IAIC Transactions on Sustainable Digital Innovation (ITSDI)
Vol. 8, No. 1, October 2026, pp. 1−11
E-ISSN: 2715-0461 P-ISSN: 2686-6285, DOI:10.34306

Design and Development of an Augmented Reality Learning Medium for the Conservation of the Endemic Flora Balikpapan Ginger (Etlingera balikpapanensis)

Fulkha Tajri M[1*], Olivia Febrianty Ngabito[2], Denny Huldiansyah[3], Azzah Nafisah Sofyan[4], Muhammad Bintang Kurniawan[5], Surya Abdi Pratama[6]
[1, 2, 4, 5, 6]Visual Communication Design Study Program, Institut Teknologi Kalimantan, Indonesia
[3]Architecture Study Program, Institut Teknologi Kalimantan, Indonesia
[1]fulkha.tajri@lecturer.itk.ac.id, [2]olivia.ngabito@lecturer.itk.ac.id, [3]denny.huldiansyah@lecturer.itk.ac.id, [4]22231012@student.itk.ac.id, [5]22231034@student.itk.ac.id, [6]22231053@student.itk.ac.id
***Corresponding Author**

Article Info

Article history:

Submission March 18, 2026
Revised March 24, 2026
Accepted April 4, 2026
Published May 29, 2026

Keywords:

Augmented Reality
Balikpapan Ginger
Etlingera balikpapanensis
Elementary School
MDLC

ABSTRACT

Balikpapan Ginger *(Etlingera balikpapanensis)* is an endemic flora of East Kalimantan with significant ecological, historical, and economic value, yet it remains largely unknown among the general public, particularly students. This condition highlights the need for innovative learning media to support environmental awareness and conservation education in a more engaging and accessible manner. Although Augmented Reality (AR) has been widely applied in environmental and biological education, prior studies mainly focus on general species and lack contextual integration of locally endemic flora into conservation learning. **This study addresses this gap by** developing a location-specific AR-based learning application that integrates scientific botanical data with interactive visualization to enhance local environmental literacy. **The development process follows** the Multimedia Development Life Cycle (MDLC), including concept, design, material collection, assembly, testing, and distribution. The evaluation involved 15 respondents, including administrators and adult visitors of the Balikpapan Botanical Garden, using a five-point Likert scale to assess technical feasibility, educational value, engagement potential, conservation relevance, and technical stability. **The results indicate** a high level of acceptance, particularly in educational value and engagement aspects, demonstrating the effectiveness of the application as a learning medium. **These findings** suggest that AR-based applications can support environmental education by providing immersive and interactive learning experiences aligned with constructivist learning theory and Mayer's Cognitive Theory of Multimedia Learning.

DOI: https://doi.org/10.34306/itsdi.v8i1.728

1. INTRODUCTION

Biodiversity constitutes an invaluable ecological asset for any nation. As one of the islands with the highest levels of biodiversity in the world, Borneo harbours extraordinary floral wealth, among which is Balikpapan Ginger *(Etlingera balikpapanensis)*, an endemic plant first discovered in the Sungai Wain Protected Forest, Balikpapan, in 2006 by Danish botanist Axel Dalberg Poulsen [1]. Morphologically, this plant features an erect stem reaching up to two metres in height, bearing flowers that do not fully open in its natural habitat a characteristic that has earned it the local epithet of ”Giant Ginger”. The Municipal Government of Balikpapan officially designated Balikpapan Ginger as the city’s floral mascot in 2022 [2], and in the 2024/2025 academic year, the plant was formally integrated into the local content curriculum under the subject of Environmental Care and Conservation Education (PKLH) for Grade IV students of elementary schools in Balikpapan [3].

Figure 1. Balikpapan Red Ginger *(Etlingera balikpapanensis)*

Despite its formal inclusion in the curriculum, students’ direct access to physical specimens of Balikpapan Ginger in its natural habitat remains severely limited, as shown in Figure 1. This limitation highlights the need for alternative learning approaches, where Augmented Reality (AR) technology emerges as a pedagogically meaningful and transformative solution. AR enables the superimposition of three-dimensional virtual objects onto the real environment in real time, allowing students to observe the ideal morphology of Balikpapan Ginger without dependence on the physical availability of specimens in the field [4].

Previous studies have demonstrated the effectiveness of AR within environmental education contexts. Dunleavy and Dede reported that AR-based learning can improve students comprehension of biodiversity content by up to 40% compared to conventional methods [5]. Mertayasa and Pascima developed an AR application for recognising rare endemic plants of western Indonesia and obtained a positive response rate of 94.83% from respondents [6]. Ardyansyah and Rahayu demonstrated that AR-based learning media integrating environmental literacy significantly enhanced students understanding of science content [5].However, these studies generally focused on national flora or general science contexts, and none has specifically developed AR media for locally endemic flora grounded in a regional content curriculum. In the context of Indonesia, this includes Environmental Care and Conservation Education (PKLH), which emphasises local environmental knowledge within formal education.

The novelty of this study resides in three fundamental dimensions. First, this research represents the first systematic effort to develop AR media specifically designed for *Etlingera balikpapanensis* as an endemic flora of East Kalimantan, with scientific content derived directly from field data provided by the Balikpapan Botanical Garden and primary botanical literature. Second, the development of this media is explicitly oriented toward the PKLH curriculum for Grade IV elementary school students in Balikpapan a curricular framework that has not previously been used as the basis for AR media development [7]. Third, this study conceptually situates AR media development within the Smart Society dimension of Balikpapan’s Smart City framework, thereby transcending mere classroom technological innovation and contributing to the regional agenda for sustainable digital transformation [8].

Based on this background, this study aims to:

- Design and develop an AR application as an interactive learning medium for Balikpapan Ginger
- Evaluate the technical feasibility and educational value of the developed AR application
- Analyse the contribution of AR media to the strengthening of the Smart Society ecosystem in Balikpapan

These objectives collectively guide the research in establishing a comprehensive framework that integrates technological development, educational effectiveness, and its broader contribution to sustainable digital innovation in the context of local environmental education.

2. LITERATURE REVIEW

This section synthesises key theoretical perspectives and empirical studies underpinning the development of Augmented Reality (AR) as an educational tool for environmental conservation. It critically examines the Smart City and Smart Society paradigm in education, the pedagogical potential of AR, its application in biodiversity learning, and the role of environmental education in fostering ecological awareness, while also outlining the Multimedia Development Life Cycle (MDLC) framework adopted in this study.

2.1. Smart City and the Smart Society Dimension in the Educational Context

Allam and Dhunny define a Smart City as an urban ecosystem that integrates information and communication technology in a coordinated manner to improve citizens quality of life, the operational efficiency of the city, and environmental sustainability [9]. Yigitcanlar, Foth, and Kamruzzaman advocate for the reimagination of the smart city concept by emphasising ecological balance within a Post-Anthropocentric Cities approach [10]. Rahmawati and Supriyono assert that the implementation of digitally-based educational technology within local curricula constitutes one of the foundational pillars of inclusive and sustainable Smart Society development [11].

2.2. Augmented Reality as a Learning Medium

Augmented Reality (AR) is a technology that integrates virtual elements into the real environment in real time, where AR systems are classified into three categories: marker-based AR, markerless AR, and position-based AR [12].

The use of AR in learning among primary school-aged children is grounded in robust theoretical foundations. Based on the constructivist learning theories of Vygotsky and Piaget [13], knowledge is actively constructed by learners through interaction with their environment [14]. AR enables students to interact directly with visual representations of real-world objects, thereby fostering deeper knowledge construction compared to passive, text-based instruction. Mayer's Cognitive Theory of Multimedia Learning posits that humans learn more effectively when information is presented simultaneously through verbal and visual channels [15]. Kolb's experiential learning principles emphasise the importance of direct experience in the learning process and AR is capable of simulating meaningful field observation experiences even when students remain within the classroom [16].

2.3. AR in Conservation and Endemic Plant Recognition

Mertayasa and Pascima developed an AR application for the recognition of rare endemic plants of western Indonesia and obtained a positive response rate of 94.83% from respondents [17]. Ardyansyah and Rahayu demonstrated that AR-based learning media integrating environmental literacy significantly enhanced students comprehension of science materials [18].

Hwang and Wu showed that marker-based AR media effectively increased the motivation and learning outcomes of elementary school students in natural science instruction [19]. In contrast to the aforementioned studies, the present research specifically targets a locally endemic flora *(Etlingera balikpapanensis)*, with content grounded in primary botanical data and developed in alignment with the PKLH curriculum of Balikpapan.

2.4. Environmental Education as the Foundation of Ecological Awareness

Environmental education represents a fundamental step in cultivating public awareness of environmental issues [20]. Outdoor learning experiences have unique educational value in fostering students scientific interest and comprehension [21]. The integration of digital technology in environmental education significantly enhances ecological awareness and pro-environmental behavioural intention among elementary school students [22].

2.5. The Multimedia Development Life Cycle (MDLC) Framework

Mustika explains that MDLC comprises six interrelated stages, namely concept, design, material collection, assembly, testing, and distribution [23]. Compared to other development models such as ADDIE, MDLC affords greater iterative flexibility during the testing and refinement of multimedia assets [24].

3. RESEARCH METHODOLOGY

This study employed a Research and Development (R&D) approach within the MDLC development framework.

3.1. Material Collection Stage

This stage involved a comprehensive field survey at the Balikpapan Botanical Garden as the primary research partner. The research team applied a data triangulation strategy by integrating three primary sources:

- Field-based visual documentation
- Scientific literature, including the original discovery publication
- Official monograph of the Balikpapan Botanical Garden

The data collected encompassed the physical dimensions of the plant, the morphology of the flowers, the information about the habitat, the economic value and the status of the conservation [25].

Figure 2. Field Documentation of Balikpapan Ginger *(Etlingera balikpapanensis)* in Full Bloom

The Balikpapan Ginger exhibits distinctive morphological characteristics during its full bloom stage, which were documented to support accurate visual representation in the AR application, as shown in Figure 2.

3.2. Design Stage

The research team designed the interaction flow, User Interface (UI), and User Experience (UX) of the application based on child-centred design principles, prioritising navigational simplicity, visual clarity, and interactive elements. Initial prototypes were mapped in the form of wireframes and storyboards.

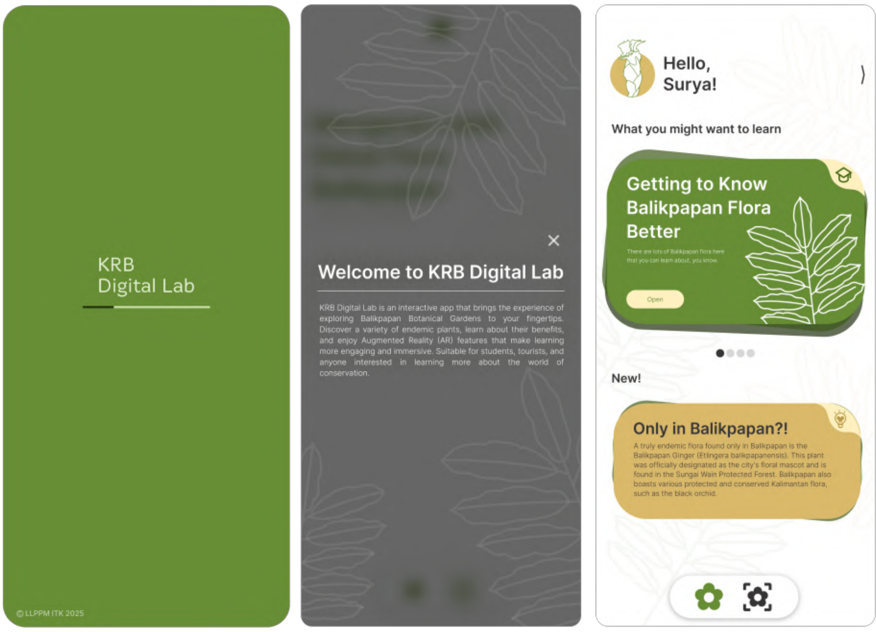

Figure 3. Initial Draft Process of the AR Ginger Application Interface Design

The initial interface design was developed through wireframing and storyboard mapping, as shown in Figure 3, emphasising user-friendly navigation, visual clarity, and child-centred interaction principles.

3.3. Assembly Stage

The Three-dimensional modeling of Balikpapan Ginger was conducted using Blender. Integration into the AR application was performed using Unity as the application development engine and Vuforia as the computer vision-based marker detection SDK. The initial prototype was successfully built and fully functional on the Android platform.

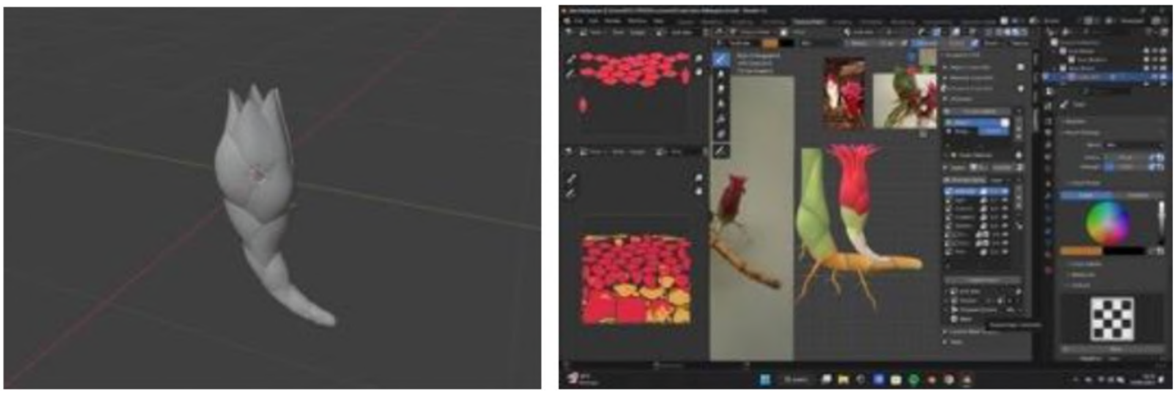

Figure 4. Initial Draft Process of 3D Asset Modeling from the Balikpapan Ginger Flower

The three-dimensional modeling process was carried out using Blender, as illustrated in Figure 4, to produce a detailed and accurate representation of the Balikpapan Ginger flower. Following the completion of the development phase, the application was deployed and evaluated in real-world conditions to assess its functionality and usability.

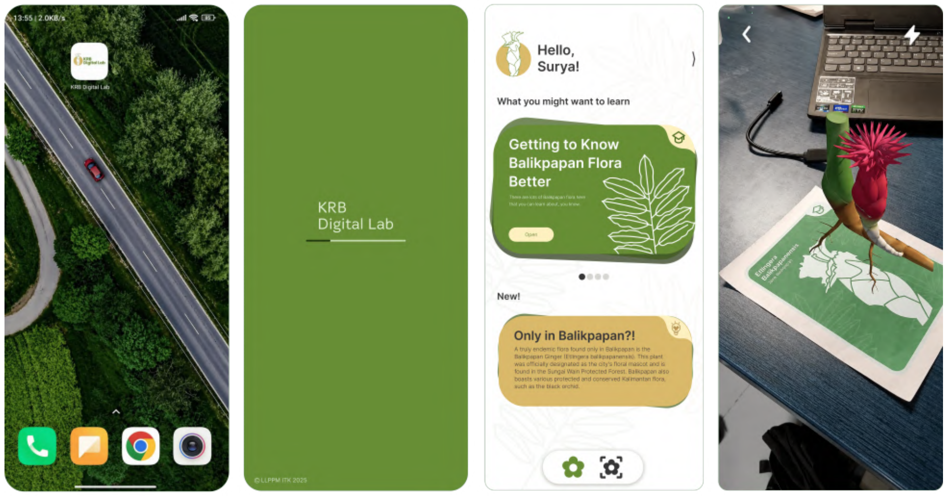

Figure 5. Augmented Reality Field Testing Process of the Balikpapan Ginger Application

The developed AR application was subsequently tested in real-world conditions, demonstrating its functionality on Android devices, with the field testing process presented in Figure 5.

3.4. Testing and Evaluation Stage

Testing was conducted in two structured phases. The first phase consisted of internal testing by the research team, focusing on technical compatibility across Android devices, marker detection stability, and overall performance reliability. The second phase comprised an initial field test involving 15 respondents drawn from the administrators and adult visitors of the Balikpapan Botanical Garden, who served as early adopters [26].

The evaluation instrument used was a questionnaire with a five-point Likert scale (1 = Very Poor, 2 = Poor, 3 = Fair, 4 = Good, 5 = Excellent). The questionnaire encompassed five evaluation aspects including the technical feasibility of the application, educational value of the content, student engagement potential, relevance of the content to the conservation of Balikpapan ginger and technical stability under real-world usage conditions [27]. Instrument validity was confirmed through expert review by two lecturers specialising in educational technology and one Balikpapan Botanical Garden administrator. Respondents were selected through purposive sampling based on the following criteria including having previously visited the Balikpapan Botanical Garden, being familiar with Android smartphone use, and being at least 18 years of age. Data were analysed using descriptive statistics in the form of mean scores and percentages and interpreted critically within the context of AR and environmental education literature [28].

3.5. Distribution and Conceptual Evaluation Stage

Formal distribution is planned following the completion of comprehensive testing. The application will be distributed to two to three elementary schools in Balikpapan that have integrated Balikpapan Ginger into their Grade IV PKLH curriculum [29].

4. RESULT AND DISCUSSION

The development outcomes of the AR application are presented and analysed in terms of technical performance and educational relevance, with reference to existing theories and prior studies.

4.1. Application Development Outcomes

The development of the Balikpapan Ginger AR application has successfully reached the testing stage on Android devices. Technically, the application is capable of rendering the three-dimensional model of *Etlingera balikpapanensis* with satisfactory visual quality. Features successfully implemented include:

- 360-degree rotation capability of the three-dimensional model

- Zoom in and zoom out functionality
- Interactive display of educational information

From a pedagogical standpoint, the implementation of 360-degree rotation and zoom in/out features aligns with the principle of interactivity in Mayer's Cognitive Theory of Multimedia Learning [30], which posits that active learner engagement in manipulating visual representations significantly enhances information retention. From a constructivist perspective, the interface design that facilitates independent student exploration creates a digital scaffolding structure that supports knowledge construction consistent with Vygotsky's concept of the Zone of Proximal Development [31].

4.2. Prototype Technical Specifications

Table 1. Technical Compatibility Test Results of the Balikpapan Ginger AR Application

No.	Specifications	Details
a.	Platform	Android (tested on Android 14, MIUI 14 Global Stable)
b.	App file size $<$ 150 MB (after asset optimization)	
c.	Minimum API Level	Android 8.0 (API 26)
d.	Minimum RAM	2 GB (3 GB recommended for optimal performance)
e.	Optimal screen resolution	4.5–6.5 inches (1080p resolution and above)
f.	Development engine	Unity 2021 LTS with Vuforia SDK 10.x
g.	Connectivity	No internet connection required (standalone app)

As presented in Table 1, the technical specifications were designed with a minimum requirement of Android 8.0 (API Level 26) and 2 GB of RAM, ensuring the application's accessibility across the mid-range Android device spectrum commonly owned by elementary schools and students families in Balikpapan. This consideration is significant given that research by Setiawan and Krisnawati demonstrates device affordability to be one of the critical factors in educational technology adoption in Indonesian elementary schools [32]. Furthermore, the application's ability to function offline represents a strategic design decision in view of limited network infrastructure in several elementary schools across Balikpapan.

4.3. Technical Limitations and Adaptive Responses

Three primary technical challenges were identified and addressed. First, device accessibility constraints were mitigated through asset compression techniques and Level of Detail (LOD) rendering. Second, interface design challenges for child users were addressed through the application of child-centred design principles. Third, marker tracking instability under natural lighting conditions was resolved through adjustments to Vuforia SDK parameters and the design of high-contrast markers [33].

4.4. Partner Evaluation Results

Table 2. Technical Performance Test Results of the Balikpapan Ginger AR Application

No.	Testing Metrics	Results	Notes
a.	Marker detection (indoor)	95% success rate at 20–100 cm	Normal lighting
b.	Frame rate	Average 30 fps	Mid-range device
c.	App load time	$<$ 5 seconds	Optimal conditions
d.	Gesture responsiveness	Rotation & zoom $<$ 100 ms	Capacitive screen
e.	Memory stability	No leaks detected	30 minutes of continuous use
f.	Marker detection (outdoor)	78% success rate	Requires further optimization

The technical testing results presented in Table 2 indicate that the Balikpapan Ginger AR application meets the minimum performance standards required for interactive learning media. The marker detection success rate of 95% (indoor) is comparable to the findings of Mertayasa and Pascima, who reported detection rates exceeding 90% for an endemic plant recognition AR application [34]. The decline to 78% (outdoor) indicates that natural lighting variability remains a technical challenge to be addressed in subsequent development cycles, consistent with Hwang and Wu's findings regarding the limitations of marker-based AR under uncontrolled lighting conditions [32].

4.5. Comparative Analysis with Prior Research

Table 3. Research Partner Evaluation Results (n=15, Likert Scale 1–5)

Evaluation Criteria	Average Score	Percentage	Category
Educational Value of Content	4,85	97,0%	Excellent
Potential for Student Engagement	4,72	94,4%	Excellent
Relevance of Conservation Content	4,68	93,6%	Excellent
Technical Feasibility of the Application	4,35	87,0%	Excellent
Outdoor Technical Stability	4,15	83,0%	Good
Content Safety	5,00	100,0%	Excellent
OVERALL AVERAGE	**4,51**	**90,2%**	**Excellent**

Based on the consolidated evaluation of all research partners (n=15), as presented in Table 3, the application obtained an overall mean score of 4.51 (90.2%), categorised as Very Good. The educational content value aspect received the highest score (4.85; 97%), followed by student engagement potential (4.72; 94.4%) and conservation content relevance (4.68; 93.6%). These findings indicate that the scientific content developed on the basis of primary botanical data possesses high accuracy and relevance. Conversely, outdoor technical stability received the lowest score (4.15; 83.0%), which consistently correlates with the technical testing finding that marker detection under outdoor conditions still requires further optimisation [35].

4.6. Comparative Analysis with Prior Research

The overall acceptance rate (90.2%) in this study is slightly below that reported by Mertayasa and Pascima (94.83%) (6). This discrepancy can be attributed to differences in testing conditions: the prior study was conducted in a controlled environment, whereas the present study incorporated more technically demanding outdoor testing. This comparison, rather than undermining the findings, reinforces the validity of this study's results, as they more accurately reflect real-world usage conditions. From the perspective of Mayer's theory, the high score on student engagement (94.4%) confirms that the combination of interactive 3D models, structured textual information, and intuitive visual navigation is consistent with the principles of Coherence, Signaling, and Personalisation principles Mayer identifies as hallmarks of effective multimedia design.

4.7. Research Limitations

This study has several limitations that must be honestly acknowledged. First, the evaluation is currently confined to a feasibility testing stage involving adult respondents, and has not yet encompassed empirical measurement of elementary school students' learning outcomes through a pre-test/post-test design with a control group. Second, the respondent sample size (n=15) is relatively small and purposive in nature, thereby limiting the generalisability of the findings. Third, the outdoor technical stability testing conducted under a single environmental condition does not yet reflect the variability of real-world conditions across different elementary schools in Balikpapan. These limitations imply that the findings should be interpreted with caution, as they may not fully represent the effectiveness of the application across diverse user groups, learning contexts, and environmental conditions. Consequently, the generalisability of the results remains limited, particularly when applied to broader educational settings beyond the study sample and location.

5. MANAGERIAL IMPLICATIONS

This study contributes to the advancement of AR-based environmental education by extending the application of multimedia learning and constructivist learning theories. The findings demonstrate how interactive AR features, such as 360-degree manipulation and user-controlled exploration, can operationalise cognitive engagement and digital scaffolding in the context of local biodiversity education. This reinforces the role of immersive technologies in facilitating experiential and student-centered learning processes, particularly for abstract or less accessible environmental content.

From a practical perspective, several actionable recommendations can be derived. Local governments and education authorities are encouraged to integrate the AR application into the PKLH curriculum through structured lesson plans and teacher training modules to ensure effective classroom adoption. Schools can implement the application as a supplementary learning tool, particularly in resource-constrained settings, given its offline functionality and compatibility with mid-range Android devices. Furthermore, developers and implementing agencies should prioritise improving outdoor marker detection performance and conduct iterative usability testing with students to enhance real-world reliability. These actions support the translation of research outcomes into scalable and sustainable educational practices.

6. CONCLUSION

This study has successfully demonstrated that Augmented Reality technology can function as an effective medium for bridging the limitations of physical access to endemic flora with the need for contextual and meaningful learning experiences. The Balikpapan Ginger AR application prototype was developed from the conceptual stage through to a fully tested, functional system representing **Etlingera balikpapanensis** as an interactive three-dimensional model.

The evaluation results indicate that the prototype achieved a Very Good rating (4.51; 90.2%) from 15 testing partners, with particularly strong validation in terms of educational value (97%) and conservation content relevance (93.6%). These findings confirm that the application is not only technically feasible but also pedagogically effective in supporting environmental learning.

From a technical perspective, the application has demonstrated stable performance on mid-range Android devices, the ability to operate in offline mode, and a marker detection rate of 95% under indoor conditions. Building on these achievements, future research should focus on quantitative evaluation of learning outcomes, integration into formal educational frameworks, expansion to other endemic species, incorporation of artificial intelligence for personalised learning, and comparative studies with conventional learning methods within the PKLH curriculum context.

7. DECLARATIONS

7.1. About Authors

Fulkha Tajri M (FM) -
Olivia Febrianty Ngabito (ON) -
Denny Huldiansyah (DH) -
Azzah Nafisah Sofyan (AS) -
Muhammad Bintang Kurniawan (MK) -
Surya Abdi Pratama (SP) -

7.2. Author Contributions

Conceptualization: FM, ON and AS; Methodology: DH; Software: FM; Validation: SP; Formal Analysis: FM and DH; Investigation: AS and MK; Resources: MK; Data Curation: FM and SP; Writing Original Draft Preparation: ON and AS; Writing Review and Editing: MK; Visualization: SP; All authors, FM, ON, DH, AS and SP, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The dataset used in this research can be obtained from the corresponding author upon request.

7.4. Funding

The authors did not receive any funding for the research, writing, or publication of this article.

7.5. Declaration of Conflicting Interest

The authors confirm that there are no conflicts of interest, financial or personal, that could have affected the results reported in this paper.

REFERENCES

[1] F. Arena, M. Collotta, G. Pau, and F. Termine, "An overview of augmented reality," *Computers*, vol. 11, no. 2, p. 28, 2022.

[2] H. A. B. Cintya, "Mascot and brand sustainability in pandemic era: Systematic literature review," in *International Conference on Sustainability in Creative Industries*. Springer, 2024, pp. 41–48.

[3] C. E. Mendoza-Ramírez, J. C. Tudon-Martinez, L. C. Félix-Herrán, J. d. J. Lozoya-Santos, and A. Vargas-Martínez, "Augmented reality: survey," *Applied Sciences*, vol. 13, no. 18, p. 10491, 2023.

[4] H. E. Riwayati, H. A. Rachman, S. Pramesworo, N. Yustisia, H. Umar, and M. Siahaan, "Unveiling the dynamics of financial literacy and inclusion in women digital loan decision making," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 3, pp. 986–998, 2025.

[5] S. Dargan, S. Bansal, M. Kumar, A. Mittal, and K. Kumar, "Augmented reality: A comprehensive review: S. dargan et al." *Archives of Computational Methods in Engineering*, vol. 30, no. 2, pp. 1057–1080, 2023.

[6] A. A. Pradana, N. P. T. Prakisya, and Y. H. Aristyagama, "Development of geo-based augmented reality learning media on the distribution of endemic animals around the world," in *5th Vocational Education International Conference (VEIC-5 2023)*. Atlantis Press, 2024, pp. 689–704.

[7] D. Kamińska, G. Zwoliński, A. Laska-Leśniewicz, R. Raposo, M. Vairinhos, E. Pereira, F. Urem, M. Ljubić Hinić, R. E. Haamer, and G. Anbarjafari, "Augmented reality: Current and new trends in education," *Electronics*, vol. 12, no. 16, p. 3531, 2023.

[8] U. Rahardja, "Blockchain education: as a challenge in the academic digitalization of higher education," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 4, no. 1, pp. 62–69, 2022.

[9] S. V. Aisyah, R. Cahyaningsih, Violita, S. Hidayat, T. Juhaeti, and D. H. Putri, "Inventory of zingiberaceae family endemic to kalimantan with medicinal uses from global database," in *IOP Conference Series: Earth and Environmental Science*, vol. 1471, no. 1. IOP Publishing, 2025, p. 012049.

[10] H. Hamzah, S. U. T. Pratiwi, D. Lestari, D. A. Azizah, N. A. Astriani, A. Jabbar, and A. Marzuki, "Investigation of antibacterial and antifungal activities of etlingera balikpapanensis extracts against staphylococcus aureus and candida albicans," *Pakistan journal of biological sciences: PJBS*, vol. 28, no. 12, pp. 765–772, 2025.

[11] A. Williams, Y. Hasudungan, and N. Azizah, "The implementation of effective financial management to increase the profitability of startups," *Startupreneur Business Digital (SABDA Journal)*, vol. 4, no. 1, pp. 47–54, 2025.

[12] Z. Siddiqui and C. A. Rivera, "Fintech and fintech ecosystem: A review of literature." *Risk Governance & Control: Financial Markets & Institutions*, vol. 12, no. 1, 2022.

[13] L. N. García, R. Tau, and M. J. Ratcliff, "Piaget as scientific diplomat: Exchanges between the geneva school and soviet psychologists during the 1950s–60s," *History of the Human Sciences*, vol. 39, no. 1, pp. 52–67, 2026.

[14] M. Avarmaa, L. Torkkeli, L. Laidroo, and E. Koroleva, "The interplay of entrepreneurial ecosystem actors and conditions in fintech ecosystems: An empirical analysis," *Journal of Entrepreneurship, Management and Innovation*, vol. 18, no. 4, pp. 79–113, 2022.

[15] Z. Zainol, N. N. A. Wahab, S. M. Shokory, and P. Harianto, "Healthy spending habits as drivers of technopreneurial and financial outcomes," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 3, pp. 823–834, 2025.

[16] F. A. Hudaefi, M. K. Hassan, and M. Abduh, "Exploring the development of islamic fintech ecosystem in indonesia: a text analytics," *Qualitative Research in Financial Markets*, vol. 15, no. 3, pp. 514–533, 2023.

[17] A. H. Y. Zheng, R. Ab-Rahim, and A. H. Y. Jing, "Examining the fintech ecosystem of asean-6 countries," *Asia-Pacific Social Science Review*, vol. 22, no. 2, p. 2, 2022.

[18] U. Rahardja, M. Miftah, M. Rakhmansyah, and J. Zanubiya, "Revolutionizing financial services with big data and fintech: A scalable approach to innovation," *ADI Journal on Recent Innovation*, vol. 6, no. 2, pp. 118–129, 2025.

[19] B. Karadag, A. Akbulut, and A. H. Zaim, "A review on blockchain applications in fintech ecosystem," in *2022 International Conference on Advanced Creative Networks and Intelligent Systems (ICACNIS)*. IEEE, 2022, pp. 1–5.

[20] A. Molla and A. Biru, "The evolution of the fintech entrepreneurial ecosystem in africa: An exploratory study and model for future development," *Technological Forecasting and Social Change*, vol. 186, p.

122123, 2023.

[21] M. W. Wicaksono, M. B. Hakim, F. H. Wijaya, T. Saleh, E. Sana *et al.*, "Analyzing the influence of artificial intelligence on digital innovation: A smartpls approach," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 5, no. 2, pp. 108–116, 2024.

[22] M. Ajouz and F. Abuamria, "Unveiling the potential of the islamic fintech ecosystem in emerging markets," *Al Qasimia University Journal of Islamic Economics*, vol. 3, no. 1, pp. 115–148, 2023.

[23] J. Migozzi, M. Urban, and D. Wójcik, ""you should do what india does": Fintech ecosystems in india reshaping the geography of finance," *Geoforum*, vol. 151, p. 103720, 2024.

[24] DLH Kota Balikpapan, "Official: Balikpapan ginger included in local content (pklh) curriculum for elementary school level 2024/2025," https://dlh.balikpapan.go.id/berita/5424/resmi-jahe-balikpapan-masuk-dalam-pembelajaran-m, 2024, accessed: 2025-05-18.

[25] G. Nicola and R. Setiawan, "Creating competitive advantage through digital innovation: Insights from startupreneurs in e-commerce," *Startupreneur Business Digital (SABDA Journal)*, vol. 3, no. 2, pp. 131–140, 2024.

[26] A. Alaassar, A.-L. Mention, and T. H. Aas, "Ecosystem dynamics: Exploring the interplay within fintech entrepreneurial ecosystems," *Small Business Economics*, vol. 58, no. 4, pp. 2157–2182, 2022.

[27] E. Koroleva, "Fintech entrepreneurial ecosystems: Exploring the interplay between input and output," *international journal of financial studies*, vol. 10, no. 4, p. 92, 2022.

[28] Y. Sudaryo, D. Hamdani, N. A. Sofiati, D. H. N. Sipahutar, and S. Sutisna, "Assessing the drivers of financial distress in indonesian rattan smes through digital and financial perspectives," *Aptisi Transactions on Technopreneurship (ATT)*, vol. 7, no. 3, pp. 904–913, 2025.

[29] A. Dudhat and V. Agarwal, "Indonesia's digital economy's development," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 4, no. 2, pp. 109–118, 2023.

[30] A. S. Bist, B. Rawat, U. Rahardja, Q. Aini, and A. G. Prawiyogi, "An exhaustive analysis of stress on faculty members engaged in higher education," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 3, no. 2, pp. 126–135, 2022.

[31] R. Ai, Y. Zheng, S. Yüksel, and H. Dinçer, "Investigating the components of fintech ecosystem for distributed energy investments with an integrated quantum spherical decision support system," *Financial Innovation*, vol. 9, no. 1, p. 27, 2023.

[32] U. Noreen, "Mapping of fintech ecosystem to sustainable development goals (sdgs): Saudi arabia's landscape," *Sustainability*, vol. 16, no. 21, p. 9362, 2024.

[33] I. Mustapha, Y. Vaicondam, A. Jahanzeb, B. A. Usmanovich, and S. H. B. Yusof, "Cybersecurity challenges and solutions in the fintech mobile app ecosystem." *International Journal of Interactive Mobile Technologies*, vol. 17, no. 22, 2023.

[34] N. P. L. Santoso, R. Nurmala, and U. Rahardja, "Corporate leadership in the digital business era and its impact on economic development across global markets," *IAIC Transactions on Sustainable Digital Innovation (ITSDI)*, vol. 6, no. 2, pp. 188–195, 2025.

[35] R. Dani, "Balikpapan ginger officially designated as the iconic flora of balikpapan city," https://www.inibalikpapan.com/jahe-balikpapan-ditetapkan-jadi-flora-khas-kota-balikpapan/, 2022, accessed: 2025-05-18.