DESIGN AND DEVELOPMENT OF A POSTCARD-INTEGRATED AUGMENTED REALITY APPLICATION FOR EDUCATIONAL EXPLORATION OF LOMBOK ISLAND TOURIST ATTRACTIONS

(Perancangan dan Pengembangan Aplikasi Augmented Reality Terintegrasi Kartu Pos untuk Eksplorasi Edukatif Destinasi Wisata Pulau Lombok)

Regania Pasca Rassy*[1], Lalu Romy Rahmad Amarta Putra[1], Muhammad Rifkyandryan Rustanto[1], Nazila Imkani[1], Risfanda Audiarrahman Charisma[1], Zahra Tri Lusiana[1]
[1]Dept Informatics Engineering, Mataram University
Jl. Majapahit 62, Mataram, Lombok NTB, INDONESIA
Email: ganiarachsy@staff.unram.ac.id.

Abstract

Indonesia possesses diverse tourism destinations, including Lombok Island, which is known for its natural landscapes and cultural heritage. However, the introduction of local tourism to elementary school students remains limited, as learning is predominantly delivered through textbooks and two-dimensional images that are less interactive. This study aims to design and develop a mobile Augmented Reality (AR) application to support the educational exploration of tourist attractions on Lombok Island, especially to elementary school students so that they can better recognize their regional natural heritage. The development process adopted the Multimedia Development Life Cycle (MDLC) model, which consists of concept, design, material collection, assembly, testing, and distribution stages. The application visualizes selected destinations, including Rinjani National Park, Gili Trawangan, and Tiu Pupus Waterfall, through interactive three-dimensional objects accompanied by concise educational information. The results of functional and device performance testing indicate that the application operates reliably, with consistent marker detection at and an average response time of approximately one second across tested devices. Although variations in frame rate were observed between high-end and mid-range smartphones, overall functional compatibility was maintained. Usability evaluation using the System Usability Scale (SUS) resulted in an average score of 81.25, which falls into the "excellent" category, indicating that the application is easy to use and well accepted by users. These findings demonstrate that the developed AR application is both technically feasible and suitable as an interactive learning medium for elementary school students. The integration of AR technology into tourism-based educational content offers potential to support digital learning innovation while promoting awareness and appreciation of local natural and cultural heritage.

Keywords: *Augmented Reality, Educational Application, Interactive Learning Media, Mobile Learning, Tourism Education*

**Corresponding Author*

1. INTRODUCTION

Indonesia is widely recognized for its diverse tourism destinations, rich natural landscapes, and cultural heritage. One prominent destination is Lombok Island, which has experienced significant growth in both domestic and international tourism due to its scenic beaches, mountains, and traditional cultural attractions such as Kuta Mandalika Beach, Mount Rinjani, Gili Trawangan, Tiu Pupus Waterfall and the Sasak traditional village of Sade [1], [2]. The development of tourism in Lombok has also been strengthened by digital promotion strategies and online media exposure, increasing its visibility as a strategic regional tourism destination [3]. These tourism assets serve as valuable contextual learning resources, particularly for elementary school students seeking to understand local geography and culture.

The selection of elementary school students as the focus of this study is based on their cognitive development stage. According to Jean Piaget's theory, children at the elementary level are generally in the concrete operational stage, where they learn more effectively through visual, tangible, and experiential representations [4]. At this stage, integrating real-world contextual content such as local tourism into learning can significantly enhance students' comprehension and meaningful learning experiences. However, the introduction of these regional assets within formal elementary education remains limited. One of the primary challenges is the lack of innovative

instructional media used in schools. Conventional two-dimensional materials are often insufficient to engage students who are accustomed to interactive digital environments [5].

Learning materials related to local culture and geography are still predominantly delivered through textbooks and static images. Such traditional instructional approaches have limitations in attracting students' attention and maintaining learning motivation, particularly among digital-native learners [5], [6]. According to multimedia learning theory, students achieve better comprehension when verbal information is combined with meaningful visual representations [7], [8]. Furthermore, based on cognitive development theory, learning at the elementary level is more effective when supported by visual, interactive, and experiential media [4]. Therefore, integrating interactive digital technologies into local content learning is pedagogically relevant and necessary to bridge this gap.

One promising technology to enhance learning effectiveness is Augmented Reality (AR). AR enables users to visualize and interact with three-dimensional virtual objects integrated into real-world environments through mobile devices such as smartphones or tablets [9], [10]. In educational contexts, AR has been shown to increase engagement, motivation, and conceptual understanding by providing immersive learning experiences [11], [12]. In addition, previous studies have demonstrated that AR-based tourism applications can effectively support educational tourism and cultural heritage learning [13]–[16].

Through an AR-based application, students can virtually explore selected tourist destinations in Lombok, including Rinjani National Park, Gili Trawangan, and Tiu Pupus Waterfall. These locations were deliberately selected as they represent diverse geographical and ecological characteristics, such as mountainous landscapes, coastal and marine environments, and freshwater ecosystems. For instance, Rinjani National Park allows students to observe volcanic topography and highland ecosystems, Gili Trawangan introduces coastal and marine biodiversity, while Tiu Pupus Waterfall provides insight into inland hydrological features and forest environments. By interacting with these varied environments through AR, students can gain a more comprehensive understanding of Indonesia's natural diversity. Beyond supporting knowledge acquisition in geography and social studies, this approach can also foster environmental awareness and strengthen appreciation of regional natural and cultural heritage.

To ensure a systematic and structured development process, this study adopts the Multimedia Development Life Cycle (MDLC) model, which comprises six stages: concept, design, material collection, assembly, testing, and distribution [17]. The MDLC model is widely implemented in multimedia application development due to its straightforward workflow and suitability for interactive educational systems [18], [19]. The application is specifically designed for mobile platforms, considering their accessibility and relevance in supporting interactive digital learning environments. Previous studies have shown that mobile-based AR applications are effective tools for delivering educational tourism content and enhancing user experience in learning contexts [16], [20].

By integrating AR technology with Lombok's local tourism content, this study aims to develop an innovative educational medium that enhances student engagement, improves conceptual understanding, and promotes regional identity and cultural preservation.

2. LITERATURE REVIEW

The development of Augmented Reality (AR) technology over the past decade has led to significant growth in its application across both the education and tourism sectors. AR enables the integration of digital content into real-world environments, allowing users to interact with three-dimensional virtual objects in real time. Recent studies indicate that AR enhances learning experiences by improving visualization, interactivity, and learner engagement [21]–[23]. Furthermore, bibliometric analyses of Scopus-indexed publications show a rapid increase in AR-related research in education, highlighting its growing importance as an innovative learning technology [24].

In the context of elementary education, AR has demonstrated strong pedagogical potential. A systematic literature review by Tarmidzi et al. [25] revealed that AR significantly improves students' motivation, interest, conceptual understanding, and higher-order thinking skills across various subjects. Similarly, AR-based learning media has been shown to enhance students' understanding of scientific concepts by transforming abstract material into interactive visual representations [26]. In language learning, AR applications have been developed to improve comprehension and retention among elementary students through immersive and interactive environments [27]. These findings indicate that AR is particularly suitable for elementary learners, who benefit from concrete and visual learning experiences.

In addition to effectiveness, recent studies highlight the emergence of various AR-based learning resources for elementary students. AR has been widely applied in science education, including topics such as ecosystems, anatomy, and physics, enabling interactive exploration of complex concepts [26]. AR is also used in literacy learning, where it supports inclusive and engaging reading experiences for young learners [28]. Moreover, AR-based applications have been developed to support cultural learning by introducing local heritage and traditions in an interactive format, significantly increasing students' interest and engagement [29]. These developments demonstrate that AR learning resources are increasingly diverse, covering multiple subject domains and learning objectives.

In the field of educational tourism, Bahari et al. [30] conducted a systematic review and found that AR consistently enhances user engagement, interactivity, and perceived authenticity in tourism experiences. However, the study also emphasized that most AR implementations focus primarily on tourism promotion rather than integrating structured pedagogical objectives aligned with formal education curricula.

Several studies on AR application development for promoting tourist attractions in Indonesia further support this trend. A. Anwar et al. [14] developed an AR-based virtual tour prototype for historical tourism in Aceh, enabling immersive visualization of cultural heritage sites. Similarly, Samar [15] implemented markerless AR technology in Ambon, improving user exploration and awareness of local tourism potential. Rahmad et al. [16] also developed an AR-based edutourism application in Bireuen, demonstrating that multimedia integration enhances user interest and interaction. Despite these advancements, these applications primarily function as tourism information tools rather than structured instructional media tailored for elementary school students.

Recent advancements in extended reality and cultural heritage applications further highlight the potential of AR in tourism-based learning. Urbanelli et al. [31] introduced the ARise application, which demonstrates how AR can enhance cultural heritage resilience through contextual and participatory learning approaches. Similarly, Warsinke et al. [32] explored the use of digital twins in extended reality tourism and found that AR-based approaches provide higher usability, comfort, and user satisfaction compared to fully immersive virtual environments. These findings suggest that AR is particularly suitable for educational contexts, as it balances immersion with accessibility for young learners.

From a user experience perspective, Basir et al. [20] emphasized that effective AR applications should provide intuitive navigation, balanced multimodal content, and strong contextual relevance. The effectiveness of AR in educational settings depends not only on technological sophistication but also on the alignment between user experience design, learner characteristics, and instructional objectives.

Based on the reviewed literature, AR has been proven effective in enhancing both learning experiences and tourism exploration. However, several research gaps remain. First, most AR applications in tourism focus on promotional and informational purposes rather than structured educational objectives for elementary school students. Second, although AR has been widely used in subject-specific learning, limited studies integrate multiple domains such as geography, culture, and environmental awareness into a unified learning platform. Third, the integration of systematic development frameworks, such as the Multimedia Development Life Cycle (MDLC) model [17]–[19], in AR-based educational tourism applications remains limited.

Therefore, this study offers novelty by developing a mobile AR application specifically designed for the educational exploration of Lombok Island tourist attractions for elementary school students using a systematic Multimedia Development Life Cycle framework. This approach aims not only to enhance media interactivity but also to strengthen contextual understanding of local geography and cultural heritage.

3. METHODOLOGY

This study adopts the Multimedia Development Life Cycle (MDLC) model to systematically develop an Augmented Reality (AR) application for the educational exploration of tourist attractions on Lombok Island. MDLC consists of six sequential stages: concept, design, material collecting, assembly, testing, and distribution.

The model is widely applied in multimedia system development due to its structured yet flexible framework that ensures systematic planning, development, and evaluation of interactive applications.

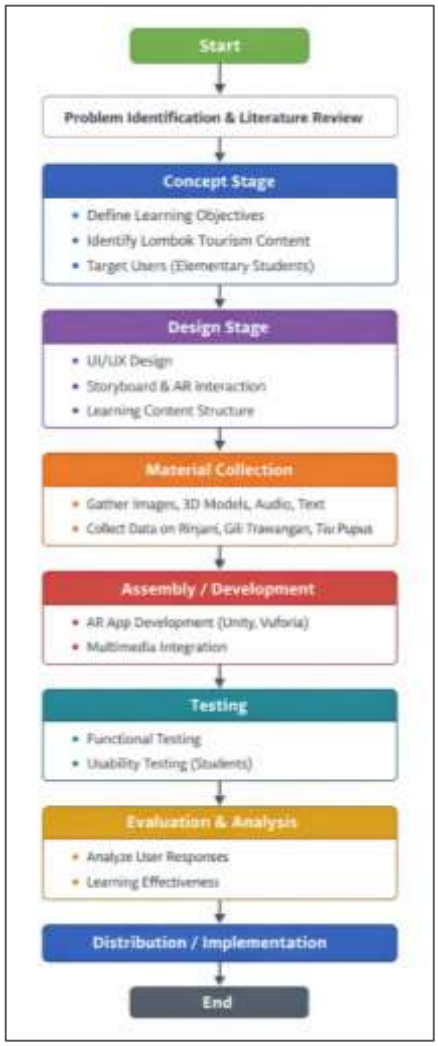

Figure 1. Research Fowchart based on MDLC Model

Each stage implemented in this research is described as follows.

A. Concept and Planning: This stage began with identifying instructional needs through a literature review and curriculum analysis of geography and local content subjects at the elementary school level. The objectives of the study were to develop a postcard-based Augmented Reality (AR) application as an interactive learning medium. The target users were determined as 5 primary school students (grades 4–6 elementary students) and one teacher. The application concept integrates printed postcard media with 3D visualization to support educational exploration of tourist destinations on Lombok Island.

B. Design: The design stage included the development of system architecture, application flowchart, interaction storyboard, and user interface layout. The AR scanning mechanism using postcard markers was designed to trigger the appearance of 3D models and to synchronize educational audio narration. Visual design elements included postcard layout, tropical-themed color schemes, and typography appropriate for elementary students.

C. Material Collecting: This stage involved collecting and developing all multimedia assets, including 3D models of selected tourist destinations (Mount Rinjani, Gili Trawangan, and Tiu Pupus Waterfall), simplified educational descriptions, audio narration, supporting images, and postcard designs functioning as AR markers.

D. Assembly: During this stage, all multimedia assets were integrated into the AR development platform (Assemblr Studio). The postcard markers were configured to display corresponding 3D models and audio narration. Navigation features and interaction logic were implemented, and the application was optimized for Android devices.

E. Testing: Black-box testing was conducted to verify system functionality, including marker detection accuracy and 3D object rendering. A limited usability trial with elementary students was also conducted to evaluate ease of use, clarity of visualization, and the suitability of the educational content.

F. Distribution: After successful validation, the application was exported as an APK and distributed, along with printed AR postcards, to teachers as a supplementary interactive learning medium based on Augmented Reality technology.

The structured implementation of MDLC ensures that the AR application development process remains organized, measurable, and aligned with pedagogical objectives.

4. Results and Discussion

A. Concept and Planning Phase

The concept phase defines the objectives, target users, system specifications, and overall development strategy of the AR application.

1) Development Objectives:

The objectives of this research are threefold:

- To develop mobile-based interactive learning media using Augmented Reality technology that visualizes major tourist attractions on Lombok Island, such as Mount Rinjani, Tiu Pupus Waterfall, and Gili Trawangan, for elementary school students.
- To enhance students' learning interest and comprehension of local geography and cultural heritage through immersive, visual, and interactive

experiences as an alternative to conventional textbook-based instruction.
- To provide concise, relevant educational information embedded in each AR object, including historical background, unique facts, and geographical characteristics, to foster environmental awareness and appreciation of regional cultural heritage.

The application is positioned not merely as a tourism visualization tool but as a curriculum-supporting educational medium aligned with local content and social science learning outcomes at the elementary level.

2) Target users

The application identifies two categories of users:
- Primary Users: 5 Elementary school students, particularly grades 4-6. This selection is based on cognitive development characteristics at the concrete operational stage, where learners benefit from visual and interactive representations. The language style, interface layout, and interaction mechanics are designed to match their comprehension level and learning needs. The application supports Social Science and local content subjects.
- Secondary Users: Teachers as secondary users. Their role is to facilitate, guide, and supervise students during the learning process. Synchronization between instructional objectives and application content ensures effective integration into classroom and home learning environments.

3) User Requirements Analysis

Based on the identified user groups, several functional and non-functional requirements were defined:

a) Functional Requirements

The application must function correctly and support all intended user interactions. The main functional requirements include:
- The application can be installed and launched on Android devices
- The AR camera can detect markers and display 3D objects correctly
- Users can interact with AR objects (view, rotate, and explore content)
- Textual information about each tourist destination is displayed properly

These requirements are verified through black-box testing, which evaluates whether each feature operates according to its intended function without examining internal code structure.

b) Non-Functional Requirements
- Usability (User-Friendliness) : The application must be easy to use, especially for elementary school students, with simple navigation and clear instructions. This requirement is evaluated using the System Usability Scale (SUS), which measures: Ease of use, Learnability and User confidence during interaction.
- Visualization Quality: The AR content must be visually clear and engaging to support understanding and recognition of tourism objects. This requirement is evaluated indirectly through User responses in SUS (perceived ease and clarity) and Successful display of 3D objects during black-box testing
- Performance and Compatibility: The application must run smoothly on Android devices without significant delays or crashes. This requirement is evaluated through device performance testing, including Application loading time, Responsiveness during AR interaction, Stability across different devices.
- Concise Educational Content: Each virtual object includes brief and child-friendly textual descriptions. The content avoids complex terminology and presents information in a structured, digestible format to prevent cognitive overload.

B. Design Phase

The design stage translates the conceptual framework into technical and visual specifications that guide system implementation. This phase includes developing the application flowchart, storyboard structure, system architecture, use case modeling, and visual interface design. All design components were created to ensure alignment with pedagogical objectives, user characteristics (elementary students), and the interactive nature of Augmented Reality–based learning.

1) Storyboard and Application Flow

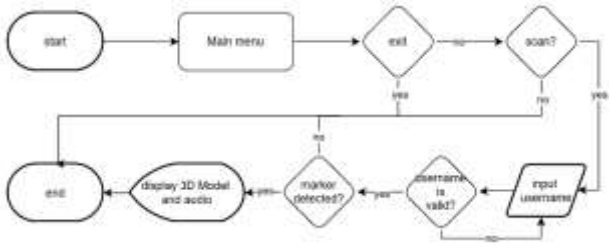

Figure 2. Flowchart

The storyboard defines the sequence of interactions between the user and the AR application. The application begins with a Start Page, which introduces the system and directs users to the Main

Menu. From the main menu, users can choose to exit the application or proceed to the AR scanning feature.

If the user selects the AR feature, the system prompts them to enter a username as a simple identification mechanism. This input personalizes the experience and records basic usage data. After validation, the application activates the device camera to detect predefined AR markers embedded in the Lombok tourism postcards.

Once the marker is successfully recognized, the system overlays a three-dimensional model of the selected tourist destination along with synchronized audio narration containing educational information. The session concludes when the user exits the AR visualization interface.

This structured interaction flow ensures logical navigation, minimizes cognitive load, and supports independent use by elementary school students.

2) System Architecture

The system architecture follows a marker-based mobile Augmented Reality structure developed using Assemblr Studio and deployed on Android devices. The architecture consists of the following components:

a. User Interface Layer
Handles user interaction, including start page, menu navigation, username input, and AR display screen.

b. Application Logic Layer
Manages input validation, marker detection triggers, and content synchronization between 3D models and audio narration.

c. AR Engine Module
Processes real-time camera input identifies predefined image markers (postcards), and renders corresponding 3D objects.

d. Content Database
Stores multimedia assets including 3D models (Mount Rinjani, Gili Trawangan, Tiu Pupus Waterfall), descriptive text, and audio narration.

3) Mobile Device Hardware Integration

Utilizes smartphone camera, processor, and display system for real-time rendering and interaction. This architecture ensures smooth integration between physical postcard markers and digital educational content, enabling immersive yet structured learning experiences.

4) Visual Style and Interface Design

The application's visual identity adopts a postcard-inspired theme to reflect Lombok's tourism character while maintaining a child-friendly aesthetic.

a. Graphic Elements

The design incorporates decorative borders, traditional pattern ornaments, circular landscape illustrations (mountains, beaches, waterfalls), and Lombok map silhouettes. These elements reinforce regional identity and cultural representation while maintaining visual engagement.

Figure 3. Element Style

b. Typography

Four typefaces are combined strategically:

- Gagalin and Chewy: playful and friendly appearance suitable for headings.
- Bellota and Montserrat: high readability for descriptive educational content.

This typographic hierarchy balances aesthetic appeal with clarity, a crucial factor for elementary-level comprehension.

Figure 4. Font and Color Style

c. Color Scheme

The selected color palette includes natural tones such as cream, brown, peach, gray, blue, and green. These colors represent Lombok's tropical landscape and create a warm, calming, and immersive atmosphere. The visual composition avoids excessive contrast to reduce visual fatigue during prolonged use.

d. Postcard

A two-sided postcard functioning as an AR marker.

1. Front Side:
Displays the main destination image, title typography, and structured information, i.ncluding location, description, and key geographical data.
2. Back Side:
Maintains a traditional postcard layout with writing space, a recipient address area, and a Lombok map silhouette indicating the destination location.

The postcards developed in this study include: Mount Rinjani, Gili Trawangan, and Tiu Pupus Waterfall. These physical postcards serve dual functions: as educational print media and as AR activation markers. This hybrid design strengthens the integration between tangible learning materials and immersive digital visualization.

Figure 5. Rinjani Mountain Design

Figure 6. Gili Trawangan Design

Figure 7. Tiu Pupus Waterfall

C. Material Collecting

The material collecting stage involved gathering and producing all supporting multimedia assets required for the development of the postcard-based AR application.

1) Information about Lombok's tourist destinations was collected from credible online sources, including official tourism websites, academic articles, and reputable news portals. The data were cross-verified across multiple sources to ensure accuracy and validity before being adapted into concise educational content suitable for elementary students.
2) Images: Visual materials were generated using AI-assisted tools, guided by detailed prompts describing Lombok's natural landscapes, including beaches, mountains, and waterfalls. The generated images were designed with a consistent visual style and quality to support engaging presentation and thematic coherence.

TABEL I. PROMPT SAMPLE AND RESULTS

Place	Prompt	Results
Gunung Rinjani	*"A cartoon-style illustration of Mount Rinjani in Lombok, Indonesia. The mountain is tall and majestic with a crater lake*	

Place	Prompt	Results
	(Segara Anak) at its center. The surrounding area features tropical greenery, clear skies, and a few clouds. The style is clean, flat, and colorful, suitable for AR postcard markers, with a friendly and vibrant tone. No text, just landscape. White or transparent background, no frame or border. Flat vector style, minimal shading, cartoonish design."	
Gili Trawan-gan	*"A cartoon-style illustration of Gili Trawangan, a small tropical island in Lombok, Indonesia. The scene features a beautiful sandy beach with clear turquoise water, coconut trees, and a small wooden boat anchored near the shore. In the background, there's a calm sea and a faint silhouette of Mount Rinjani. The style is colorful, clean, and flat with a friendly cartoon look, perfect for AR postcard markers. No people, no text, and no buildings. Just nature and scenery. White or transparent background."*	
Air Terjun Tiu Pupus	*"A cartoon-style illustration of Tiu Pupus Waterfall in Lombok, Indonesia. The waterfall cascades down a tall rocky cliff surrounded by lush green tropical forest. The water flows into a calm, clear pool at the bottom, with smooth rocks and moss around. Sunlight gently shines through the trees above, creating a serene and peaceful vibe. The scene should be vibrant, colorful, and stylized in a clean cartoon or flat vector style, suitable for an AR postcard marker. No people or text, just the natural waterfall and surroundings. White or transparent background."*	

3) 3D Models: Three-dimensional assets were created to represent key tourist attractions and supporting elements. These included mountain-topography models reflecting Lombok's geographical characteristics, as well as additional objects, such as title text elements, birds, and clouds, integrated into the AR scene.
4) Audio: Environmental sound effects were collected from online platforms to represent the natural atmosphere of Lombok, including ocean waves, mountain wind, and other ambient sounds. The selected audio files were converted to MP3 format for integration as background audio, enhancing the immersive learning experience in the application.

D. Assembly

The assembly stage involved integrating and constructing all multimedia components into a functional postcard-based Augmented Reality (AR)

application. This phase transformed the prepared assets into an operational AR learning system.

1) 3D Asset Development

All previously collected materials were used to construct three-dimensional models of Mount Rinjani. The modeling process was carried out in Blender to produce a complete, visually engaging 3D representation. Additional environmental elements, such as clouds and birds, were incorporated to enhance realism and create a more immersive landscape visualization.

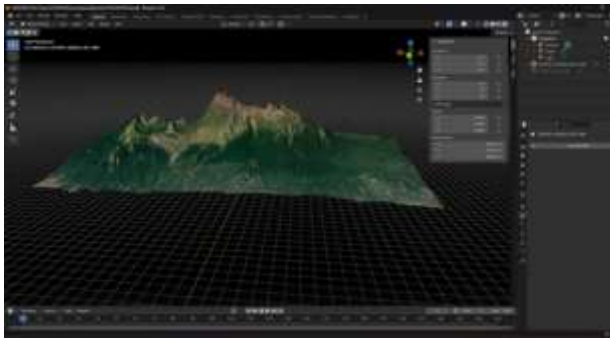

Figure 8. 3D Asset Development Sample

2) AR Development Using Assemblr Studio

The AR application was developed using Assemblr Studio, which served as the primary platform for marker-based AR integration. The first step involved registering the postcard images as AR markers within the platform. These markers function as visual triggers that activate digital content when scanned by the device camera. The selected postcard images were designed with sufficient visual uniqueness and high resolution to ensure accurate detection.

After registration, the system generated a marker ID used for further configuration and testing. Subsequently, all multimedia assets, including background images, audio narration, environmental sound effects, and 3D objects, were imported into the project library in Assemblr Studio. Each asset was uploaded individually to ensure proper organization and management. The assets were then adjusted in scale, rotation, and spatial position to align precisely with the registered markers.

Following the import process, all components were arranged within the 3D workspace. This stage involved carefully placing and refining each object to achieve a balanced, natural visual composition when displayed through AR technology. Spatial configuration was optimized to maintain clarity, realism, and user-friendly interaction

Figure 9. The Process of Arranging Components

.

3) Finalization and Preview Testing

After completing the integration, the application underwent internal testing using the preview feature in Assemblr Studio. The device camera was directed toward the registered postcard markers to verify marker recognition and content synchronization. When successfully detected, the system displayed the integrated digital elements, including 3D models, background visuals, audio narration, animations, and textual information simultaneously on the screen. This final verification ensured functional stability and readiness for the subsequent testing phase.

Figure 10. Finalization Stage Preview

E. Testing

The testing phase used alpha testing to ensure that the postcard-based AR application functioned according to its design specifications before user deployment. The evaluation focused on marker detection accuracy, 3D object rendering, clarity of educational text, and audio performance. After that, black-box testing and device testing were conducted.

1) Black-Box Testing

Black-box testing was performed to evaluate the system's functional correctness against predefined specifications. The testing focused on user interaction

scenarios without examining internal code structures. All primary features were tested, including application launch, username input validation, access to the AR scan feature, marker detection, 3D object visualization, audio playback, information display, screen orientation adjustment, and exit functionality.

TABEL II. BLACK BOX TESTING RESULTS

Feature	Test Scenario	Expected Result	Result
Start Page	User taps "Get Started"	Main menu is displayed	Successful
Username Input	User enters username	System validates input and grants access to AR feature	Successful
Main Menu	User selects AR Scan	AR camera interface is activated	Successful
Marker Scanning	User scans postcard marker	System detects marker and loads AR content	Successful
3D Object Display	Marker successfully detected	Corresponding 3D tourist object appears	Successful
Audio Playback	3D object appears	Educational narration and background audio play	Successful
Text Information	AR content displayed	Concise educational information is shown clearly	Successful
Orientation Mode	User switches device orientation	Display adjusts to vertical/horizontal mode	Successful
Exit Feature	User presses Exit	Application closes properly	Successful

The results indicated that all core features operated as intended. The system successfully displayed the main menu, activated the camera for scanning, detected postcard markers, rendered the corresponding 3D tourist objects, and played synchronized educational audio. Thus, functionally, the application met the specified design requirements.

a. Device Specification Testing

Device compatibility testing was conducted to evaluate application performance across different Android smartphones and ensure optimal usability. The application was tested on multiple devices with varying Android versions and hardware specifications.

The evaluation considered detection distance (approximately 15 cm), response time (average 1 second), and frame rate performance. The results demonstrated that the application successfully detected markers and rendered 3D objects across the tested devices. Frame rates varied by device, but overall performance remained within acceptable limits for smooth interaction.

TABLE III. DEVICE PERFORMANCE TESTING RESULTS

Device	Android Version	Distance (cm)	Response Time (s)	FPS	Result
Samsung S23 FE	Android 14	15	1	58	Detected
POCO F3	Android 13	15	1	52	Detected
Redmi Note 13 Pro	Android 14	15	1	45	Detected
VIVO V29	Android 14	15	1	43	Detected

Although minor visual jittering was observed in the 3D Mount Rinjani model and slight audio latency was observed on some devices, the system maintained stable marker recognition and AR visualization. These findings indicate that the application is functionally reliable but requires further optimization to improve visual stability and audio synchronization for a more immersive learning experience.

b. SUS Testing

The bar chart (Figure 11) presents the System Usability Scale (SUS) scores obtained from five students and one teacher, indicating overall high usability of the developed AR application.

Usability evaluation was conducted using the System Usability Scale (SUS), involving five elementary school students and one teacher. The results of the SUS assessment are presented in Table X.

The overall mean SUS score obtained was 81.25, which falls into the "excellent" category based on standard SUS interpretation. This indicates that the

developed AR application demonstrates high usability and is well accepted by users.

The student group achieved an average score of 80.0, suggesting that the application is easy to use and suitable for their level of understanding. Meanwhile, the teacher provided a higher score of 87.5, indicating strong agreement regarding the application's usability and its potential effectiveness as a learning medium.

Overall, these findings confirm that the application meets usability requirements and can be effectively implemented in elementary-level learning environments.

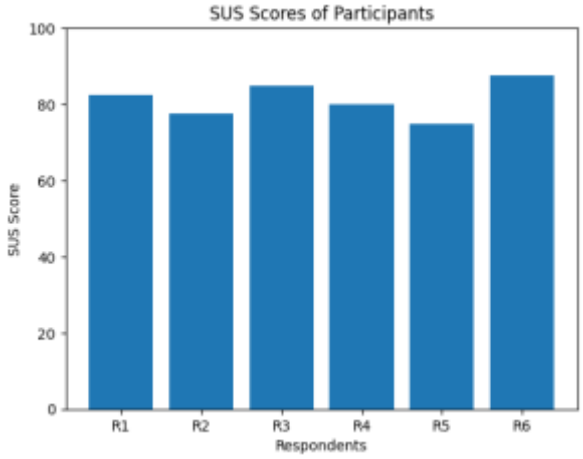

Figure 11. SUS Score

F. Distribution

The distribution of the postcard-based AR learning media was conducted digitally to facilitate accessibility for teachers and parents. Before assisting students, users are encouraged to review a digital user guide that includes operational instructions, feature explanations, and descriptions of the educational content. The guide can be accessed via the following link:
s.id/BukuPanduanAR_WisataLombok.
In addition, a demonstration video has been published on YouTube to provide visual guidance on how to operate the AR application. This video supports user comprehension and initial familiarization with the system. It is accessible at: s.id/VideoAR_WisataLombok.

5. CONCLUSION AND SUGGESTIONS

This study presented the design and development of a postcard-integrated Augmented Reality (AR) application to support the educational exploration of tourist attractions on Lombok Island. The system integrates physical postcards as visual markers with interactive 3D models, textual descriptions, and audio elements to create an immersive and contextual learning experience.

The results of alpha testing confirm that the application operates reliably in marker detection, content rendering, and multimedia integration. Marker recognition was consistently achieved at a distance of 15 cm with an average response time of approximately one second. Device performance testing showed that high-end smartphones provide smoother rendering and higher frame rates, while mid-range devices exhibit slightly lower performance with minor visual instability. Nevertheless, the application remains functionally compatible across all tested devices.

In addition, usability evaluation using the System Usability Scale (SUS) resulted in an average score of 81.25, which falls into the "excellent" category. This indicates that the application is easy to use, well accepted by users, and suitable for elementary school students.

Overall, the findings demonstrate that the developed AR application is both technically feasible and pedagogically promising as an interactive learning medium. The integration of AR technology with tourism-based educational content also highlights its potential to support digital learning innovation and smart tourism communication.

To further enhance system performance, optimization of 3D assets, texture resolution, and audio synchronization is recommended, particularly to improve rendering stability on mid-range devices. Migrating from third-party platforms to a more customizable AR development framework may also provide better control over performance optimization and system scalability.

Future research should extend the evaluation through beta testing involving a larger group of users, including students, teachers, and parents. This will allow for a more comprehensive assessment of usability, user experience, and learning effectiveness using quantitative and experimental approaches.

Additionally, the application can be further developed by incorporating advanced features such as location-based AR, interactive storytelling, and adaptive learning content. Integrating the system into a broader digital tourism ecosystem may also enhance its practical relevance, supporting both educational use and regional tourism promotion.

REFERENCES

[1] R. E. Mayer, Multimedia Learning, 2nd ed.

Cambridge, UK: Cambridge University Press, 2009.
[2] J. Piaget, The Psychology of the Child. New York, NY, USA: Basic Books, 1969.
[3] R. T. Azuma, "A Survey of Augmented Reality," Presence: Teleoperators and Virtual Environments, vol. 6, no. 4, hal. 355–385, 1997.
[4] I. Binanto, Multimedia Digital: Dasar Teori dan Pengembangannya. Yogyakarta, Indonesia: Andi Publisher, 2010.
[5] L. Luther, Authoring Interactive Multimedia. Boston, MA, USA: Academic Press, 1994.
[6] D. I. Suryani dan A. F. Putra, "Tourism Development Strategy in Lombok Island," Journal of Indonesian Tourism and Development Studies, vol. 8, no. 2, hal. 85–94, 2020.
[7] N. Hadiwijoyo, "Cultural Tourism and Local Community Empowerment in Lombok," International Journal of Tourism Research, vol. 22, no. 4, hal. 412–420, 2020.
[8] D. Iswanto, Z. Irsyad, Istiqlal, dan S. S. Sangadji, "Optimizing Social Media Marketing to Preserve Lombok's Traditions and Culture," Apollo: Journal of Tourism and Business, vol. 2, no. 3, hal. 264–276, 2024.
[9] M. Prensky, "Digital Natives, Digital Immigrants," On the Horizon, vol. 9, no. 5, hal. 1–6, 2001.
[10] Yuliantoro et al., "Developing Digital Media Based on Local Wisdom to Increase Student Engagement in Social Studies Learning," Al-Ishlah: Jurnal Pendidikan, vol. 15, no. 1, hal. 102–113, 2023.
[11] R. E. Mayer dan R. Moreno, "A Cognitive Theory of Multimedia Learning: Implications for Design Principles," Journal of Educational Psychology, vol. 91, no. 2, hal. 358–368, 1998.
[12] P. Milgram dan F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," IEICE Transactions on Information and Systems, vol. E77-D, no. 12, hal. 1321–1329, 1994.
[13] H. Wu, S. W. Lee, H. Y. Chang, dan J. C. Liang, "Current Status, Opportunities and Challenges of Augmented Reality in Education," Computers & Education, vol. 62, hal. 41–49, 2013.
[14] G. Bacca, S. Baldiris, R. Fabregat, S. Graf, and Kinshuk, "Augmented Reality Trends in Education: A Systematic Review of Research and Applications," Educational Technology & Society, vol. 17, no. 4, hal. 133–149, 2014.
[15] A. Sutopo, Teknologi Informasi dan Komunikasi dalam Pendidikan. Yogyakarta, Indonesia: Graha Ilmu, 2012.
[16] A. O. Bahari et al., "Analysis of the Experience of Using Augmented Reality Applications for Educational Tourism: A Systematic Review," Research Horizon, 2025.
[17] A. F. Siregar dan E. Hutabri, "Aplikasi Pengenalan Objek Wisata Kota Batam Menggunakan Marker Augmented Reality," Computer & Science Industrial Engineering, vol. 8, no. 1, hal. 86–95, 2023.
[18] A. Anwar et al., "Augmented Reality-Based Virtual Tour for Historic Tourist Attractions in Aceh," Journal of Informatics and Telecommunication Engineering, vol. 5, no. 2, 2022.
[19] I. Samar, "Implementasi Augmented Reality pada Aplikasi Pengenalan Objek Wisata di Kota Ambon," Jurnal Informatika Polinema, vol. 9, no. 2, hal. 183–192, 2023.
[20] R. Rahmad, C. Fadhilah, dan N. Nunsina, "Development of Edutourism Media Based on Augmented Reality Tourism Bireuen using Android," Gameology and Multimedia Expert, 2025.
[21] A. Basir, M. H. L. Abdullah, dan M. H. Zakaria, "User Experience Guidelines of Augmented Reality Application for Historical Tourism," International Journal of Advanced Science, Engineering and Information Technology, vol. 12, no. 3, hal. 1196–1205, 2022.
[22] A. Urbanelli et al., "ARise: An Augmented Reality Mobile Application to Improve Cultural Heritage Resilience," 2025.
[23] M. W. Warsinke et al., "Digital Twins for Extended Reality Tourism: User Experience Evaluation Across User Groups," 2025.
[24] R. T. Azuma, "A Survey of Augmented Reality," Presence: Teleoperators and Virtual Environments, vol. 6, no. 4, hal. 355–385, 1997.
[25] M. Billinghurst, A. Clark, and G. Lee, "A Survey of Augmented Reality," Foundations and Trends in Human–Computer Interaction, vol. 8, no. 2–3, hal. 73–272, 2015.
[26] J. Radianti, T. A. Majchrzak, J. Fromm, dan I. Wohlgenannt, "A Systematic Review of Immersive Virtual Reality Applications for Higher Education: Design Elements, Lessons Learned, and Research Agenda," Computers & Education, vol. 147, 2020.
[27] H. Y. Tom Dieck dan T. Jung, "Value of Augmented Reality at Cultural Heritage Sites: A Stakeholder Approach," Journal of Destination Marketing & Management, vol. 6, no. 2, hal. 110–117, 2017.
[28] T. Jung, H. tom Dieck, M. C. Lee, dan N. Chung, "Effects of Virtual Reality and Augmented Reality on Visitor Experiences in Museum," Information & Management, vol. 55, no. 5, hal. 621–635, 2018.
[29] N. Chung, H. G. Lee, J. Y. Kim, and C. Koo, "The Role of Augmented Reality for Experience-Influenced Environments: The Case of Cultural Heritage Tourism in Korea," Journal of Travel Research, vol. 57, no. 5, hal. 627–643, 2018.
[30] U. Gretzel, M. Sigala, Z. Xiang, and C. Koo, "Smart Tourism: Foundations and Developments," Electronic Markets, vol. 25, hal. 179–188, 2015.

[31] T. Yovcheva, D. Buhalis, dan C. Gatzidis, "Engineering Augmented Tourism Experiences," dalam Information and Communication Technologies in Tourism. Springer, 2013, hal. 24–35.

[1] D. I. Suryani and A. F. Putra, "Tourism Development Strategy in Lombok Island," *Journal of Indonesian Tourism and Development Studies*, vol. 8, no. 2, pp. 85–94, 2020.
[2] N. Hadiwijoyo, "Cultural Tourism and Local Community Empowerment in Lombok," *International Journal of Tourism Research*, vol. 22, no. 4, pp. 412–420, 2020.
[3] D. Iswanto et al., "Optimizing Social Media Marketing to Preserve Lombok's Traditions and Culture," *Apollo: Journal of Tourism and Business*, vol. 2, no. 3, pp. 264–276, 2024.
[4] J. Piaget, *The Psychology of the Child*. New York, NY, USA: Basic Books, 1969.
[5] M. Prensky, "Digital Natives, Digital Immigrants," *On the Horizon*, vol. 9, no. 5, pp. 1–6, 2001.
[6] Yuliantoro et al., "Developing Digital Media Based on Local Wisdom to Increase Student Engagement in Social Studies Learning," *Al-Ishlah: Jurnal Pendidikan*, vol. 15, no. 1, pp. 102–113, 2023.
[7] R. E. Mayer, *Multimedia Learning*, 2nd ed. Cambridge, UK: Cambridge University Press, 2009.
[8] R. E. Mayer and R. Moreno, "A Cognitive Theory of Multimedia Learning," *Journal of Educational Psychology*, vol. 91, no. 2, pp. 358–368, 1998.
[9] R. T. Azuma, "A Survey of Augmented Reality," *Presence*, vol. 6, no. 4, pp. 355–385, 1997.
[10] P. Milgram and F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," *IEICE Transactions*, vol. E77-D, no. 12, pp. 1321–1329, 1994.
[11] H. Wu et al., "Augmented Reality in Education," *Computers & Education*, vol. 62, pp. 41–49, 2013.
[12] G. Bacca et al., "Augmented Reality Trends in Education," *Educational Technology & Society*, vol. 17, no. 4, pp. 133–149, 2014.
[13] A. F. Siregar and E. Hutabri, "Aplikasi AR Objek Wisata Batam," *Computer & Science Industrial Engineering*, vol. 8, no. 1, pp. 86–95, 2023.
[14] A. Anwar et al., "AR-Based Virtual Tour Aceh," *Journal of Informatics and Telecommunication Engineering*, 2022.
[15] I. Samar, "Implementasi AR Objek Wisata Ambon," *Jurnal Informatika Polinema*, vol. 9, no. 2, pp. 183–192, 2023.
[16] R. Rahmad et al., "AR Tourism Bireuen Android," *Gameology and Multimedia Expert*, 2025.
[17] I. Binanto, *Multimedia Digital*. Yogyakarta: Andi, 2010.
[18] L. Luther, *Authoring Interactive Multimedia*. Boston: Academic Press, 1994.
[19] A. Sutopo, *Teknologi Informasi dan Komunikasi dalam Pendidikan*. Yogyakarta: Graha Ilmu, 2012.
[20] A. Basir et al., "User Experience AR Tourism," *IJASEIT*, vol. 12, no. 3, pp. 1196–1205, 2022.
[21] M. Billinghurst, A. Clark, and G. Lee, "A Survey of Augmented Reality," *Foundations and Trends in Human–Computer Interaction*, vol. 8, no. 2–3, pp. 73–272, 2015.
[22] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A Systematic Review of Immersive Virtual Reality Applications for Higher Education," *Computers & Education*, vol. 147, 2020.
[23] N. Chung, H. G. Lee, J. Y. Kim, and C. Koo, "The Role of Augmented Reality for Experience-Influenced Environments," *Journal of Travel Research*, vol. 57, no. 5, pp. 627–643, 2018.
[24] U. Gretzel, M. Sigala, Z. Xiang, and C. Koo, "Smart Tourism: Foundations and Developments," *Electronic Markets*, vol. 25, pp. 179–188, 2015.
[25] T. Tarmidzi et al., "Augmented Reality and Its Use in Elementary School Education: A Systematic Literature Review," 2025.
[26] I. M. Siki and I. H. Leba, "Effectiveness of Augmented Reality-Based Learning Media in Elementary Science," 2025.
[27] S. Apriyanto, "Augmented Reality-Based Learning Media for English Learning in Elementary School," 2025.
[28] Rosita et al., "Enhancing Reading Literacy through Augmented Reality in Primary Education," 2025.
[29] K. Anam et al., "Optimizing Cultural Awareness through Augmented Reality in Elementary Education," 2025.
[30] A. O. Bahari et al., "Analysis of the Experience of Using Augmented Reality Applications for Educational Tourism: A Systematic Review," *Research Horizon*, 2025.
[31] A. Urbanelli et al., "ARise: An Augmented Reality Mobile Application to Improve Cultural Heritage Resilience," 2025.
[32] M. W. Warsinke et al., "Digital Twins for Extended Reality Tourism: User Experience Evaluation Across User Groups," 2025.