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ReplikaGO: Digitizing the Artifacts of the Balla Lompoa Museum through Augmented Reality and Gamification

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Abstract

Cultural preservation among younger generations faces increasing challenges due to globalization and rapid technological change. One example is the declining awareness of the Gowa Kingdom's heritage in South Sulawesi, Indonesia. The Balla Lompoa Museum still relies on conventional exhibitions that are less engaging for digital-native audiences. This study presents ReplikaGO, an Augmented Reality (AR) application using Vuforia Model Target technology to visualize museum artifacts in 3D and integrate gamification elements such as interactive puzzles and educational quizzes. Developed using a User-Centered Design (UCD) approach, the system focuses on usability and learning engagement. Three main artifacts—Gendang, Sarung, and Keris Tatarapang—are presented in immersive AR form. User testing with seven participants shows that ReplikaGO offers a more engaging and enjoyable cultural learning experience. Qualitative feedback indicates improved understanding of artifact meanings after interaction. These results suggest that AR combined with gamification has strong potential for digital heritage education and youth-oriented cultural preservation.

Keywords: Augmented Reality; Digital Heritage; Museum Artifacts; Gamification; User-Centered Design

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1. Introduction

Local culture forms the identity and character of a society; however, in recent decades, value shifts have caused younger generations to become increasingly disconnected from their own cultural roots [1]– [4]. This phenomenon is evident in

many regions of Indonesia, including Gowa, South Sulawesi, where public understanding of the history and cultural values of the Gowa Kingdom has gradually declined. During a field visit in November, the research team observed that Balla Lompoa—both as a traditional house and as a museum—serves as a central repository of Gowa’s cultural heritage, preserving artifacts such as royal keris, crowns, and ceremonial objects. Ideally, these collections should function as effective learning media. However, their largely static presentation and limited interactivity reduce their appeal, especially for digital-native generations accustomed to dynamic visuals, interactive technology, and immersive learning experiences [5]– [8].

This situation is further exacerbated by the decreasing frequency of traditional rituals that were once routinely practiced [9], [10], while much cultural knowledge continues to be transmitted orally and remains insufficiently documented in multimedia formats [10]. As a result, younger audiences often struggle to understand the broader cultural context, symbolic meanings, and functional roles of artifacts. Without innovations aligned with contemporary learning habits, the cultural wealth of Gowa risks being eroded by modernization, assimilation, and the loss of intergenerational continuity.

To address these challenges, there is a need for solutions that bridge cultural preservation with the technological practices of younger generations. This study therefore proposes ReplikaGO, an educational application based on Augmented Reality (AR) that dynamically visualizes artifacts from the Balla Lompoa Museum through 3D models, interactive puzzles, and educational quizzes. AR is selected because it integrates real and digital environments, enabling more immersive, engaging, and learner-centered experiences [11]– [14].

Rather than viewing artifacts as static objects, users can scan, rotate, assemble artifact components through puzzle mechanics, and answer quiz questions that reinforce their understanding of cultural values. Through this approach, ReplikaGO aims to stimulate curiosity among young users about Gowa’s heritage via relevant digital media, provide interactive learning methods, and deliver 3D visualizations of artifacts using Model Target technology. Overall, this project is expected to serve as an alternative medium for cultural preservation and education, ensuring that the cultural legacy of the Gowa Kingdom continues to be recognized, appreciated, and learned by future generations.

2. Methodology: User-Centered Design (UCD) Approach

The primary approach adopted in the development of the ReplikaGO application is User-Centered Design (UCD), a design methodology that places users at the core of the entire development process. In this approach, all aspects of the

system—including visual design, interaction mechanisms, and functional features—are shaped by the needs, preferences, and capabilities of the target users.

The UCD process in this project follows a structured and iterative framework consisting of five main stages:

1. **Understanding the context of use** through field observations and problem identification at the Balla Lompoa Museum environment.
2. **Specifying user requirements** based on the issues and needs identified during the contextual inquiry.
3. **Designing application features** and interaction flows derived from the results of field observations and user analysis.
4. **Developing and testing prototypes**, including usability testing with representative users.
5. **Evaluating the system** to ensure that the application provides optimal usability, comfort, and educational value for its users.

This iterative UCD process ensures that ReplikaGO not only meets technical requirements but also delivers a meaningful, intuitive, and engaging user experience aligned with the learning habits of younger generations.

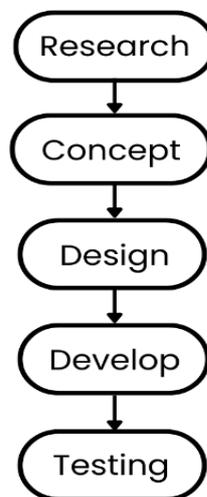


Figure 1. ReplikaGO Development Flowchart based on UCD

2.1 Target Users and Context Analysis

The target users of the ReplikaGO application are secondary school students, university students, and young people in the Sengka Village area who are interested in visiting the Balla Lompoa traditional house and museum. To understand their needs, the research team conducted field observations and informal interviews focusing on the challenges they face in maintaining and learning about Gowa’s cultural heritage.

The findings from this phase formed the basis for designing the user experience concept of ReplikaGO. Field observations were carried out as an initial step to understand the real context of the artifacts and the museum environment. The team conducted visits to two main locations: the Balla Lompoa Museum and Sengka Village, where several Gowa cultural traditions are still preserved.

At the museum site, the team documented the physical characteristics of the artifacts, exhibition layout, informational labels, and visitor responses—particularly from younger audiences. Several key findings emerged:

1. In Sengka Village, highly sacred and historically valuable artifacts, such as royal keris, crowns, and traditional musical instruments, are not publicly displayed and can only be seen during ceremonial rituals such as Accera Kalompoang.
2. The museum presentation is largely static, with artifacts displayed inside glass vitrines.
3. There is a lack of detailed explanations regarding the history, function, and philosophical meaning of the artifacts.
4. Digital support media, such as interactive screens or audiovisual content, are absent.
5. Youth interest is relatively low because the educational media do not align with their digital habits.

Based on this needs analysis, three representative artifacts were selected: Gandrang (traditional drum), Sarung, and Keris Tatarapang. These artifacts were adapted into digital objects in the form of 3D models and interactive puzzles within the ReplikaGO application.

2.2 AR Implementation and System Development

The Augmented Reality technology was developed using Unity 3D as the main platform due to its flexibility, cross-platform support, and compatibility with multiple AR SDKs. For artifact recognition, Vuforia Model Target Generator was employed, enabling the system to detect physical 3D objects rather than flat images. With Model Target technology, users can point their device camera at the real artifact, and the application accurately overlays a digital 3D model that aligns with the physical object's shape.

Each artifact's 3D model was created or adjusted to closely resemble the original form, including surface details and proportions. User interactions—such as displaying information, rotating models, and accessing puzzle mode—were controlled through C# scripts within Unity. This integration results in a stable, responsive, and realistic AR experience, allowing users to explore artifacts in a more engaging and interactive manner than conventional learning methods.

2.3 Gamification Design: Puzzle and Educational Quiz

The puzzle feature was designed as a core gamification element to increase user engagement while deepening users' understanding of the artifact structure. Each artifact was divided into five to six logical parts (e.g., hilt, blade, sheath, ornaments). In puzzle mode, users select and rotate each piece left or right using simple rotation controls.

The interaction design prioritizes simplicity and accessibility for young users. To enhance usability, an automatic "snap" feature was implemented, allowing each piece to lock into place when correctly oriented. Once all parts are successfully assembled and the artifact is complete, the system automatically advances users to the next stage: the educational quiz. Thus, the puzzle functions not merely as a game, but as a visual-spatial learning tool that reinforces users' understanding of the artifact's form.

The educational quiz serves as the final learning stage in ReplikaGO. It uses a multiple-choice format to assess users' comprehension after interacting with the artifact through AR and puzzle modes. The questions cover:

1. The function of the artifact in royal or ceremonial contexts,
2. Cultural values and symbolic meanings,
3. Historical and philosophical background, and
4. The artifact's role in traditional rituals such as Accera Kalompoang.

The quiz is an essential gamification component that not only evaluates learning outcomes but also strengthens motivation through an interactive and informative process.

3. Results and Discussion

The development and evaluation of the ReplikaGO application represent critical steps in ensuring the effectiveness of Augmented Reality-based cultural learning media. This section presents the implementation results, including the application development process and the testing phases conducted to assess system functionality, user experience, and the educational value of the application.

The overall process consists of two main stages, namely:

3.1 Application Development

The main outcome of this project is a prototype mobile application based on Augmented Reality (AR) called ReplikaGO, developed as an interactive cultural learning medium for residents of Sengka Village and young visitors who wish to explore the heritage of the Balla Lompoa Museum. The application was built using Unity 3D and employs the Vuforia Engine for object detection functionality, enabling the system to recognize 3D-printed physical replicas of artifacts used as markers.

When a replica is detected by the mobile device camera, the application overlays a digital 3D model of the artifact in the real environment, complete with historical descriptions and contextual information. To ensure an interactive learning experience aligned with the characteristics of the target users, the application integrates two gamification mechanisms whose effectiveness has been widely supported in educational contexts.

First, a 3D artifact puzzle encourages users to understand the structure and components of each artifact in greater depth. Second, an interactive historical quiz related to the model target functions as both a knowledge assessment tool and a reward mechanism through a point-based system. Through this combination, the learning process shifts from passive observation to an active and enjoyable exploration of cultural history.

Based on the development results, the ReplikaGO prototype has been successfully implemented as an AR-based mobile application with several integrated core features. The application begins with a tutorial module that serves as an initial guide for users to understand the application workflow, including how to scan artifacts, interact with 3D models, and complete the gamified stages. The tutorial is designed with simple visuals and concise instructions to ensure accessibility for novice users, particularly younger audiences.

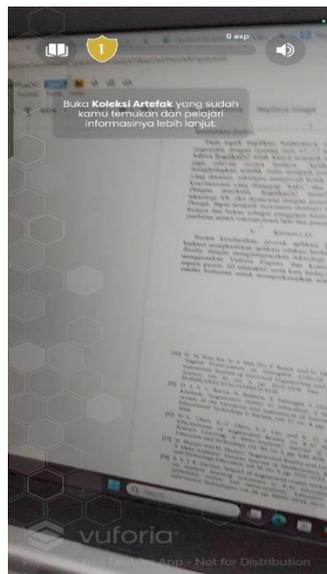


Figure 2. ReplikaGO Application Feature Tutorial Prototype

As a form of gamification, ReplikaGO incorporates a 3D model rotation puzzle in which each artifact is divided into several components based on its logical structure. Users are required to rotate each part until it reaches the correct orientation. This feature is designed to enhance users' visual and spatial engagement while helping them develop a deeper understanding of the artifact's form and construction.

An automatic snap mechanism is implemented to assist users in assembling the puzzle and to prevent excessive difficulty. When a piece is correctly aligned, it locks into place, providing immediate feedback and ensuring a smooth and user-friendly interaction experience.



Figure 3. ReplikaGO Puzzle Gamification Prototype

After successfully completing the puzzle, users are directed to an educational multiple-choice quiz. The quiz is designed to assess users' understanding of the artifact they have explored, covering aspects such as its function, historical background, philosophical meaning, and relationship to traditional rituals.



Figure 4. ReplikaGO Quiz Gamification Prototype

In addition to serving as an evaluation tool, the quiz functions as a motivational element through a point-based system and immediate feedback on the selected answers. This mechanism reinforces learning outcomes while maintaining user engagement through interactive and rewarding experiences.

After users successfully complete both the puzzle and the quiz, the application presents an artifact explanation directly in AR mode. The information displayed includes the artifact's name, function, brief history, and symbolic meaning, delivered through interactive text integrated with the 3D model.

With this approach, users do not only view the artifact visually but also gain a contextual understanding of the cultural values embedded within it. This AR-based explanation stage strengthens the learning process by combining visual immersion with informative content in a coherent and engaging manner.



Figure 5. ReplikaGO Quiz Gamification Prototype

As a form of user reward and progression, the application provides an artifact collection feature. An artifact is unlocked and added to the collection menu after users successfully complete all learning stages, including scanning, puzzle solving, and the educational quiz.

This feature encourages continuous exploration and provides a sense of achievement, while reinforcing the concept of gamified learning in cultural preservation. By visualizing progress through collected artifacts, users are motivated to engage more deeply with the content and to complete all available learning modules.

3.2 Testing and Evaluation

In the testing phase, the ReplikaGO AR application prototype was evaluated with seven respondents aged 12–22 years, representing the target segment of younger users. The evaluation not only examined user experience with the application but also considered participants' background experiences as supporting variables, namely: (1) whether they had previously played AR-based games, and (2) whether they had visited the Balla Lompoa Museum or possessed prior knowledge of Gowa artifacts.

The testing focused on six main aspects: (1) AR model target detection performance, (2) 3D puzzle interactivity, (3) quiz effectiveness, (4) attractiveness of the learning experience, (5) quality of cultural information, and (6) suitability for digital-native learning styles. The results are summarized as follows.

1) AR Detection (Model Target).

Most respondents (5 out of 7) reported that objects were detected accurately. However, some experienced delays or tracking jitter under suboptimal lighting conditions or when using low-specification devices. One respondent described the object as "occasionally drifting," indicating the need for improved tracking stability in edge-case conditions.

2) 3D Puzzle Interactivity.

All respondents found the puzzle easy to understand. Nevertheless, several suggested improving visual feedback, particularly highlighting the selected pieces more clearly. Some users also reported initial confusion due to unclear rotation buttons, indicating the need for text labels or animated cues.

3) Effectiveness of the Cultural Quiz.

All respondents stated that the quiz was informative, relevant, and helpful for understanding artifact meanings. Most participants (6 out of 7) answered at least two questions correctly, suggesting that the quiz effectively reinforced contextual knowledge about Gowa culture.

4) Learning Attractiveness and Experience.

All respondents described the experience as "interesting," "unique," and "different from a typical museum." They expressed a desire to explore additional artifacts and to recommend the application to their peers.

5) Quality of Cultural Information.

Participants reported that the information provided was clear and engaging. They appreciated the combination of text and audio narration, which helped them understand the cultural values embedded in the artifacts.

6) Suitability for Digital-Native Learning Styles.

All respondents agreed that ReplikaGO was more engaging and interactive than conventional methods such as books or static exhibitions. Several highlighted the 3D visuals and audio support as key factors making the information easier to remember.

Overall, the ReplikaGO AR prototype demonstrates significant potential in addressing the decline of cultural understanding among young people in Sengka Village. The successful Proof of Concept (PoC) implementation using object detection-based AR with Vuforia Engine and 3D-printed replicas shows that technical barriers to interactive artifact presentation can be overcome, offering a more reliable, engaging, and immersive alternative to conventional 2D image markers.

The findings support the initial hypothesis that an AR- and gamification-based approach can bridge the gap between younger generations and local cultural heritage. Although only three of the seven respondents had prior experience with AR games and only two had previously visited the Balla Lompoa Museum, all participants were able to complete the puzzles and answer the quiz questions. Despite minor technical challenges in AR detection—particularly on low-end devices—the overall experience was rated very positively.

One of the key successes of the ReplikaGO prototype is the 3D puzzle concept, which transforms passive learning into active exploration and encourages users to understand artifact structures in depth. The educational quiz also serves a dual role as both a learning assessment and a memory reinforcement tool, aligning with the principle of active recall in cognitive psychology. In addition, the combination of text and audio narration enhances accessibility and information retention, particularly for users who prefer multimodal learning approaches.

Several areas for improvement were also identified. AR stability should be optimized further for low-light conditions and low-performance devices. In the puzzle interface, clearer text labels and more distinct visual highlights (e.g., outline strokes) for selected pieces are recommended. Furthermore, a concise onboarding process in the form of short animations or tooltips is needed when users first enter the puzzle mode to clarify interaction mechanics.

From a cultural perspective, the positive responses from users aged 12–22 indicate that ReplikaGO is not only technically appealing but also culturally relevant. The application successfully transforms static artifacts into dynamic educational experiences, addressing common criticisms of conventional museums as being “rigid” and “non-interactive.” Thus, ReplikaGO demonstrates that AR technology, when designed with User-Centered Design principles, can become a strategic instrument for cultural preservation—not as a replacement for tradition, but as a bridge between past heritage and future generations.

4. Conclusion

Overall, the ReplikaGO project has successfully delivered an Augmented Reality–based educational application by integrating Vuforia Engine’s Model Target technology with gamification concepts such as interactive 3D puzzles and cultural quizzes. The application aims to introduce Gowa Kingdom artifacts—including Sarung, Keris Tatarapang, and Gandrang—in a more engaging, enjoyable, and immersive way for users. The prototype was tested with seven participants aged 12–22 years, and the results indicate that the application is significantly more engaging and effective than conventional cultural learning methods. Most respondents were able to complete the puzzles and answer the quizzes correctly, and they described the experience as “unique,” “interesting,” and “different,” confirming that the intended immersive learning experience was successfully achieved. Nevertheless, several minor technical challenges remain, particularly related to the stability of AR model target detection, where occasional delays and tracking jitter were observed. Despite these issues, the core elements of immersive learning—active user engagement, spatial context, and immediate feedback—were effectively realized. Thus, ReplikaGO is not merely a visualization tool for artifacts but also a relevant immersive educational platform for digital-native generations, especially in understanding and appreciating Gowa’s cultural heritage. Future development will focus on optimizing model target stability under varied lighting conditions and on low-end devices, as well as expanding the number of scannable artifacts. These enhancements are expected to strengthen the application’s role as a cultural bridge connecting past heritage with the future of younger generations.

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