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Research Article

NusaAR: A Location-Based Augmented Reality Hologram App for Historical Learning

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Abstract: Historical learning has been challenging for students due to passive learning and traditional teaching method. Even though it can be supported with site visits or field trips, it is often limited by static signboards and brief explanations. This paper presents **NusaAR**, a location-based augmented reality (AR) mobile application designed to support historical learning through immersive, site-specific experiences. Using geolocation technology, AR hologram guides are activated when users reach designated locations, providing historical narratives, visual reconstructions, and micro-learning content. Besides that, gamified activities are integrated to promote engagement and active participation among students. Leveraging the widespread use of smartphones, NusaAR able to offers an accessible approach to extend learning beyond the classroom and into authentic historical environments which make the learning process more interactive, interesting and engaging .



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1. INTRODUCTION

Historical education is a crucial component in shaping students' awareness of cultural identity, national heritage, and the evolution of society. Currently, in order to support students learning process in history education, educational visits or field trips to heritage sites such as museums are frequently organized which aims to encourage learning through real-world exposure. However, these approach

often depend on largely passive approaches, such as static information displays or brief explanations from instructors. Such methods may restrict students' active involvement and make it difficult for them to imagine past events in a meaningful way (Rosman, Ismail, & Masrek, 2020).

Moreover, mobile technology has become an important educational tools in students' everyday routines. Smartphones are commonly used for accessing information, social interaction, and informal learning activities. This widespread use creates opportunities to reposition mobile devices as purposeful educational tools that can facilitate experiential learning outside conventional classroom environments (Rosman et al., 2021).

Augmented reality (AR) has gained increasing attention in education due to its ability to blend digital content with real-world environments. Research has shown that AR can improve student engagement, deepen understanding, and support visualisation, especially in subjects that involve abstract concepts or spatial thinking (Zhang, Wan Ahmad Jaafar, & Sanmugam, 2024). In historical education, AR offers a meaningful way for learners to interact with historical content by experiencing it within the actual locations where events took place.

Location-based AR applications, such as Pokémon GO, demonstrate how digital enhancements can motivate users to explore physical spaces. Studies have found that these applications encourage active participation and outdoor exploration, effectively extending learning beyond the classroom (Althoff, White, & Horvitz, 2016; Mozelius, Bergström-Eriksson, & Jaldemark, 2017). Building on these findings, this paper introduces NusaAR, a location-based AR hologram application designed to support historical learning at heritage sites.

2. LITERATURE REVIEW

2.1 Mobile Augmented Reality in Education

Augmented reality has gained considerable attention as an innovative educational technology in recent years. A comprehensive meta-analysis conducted by Zhang et al. (2024) revealed that learning environment supported by AR have a positive impact on students' academic performance, engagement levels, and motivation. These benefits are evident in learning activities that requires spatial learning or understanding information within specific content like historical learning.

Furthermore, study by Lin, Chen, and Chang (2025) found that mobile AR applications are not only enhanced students' learning performance but also able to reduced cognitive load as compared to traditional instructional approaches. Their study indicates that AR facilitates meaningful learning by delivering information through interactive and visually enhanced formats, allowing learners to process complex content more effectively.

2.2 AR in Heritage and Museum Education

The application of AR in museum and heritage settings has demonstrated strong potential in improving both visitor experience and educational outcomes. Research by Chen, Lai, and Ho (2024) showed that AR-based applications significantly increased visitor engagement and supported deeper understanding of cultural artifacts. Similarly, Khor and Mubin (2024) showed that mobile AR tools

made it easier for users to visualise historical content and understand heritage information in a more engaging way.

However, despite these advantages it is found that most of the existing AR applications at heritage sites are primarily designed for tourist experiences in tourism industry rather than focusing on formal or structured educational settings. This gap suggests that there is a need for AR solutions that are specifically developed to support academic learning objectives particularly in historical learning which align with curricular requirements.

2.3 Gamification and Motivation

Gamification strategies, such as the use of points, badges, and leaderboards, have been widely recognised for their ability to enhance learner motivation, participation, and knowledge retention (Rosman et al., 2021). In addition, these elements encourage learners to actively explore heritage environments when combined with AR applications instead of engaging in passive observation during the learning process. Being actively involved helps learners stay interested and engage more deeply with learning in real-life settings.

2.4 Location-Based Games and Learning Beyond the Classroom

Location-based AR games have drawn growing interest among researchers due to their ability that allow learning to take place in real world settings with more interesting and engaging ways. Pokémon GO is frequently served as clear example of how digital gameplay can encourage physical movement and outdoor exploration. Althoff et al. (2016) found that physical activity among players has increase, while Mozelius et al. (2017) highlighted the increasing potential use of gamification element in formal educational contexts. In addition, Pang (2022) argued that location-based mobile games create informal learning spaces that extend learning beyond traditional classroom boundaries. Collectively, these studies provide strong justification for incorporating location-based AR features into educational applications, including systems such as NusaAR.

2.5 AR and Sustainable Development Goals

The integration of Augmented Reality (AR) in education able to supported the achievement of the Sustainable Development Goals, particularly the Quality Education (SDG 4). By embedding interactive digital content within real-world learning environments especially in historical learning, AR able to enhances student engagement, conceptual understanding, and practical skill development. Studies across different disciplines show that AR-based applications support experiential learning, collaborative problem-solving, and innovative teaching practices that align with SDG 4 goals (Llanos et al., 2025).

Previous studies also emphasise the significant benefits of incorporating modern educational technologies in history and geography instruction. Tools such as Geographic Information Systems (GIS), virtual simulations, interactive maps, and online learning platforms have been found to improve student engagement, spatial reasoning, knowledge retention, and critical thinking skills. These findings strengthen the argument for adopting AR, particularly geolocation-based AR in history education, as it offers immersive and context-rich learning experiences that situate historical events within authentic physical spaces. Through the use of AR technology, historical education can be modernised while also

supporting the achievement of Quality Education (SDG 4) and fostering inclusive, interactive, and sustainable learning environments (Adashvovich, 2025).

3. METHODOLOGY

3.1 System Design

The idea of NusaAR is designed as a mobile application developed using Unity in combination with AR Foundation, which compatible with both Android and iOS operating systems. The application incorporates geolocation technology to identify users' latitude and longitude, allowing AR content to be activated automatically when users reach predetermined heritage locations.

The system includes AR hologram guides that function as virtual narrators which provides historical explanations. This is supported with visual reconstructions of past events or structures to helps students to have better understanding and able to visual the historical events. Through NusaAR, learning content is presented through micro learning modules. This elements will break the lesson into small pieces through brief and focused information tailored to each specific historical site. Gamified elements such as quizzes and location-based missions are also planned to be included in the application to boost learning and maintain user interest.

3.3 Data Analysis

Since the study is currently at the conceptual stage, the following methods are planned for future evaluation to visualize and validate the effectiveness of the NusaAR:

- a) Knowledge acquisition and retention: Pre- and post-tests are proposed to measure learning outcomes.
- b) User engagement and usability: Likert-scale questionnaires are planned to assess motivation, engagement, and user experience.
- c) Qualitative insights: Semi-structured interviews are envisioned to explore user perceptions and feedback.
- d) Usage analytics: Interaction logs, time spent, and mission completion will be tracked for data-driven evaluation.

Quantitative data will eventually be analyzed using descriptive and inferential statistics, while qualitative feedback will undergo thematic analysis. For now, these methods serve as a blueprint for visualizing how NusaAR could be assessed once deployed.

4. FINDINGS

The conceptual implementation of NusaAR is expected to demonstrate several potential benefits for students engaging with heritage sites:

- a) Enhanced student engagement and motivation through interactive hologram guides and gamified missions.
- b) Improved comprehension and retention of historical content via immersive AR experiences.

- c) Positive user perceptions regarding accessibility, usability, and the integration of gamification elements.

These anticipated outcomes are supported by prior research indicating that augmented reality and gamified learning environments can increase learner engagement, knowledge retention, and active participation (Lin et al., 2025; Zhang et al., 2024).

4.1 Conceptual Insights

Although empirical testing has not yet been conducted, visualization of NusaAR allows for preliminary insights into design efficacy and user experience. Simulated walkthroughs of the application suggest that the interactive features, including 3D reconstructions and site-specific micro-learning modules, can guide students through structured learning experiences at heritage sites (Ahmad, 2022; Mohamad & Ali, 2019).

4.1.1 Potential User Interaction Patterns

Based on design modeling, students are expected to engage with missions sequentially, earning digital badges and points as they explore historical content. These interaction patterns can inform future usability studies and evaluation frameworks for NusaAR.

4.1.2 Design Considerations for Engagement

Initial visualizations emphasize the need for intuitive navigation, clear feedback, and gamified rewards to keep users motivated. Future pilot studies will help refine these features to enhance both learning outcomes and overall user satisfaction.

5. COMMERCIALISATION

NusaAR shows strong potential for commercialisation across different sectors particularly in the education and tourism sectors. The application can be offered as a software solution to schools, museums, heritage sites, and tourism boards. Educational institutions could adopt NusaAR as a supplementary tool aligned with history and social studies curricula, while museums and heritage sites could use it to enhance visitor engagement through interactive AR-guided tours.

Potential revenue models may include institutional licensing, subscription-based access, and customised content development for specific heritage locations. Furthermore, collaborations with government agencies, cultural organisations, and tourism authorities could further support wider deployment of the application. Over time, NusaAR could be expanded to offer multilingual support, premium content, and analytics dashboards, enabling institutions to track user engagement and learning outcomes.

6. NOVELTY

The novelty of NusaAR focused on its integration of location-based AR, hologram guides, and micro-learning within authentic heritage environments. As compared to conventional AR learning tools, which often rely on markers or classroom-based interactions, NusaAR delivers content through

real-world geolocation, encouraging learners to engage physically with historical sites while interacting digitally.

Additionally, the combination of gamified missions, 3D holographic storytelling, and curriculum-aligned learning objectives distinguishes NusaAR from entertainment-focused location-based AR applications such as Pokémon go. By balancing immersive technology with educational structure and historical accuracy, NusaAR will be able to offer a unique, scalable, and meaningful approach to location-based historical learning.

7. DISCUSSION

The design of NusaAR reflects a shift towards experiential and location-based learning approaches. This is inspired by the success of location-based AR games such as Pokémon GO, the application that applies similar engagement mechanisms within an educational framework. Unlike entertainment-oriented games, NusaAR emphasises structured learning objectives and historical accuracy.

The use of smartphones ensures accessibility and scalability, allowing learning to occur beyond formal classroom environments. However, challenges such as GPS accuracy, device compatibility, and content maintenance must be addressed to ensure effective implementation.

8. CONCLUSION

This paper presents NusaAR as a location-based AR hologram application designed to enhance historical learning at heritage sites. By integrating geolocation technology, AR hologram guides, and gamified learning activities, NusaAR supports interactive and contextual learning experiences. Leveraging widespread smartphone usage, the application offers a practical approach to extending learning beyond the classroom. Future work will focus on empirical evaluation and system refinement based on user feedback.

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