviews were conducted among three key participant groups: industry experts, residents, and tourists. It allowed respondents to share their thoughts on how they experience visiting and exploring heritage sites. In addition, observations documented real-time application interactions regarding user engagement with the application, ease of application navigation, and learning. Triangulation of data was done to ensure accuracy through cross-referencing insights from interviews with findings from observations.

A purposive sampling strategy was used to select a total of nine respondents who brought meaningful insights into the effective usage of the app. Two industry experts involved in AR technology and cultural heritage evaluation reviewed the design of the app for its functionality, including its cultural appropriateness. Two residents, native to Malacca traditional Malay houses, evaluated how this app represented their cultural heritage. Five tourists, both domestic and international, tested the app while touring Malacca and shared their feedback on usability, cultural representation, and overall experience.

The tools in the data collection in this study are semi-structured interviews and observation checklists. These interviews provided more details concerning satisfaction and user engagement by usability, interactivity, and cultural authenticity questions. The observation checklist recorded respondents' behaviors, any technical challenges that arose, their emotional reactions while observing comprehension of the content, ease of navigation, and prototype satisfaction. Taken together, these tools gave a comprehensive view of how the AR application affects the users.

The data collection began by receiving the ethical approvals and informed consent of respondents to ensure voluntary participation by being transparent. Respondents were briefly explained what they needed to do and about the app. Pre-test interviews were conducted to grasp an idea about user expectations and cultural insights prior to their experience with the application. Observations followed next when the

respondents interacted in realistic settings, such as around historical landmarks and cultural sites. In the post-test interviews, detailed feedback was solicited pertaining to satisfaction and engagement. All data from the transcripts, observation notes, and recordings were handled, stored, and analyzed accordingly, using triangulation: comparing findings from different sources.

RESULTS

The findings section discusses the analysis of themes arising from the interpretation and data triangulation of interviews and observation. It focuses on user experience in using the AR application, Exp AR: Malacca, to use in cultural tourism. It pools insights from the three types of participant groups, namely, the expert groups, residents, and tourists themselves, in light of the research objectives and questions. The findings were adapted from Yusof et al. (2024) and categorized into themes: user engagement, overall satisfaction with the prototype, and usability in providing insight on how AR has the potential to transform cultural heritage tourism (see Table 1).

Based on a qualitative research design, the reaction of the respondents towards the application was obtained. It emerged from the findings that the application greatly enhanced the users' engagement because the users found the interactive features entertaining and immersive. Most users were excited about the potential of discovering cultural heritage using AR because it offered a new and interactive method of discovering traditional Malay houses.

General user satisfaction was positive, with a high satisfaction rate, especially regarding the aesthetics of the app. The 3D house models, along with the historical context, provided a more engaging learning process. Yet, there were also some slight user frustrations regarding accessing some of the features or facing some technical glitches now and then. From a usability perspective, the app was deemed usable and straightforward to navigate by the majority of the respondents. Yet, some incompatibility problems with devices were faced, particularly by users with older or weaker smartphones, which disrupted their seamless experience utilizing the AR features.

Table 1: Data triangulation from interviews and observation

Context	Interview Results	Observation Results
Engagement		
Interested	High	Curious
Enjoy	High	Smile, Frustrated
Immersed	Medium	Focus
Engaged	Medium	Curious
Satisfaction		
Visual	High	High
Control	Medium	Medium
Usability		
Interaction	Medium	Medium
Accessible	High	High

DISCUSSION

Augmented Reality (AR) is transforming cultural heritage tourism as it makes historical places more interactive and informative. Rather than looking at buildings or simply reading signs, people can use AR to discover digital reconstructions, which increase knowledge. The Exp AR: Malacca app was able to make this idea a reality because it offered 3D models and interactive features regarding traditional Malay houses. People found the app useful, with some commenting that it enhanced their knowledge of Malacca's cultural heritage. AR also enhances accessibility with translations, audio descriptions, and visual aids. Exp AR: Malacca research demonstrated that visitors, particularly those who were not acquainted with Malay culture, appreciated the interactive elements within the app. Some, however, recommended including audio guides for an even better experience. AR can also safeguard vulnerable heritage sites by limiting direct contact while providing immersive exploration. The research identified that the users who interacted with the app were more inclined to go to the real heritage places, where AR plays a role in stimulating cultural tourism.

While it is strong, AR has its downfalls in the areas of historical accuracy and technological accessibility. In order to achieve authenticity, there must be consultation with historians and cultural experts. Compatibility is another issue, as a few users struggled with technical limitations. Future updates could make the app compatible with older phones and add offline functionality to expand accessibility. Worldwide, AR has been effectively incorporated into cultural heritage tourism, including China's Mogao Caves (Ma & Lu, 2019) and Egypt's Bibliotheca Alexandrina (n.d.). Exp AR: Malacca is within such initiatives since it utilizes AR to promote a lesser-known side of Malaysian heritage. Generally, the research validates AR's capability in enhancing cultural tourism through increased participation, accessibility, and visibility. Tackling historical accuracy, technical issues, and alignment with prevailing tourism practice will also maximize AR's potential for cultural heritage promotion and preservation.

LIMITATIONS AND RECOMMENDATIONS

The research had to overcome a series of challenges that influenced not only the implementation but also the results; however, these also provided useful lessons. One of the serious issues was related to using technology: device compatibility, network connectivity, and hardware requirements raised several problems for those users with older or less advanced devices to use the AR app smoothly. Therefore, in the future, the application should be more accessible and reliable, which would mean compatibility with a wider range of devices and the possibility to work offline (Ghafar et al., 2023). Another challenge was the cultural sensitivity that needed to be applied in using technology to accurately represent traditional Malay houses. Thus, the collaboration of experts in the culture is necessary in ensuring that the heritage content maintains its authenticity. Such collaborations on subsequent projects should ensure that the technology is supporting, rather than harming, cultural preservation.

Moreover, the sample size limited the findings of the study. A diversified number of respondents would increase the variety in their opinions and make the findings general. Additionally, the limitation in time constrained the data to be collected and the refinement that could have been done with the application. The more time for research, the more detailed the analysis, together with improvements from users. Furthermore, additional studies may analyze the impact of AR personalization, such as language adaptation or guided vs. free exploration, on the user experience. In addition, the incorporation of AR applications with popularly used tourism tools that are already being utilized, like Google Maps, TripAdvisor, or other heritage tourism applications, could additionally bring convenience and accessibility to tourists. Similarly, how AR can be incorporated with social media for culture promotion can provide practical value by expanding audiences and enhancing engagement with heritage content.

Despite these limitations, the research demonstrated that AR has immense potential to revolutionize cultural tourism. With additional enhancements to overcome its flaws, including those proposed, augmented reality applications will not only be more effective in preserving cultural heritage but also will enable more human interaction and provide more immersive and richer touristic experiences.

CONCLUSION

As the discussion shows, Exp AR: Malacca is of great help for cultural tourism promotion. This app offers a unique experience in learning and provides more chances to showcase Malay heritage. The usability challenges noted in this study are related to specific points, but generally, this application improves user engagement in understanding and overall satisfaction. Technical fixes, besides taking feedback from its users, could enable the application to set a benchmark for using AR technology in preserving and promoting cultural heritage. With its creative approach, it connects traditional Malay houses with modern technology, and thus their cultural importance is assured to remain relevant in today's digital world.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this research.

AUTHOR CONTRIBUTIONS

Siti Nur Farah Natasha Azhar: Conceptualization, Visualization, Investigation, Writing original draft. **Erni Marlina Saari:** Supervision, Data curation, Writing- Original draft preparation**. Yeka Hendriyani:** Writing, Reviewing and Editing**. Wesam Shishah:** Writing, Reviewing and Editing.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the authors used ChatGPT to enhance the clarity of the writing. After using ChatGPT, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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