



Integration of Local Wisdom into Problem-Based Books with Augmented Reality to Improve Students' Conservation Literacy

Iwan¹, Jeni², Nurfathurrahmah,³ Sumaifa⁴

^{1,2}Department of Biology Education, Universitas Papua, Indonesia

³Department of Biology Education, Universitas Nggusuwaru, Indonesia

⁴Department of Midwifery, Universitas Syekh Yusuf Al Makssari Gowa

*Email: bioiwan19@gmail.com

ARTICLE INFO

Keywords:

Augmented Reality
Conservation literacy
Local wisdom
Problem-Based Learning
Student book

ABSTRACT

Purpose - Students' conservation literacy could be greatly increased by integrating local knowledge with the PBL approach and augmented reality technology. In order to increase students' conservation literacy, this study aimed to create a student book on biodiversity that was focused on problem-based learning, incorporated local knowledge, and supported by augmented reality media.

Methodology - The ADDIE paradigm of research and development is referred to as the research technique. Manokwari high school students served as the study's 32 subjects. Validation sheets and questionnaires were used as data collection tools to assess the validity of the student book and the students' answers to conservation literacy questions. Students' replies, validation results, and conservation literacy abilities were all examined in the descriptive data analysis.

Findings - The findings of this study indicate that the validation results for the Biodiversity Student Book were 93.65% (very valid category), indicating that it is suitable for implementation in learning. The validation of the conservation literacy instrument yielded a 96.13% validity rate (very valid). The results of student responses after the trial of the student book in learning were 85% (very practical or effortless to use category). The results of the trial evaluating the effectiveness of student conservation literacy showed a Sig of 0.000 (<0.05), indicating a difference in the average level of student conservation literacy before and after learning.

Contribution - This study concludes that the use of student books on biodiversity is highly effective in improving and developing students' conservation literacy.

Received 17 November 2025; Received in revised form 28 November 2025; Accepted 12 February 2026

Jurnal Eduscience (JES) Volume 13 No. 1 (2026)

Available online 28 February 2026

©2025 The Author(s). Published by LPPM Universitas Labuhanbatu. This is an open-access article under the [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License \(CC BY-NC-SA 4.0\)](https://creativecommons.org/licenses/by-nc-sa/4.0/)

INTRODUCTION

Conservation literacy refers to students' ability to understand, appreciate, and apply conservation principles in everyday life, especially in efforts to conserve natural resources and biodiversity. Students with strong conservation literacy can make informed decisions to protect the surrounding environment. The main benefit of conservation literacy is to create a generation that understands the importance of maintaining ecosystem balance, which is essential for environmental sustainability and community welfare. However, low conservation literacy can lead to indifference toward environmental issues, a lack of skills to address environmental problems, and minimal involvement in conservation efforts (Agustiani & Imtihana, 2023; Abdullah et al., 2019; Al Balushi, 2023).

Research and observation show that Indonesian students' conservation literacy is still comparatively low. The significance of protecting biodiversity and the effects of human activity on the environment are not well understood by many students. This is illustrated by students' minimal involvement in environmental conservation initiatives and their weak awareness of biodiversity in their studies. Students find it difficult to fully comprehend conservation values because of learning that still emphasizes theory and memory. This issue is made worse by the absence of contextually and pertinently based approaches to students' everyday lives (Tresnawati et al., 2021).

The absence of engaging and pertinent teaching strategies in the local setting is the primary obstacle to raising students' conservation literacy. Conservation education frequently ignores students' active participation in the learning process in favor of concentrating only on knowledge transfer. Additionally, a barrier to raising students' comprehension of conservation issues is the underutilization of contemporary technology in the classroom. Pupils require a more demanding curriculum and be inspired to actively participate in resolving actual conservation and environmental preservation issues (Endang Purnama et al., 2024; Iwan et al., 2020)

Integrating local knowledge with the Problem-Based Learning (PBL) method is the suggested way to raise students' conservation literacy. Values passed down from ancestors about protecting the environment and the natural world are part of local wisdom. Students can learn strategies that have been shown to be successful in preserving biodiversity by incorporating local knowledge into their education. In contrast, PBL encourages students to work on solving actual conservation-related challenges. This method fosters critical thinking, analysis, and problem-solving skills in pupils that are applicable to their everyday lives (Damopolii et al., 2024; Regala, 2019).

By fusing digital and real-world items, augmented reality is a technology that can improve education. AR can offer more accurate and realistic biodiversity visualizations in the context of conservation education. For instance, students' interest and engagement in learning are increased when they can interactively view and comprehend different species of flora and fauna. Additionally, AR can make abstract conservation concepts more interesting and participatory for kids, which will ultimately greatly increase their conservation literacy (Ratnasari et al., 2022; Aprilinda et al., 2020; Anwar et al., 2023; Aripin & Suryaningsih, 2019).

Students' conservation literacy could be greatly enhanced by combining local knowledge with the PBL method and augmented reality technologies. Students are encouraged to learn about cultural values associated with nature protection through local wisdom, and PBL empowers them to actively look for answers to pertinent environmental issues. AR offers powerful visual assistance, enhancing students' educational experiences and assisting them in comprehending the true effects of human activity on biodiversity. These three components work together to provide an engaging, relevant, and dynamic learning environment that greatly enhances students' comprehension of conservation (Tamam & Qomaria, 2023).

The low level of student conservation literacy in Indonesia is a challenge that must be addressed immediately through innovative, relevant learning approaches. The integration of local wisdom, PBL, and AR technology in biodiversity learning provides an effective solution to improve students' understanding of conservation. This approach not only strengthens students' knowledge but also their critical thinking skills in dealing with environmental problems. It is hoped that through this research, a more interactive, contextual, and technology-based conservation learning model can be widely implemented in schools in Indonesia, so

that future generations are better prepared to maintain environmental sustainability and biodiversity (Lubis et al., 2022).

Learning media is still classified as a manual learning challenge. This is less effective in practice since biology requires specialized media, such as original media, that illustrate elements of the human body that are easily accessible inside and outside the classroom. As a result, creating an augmented reality-based biology teaching module is essential (Rahma Sari et al., 2023). The increasingly complicated challenges and needs of education in today's modern world require interactive learning (Lintangesukmanjaya et al., 2024). Students receive less than ideal grades as a result of the shortcomings of technology-based education modules. Augmented reality is one of the learning media that must be used to create instructional materials that promote technology-based learning (Kumalasari & Fikroh, 2023).

The novelty of this research lies in the development and testing of a textbook that simultaneously integrates local wisdom and augmented Reality within a problem-based learning framework to improve students' conservation literacy. Unlike previous studies that examined local wisdom, problem-based learning (PBL), and AR partially, this study presents a comprehensive pedagogical, cultural, and technological integration, with conservation literacy as the primary and measurable objective. This approach offers new conceptual, pedagogical, and empirical contributions to the development of conservation learning based on local contexts and immersive technology.

Therefore, one of the educational resources to be created as part of this study is a student textbook that uses augmented reality media and a problem-based learning paradigm on biodiversity to include local knowledge. The goal of this study is to create a textbook for students that incorporates local knowledge and a problem-based learning model, utilizing valid, practical, and effective augmented reality technology to improve students' conservation literacy.

METHODOLOGY

Research Design

This research is a type of research and development that follows the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009). The stages of the ADDIE model development research include:

Analyze

It was discovered through an investigation of student book needs that the student books now in use are still restricted to common books. Only visual (photos), audiovisual (video), and basic 3D media are still utilized. There has never been use of innovative learning materials.

Design

At this point, student books that are integrated with the PBL model, local knowledge, and augmented reality media are designed based on learning achievements. Specifically, students can develop solutions to problems based on local, national, or global issues related to understanding the diversity of living things and their roles, viruses and their roles, biological technology innovation, ecosystem components and interactions between components, and environmental changes. The Assemblr application is used to create educational materials. Pretests and post-tests are formative assessments of students' literacy skills that use AI-based media (Quiziz).

Development

The Learning Expert and Media Expert validators will validate the Student Book and the conservation literacy assessment tool once they have been developed into prototypes.

Implementation

This stage is carried out to implement the Student Book and the tools considered feasible. Everything that has been developed will now be put to the test under actual circumstances. In order to assess conservation

literacy abilities following the use of the student book, a pretest is given during this implementation stage and a post-test is given at the conclusion of the meeting.

Evaluation

At the conclusion of each development phase, an evaluation will be carried out. Additionally, a summative assessment will be carried out at the conclusion of this phase to gauge the effectiveness of creating the learning media product. At this point, a normality test is performed before a Paired T-test is used to compare conservation literacy abilities before and after the student book is implemented.

Population and Samples

The population in this study is defined as all elements, including objects and people, that possess the characteristics under study. The study population comprised 32 students in class X at SMA Immanuel Pasir Putih Manokwari. The sampling technique used was total sampling, with the entire population serving as the research sample.

Data Collection and Instrument

The instruments in this study are (a) a validation instrument: A 5-point Likert scale response format is used in this validation tool. Each item on the development instrument has a gradation of (1) extremely bad, (2) bad, (3) very good, (4) good, and (5) very good. Two expert validators' evaluations served as the basis for the collection of instrument validation data. (a) A questionnaire was utilized as an instrument to assess the usefulness of the instructional materials. Student reactions to student books that use Augmented Reality and local knowledge were used to gather practicality data. (c) Test instrument: There were twenty multiple-choice questions on the test. Pretests and posttests of students' learning that incorporates local knowledge into problem-based learning supported by augmented reality media on biodiversity were used to gather data on the conservation literacy exam outcomes.

Data Analysis

Analysis of research data is grouped into two, namely validity and practicality. Calculate the validity of learning media using the following formula:

$$\text{Eligibility percentage} = \frac{\text{obtained item score}}{\text{Maximum scorekor}} \times 100\%$$

The table shows the learning device validity category based on the final score on a scale (0-100).

Table 1. Categories of Learning Media Validity (Anapia et al., 2024)

Interval (%)	Category
81-100	Completely
61-80	Valid
41-60	Less valid
21-40	Invalid
0 - 20	Completely Invalid

The product is tested to see the student response. The student book will then be analyzed using the student response data. Response to the student book using the formula:

$$\% \text{ Eligibility percentage} = \frac{\text{obtained item score}}{\text{Maximum score}} \times 100\%$$

The student response criteria for seeing the practicality of the student book can be seen in Table 2.

Table 2. Response Questionnaire Criteria (Kartini et al., 2020)

Interval (%)	Category
81-100	Very Good
61-80	Good
41-60	Good enough
21-40	Not good
0- 20	Not very good

A normality test is the first of several steps in the study of effectiveness data. To ascertain if the data are normally distributed, one fundamental assumption test is the normality test. Researchers apply the Shapiro-Wilk normalcy test using SPSS version 25. The data is regularly distributed if the significance value is higher than 0.05; (c) Paired Sample t-test. The average of two paired measurements taken before and after treatment within the same group is compared using the paired-samples t-test. SPSS version 25 is used to compute the paired-samples t-test. The significant value (Sig.) in the paired sample t-test determines the outcome.

FINDINGS

Analysis

The constraints of teaching materials based on local knowledge, their focus on problem-based learning, and the challenges of using learning media technology like augmented reality were all documented. Teachers still only use standard textbooks as teaching resources instead of ones that they have created specifically to fit the needs of their pupils. As a result, pupils' environmental literacy is still lacking, particularly when it comes to biodiversity resources. As a result, using augmented reality media technology and creating a textbook based on local knowledge are essential.

Design

With the use of augmented reality media on biodiversity content and in line with learning objectives, a student book prototype that incorporates local knowledge and is focused on problem-based learning was acquired. At this point, Quiziz has also been used to create a conservation literacy questionnaire. Here is an illustration of a design image.

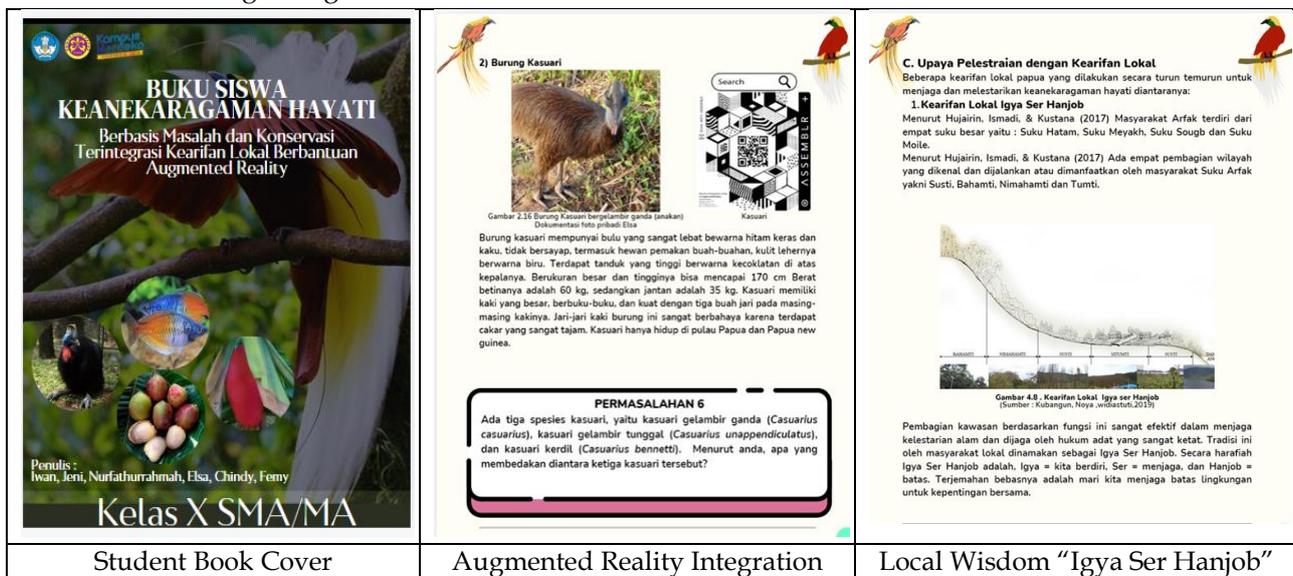


Figure 1. The Display of Book

Development

This stage produces a prototype of a Student Book product that integrates local wisdom, is oriented towards problem-based learning, and is supported by Augmented Reality media on biodiversity.

Furthermore, at this stage, validation is carried out by Learning Media and material experts to assess the feasibility of the student book that has been developed. Validation includes construct, content, and readability validation. The following validation results are presented in Table 3.

Table 3. Results of Material and Media Expert Assessment

No	Aspect	Percentage (%)	Criteria
1	Design (landing page, header, navigation, footer)	89,06	Very valid
2	Ease of use	95,83	Very valid
3	Information Quality	95,83	Very valid
4	Language	93,75	Very valid
5	According to student development	93,75	Very valid
	Average	93,65	Very valid

Based on Table 3, the average validation percentage for the student textbook across all aspects was 93.65%, indicating high validity. This indicates that the student textbook, integrated with the PBL model and local wisdom on biodiversity, and supported by augmented reality media, is suitable for classroom testing. In addition to validating the student textbook, a similar validation was conducted for the Conservation Literacy instrument. The purpose of this validation was to determine the level of suitability of the conservation literacy instrument. The validation data for conservation literacy are presented in Table 4

Table 4. Validation of Conservation Literacy Question Instrument

No	Aspect	Percentage (%)	Criteria
1	Material	96	Very valid
2	Construct	86,67	Very valid
3	Language	98	Very valid
4	Students' Conservation Knowledge	100	Very valid
5	Students' Conservation Attitudes	100	Very valid
	Average	96,13	Very valid

Table 4 shows that the validation results for the student conservation literacy instrument across all aspects were 96.13%, indicating high validity. This indicates that the conservation literacy instrument, as assessed by the validator, is suitable for implementation in the learning process.

Implementation and Evaluation

Evaluation will be carried out at the end of each Analyze, Design, Development, and Implementation stage. This stage conducted a summative evaluation to assess the success of developing Augmented Reality-assisted student books for biological diversity systems. Table 5 presents students' conservation literacy scores.

The normality test determines whether the data are typically distributed. If the data is normally distributed, a paired t-test can be conducted, which is a prerequisite for the test. Table 5 presents the results of the normality test for students' conservation literacy data.

Table 5. Results of the test of normality

No	Class	Statistic	Df	Sig.	Information
1	Pretest	0.965	32	0.417	Normality
2	Posttest	0.970	32	0.550	Normality

Based on Table 5, the results of the normality test for the pretest and post-test of conservation literacy are normally distributed; this is evident from the pretest sig = 0.417 > 0.05 and the post-test Sig = 0. This indicates that the pretest and post-test scores are normally distributed.

Next, after the data were normally distributed, a paired t-test was conducted to determine the difference in average conservation literacy scores before and after the learning was implemented. The results of the paired t-test are presented in Table 6.

Table 6. Results of Paired t-Test Literacy Conservation

Data	Mean	t	df	Sig.	Information
Pretest/ Posttest conservation literacy	-10.033	-6.271	32	0.000	significant influence

Table 6 shows that the paired t-test indicates Sig. (2-tailed) $0.000 < 0.05$. This indicates a significant difference in the average level of conservation literacy before and after the implementation of PBL learning integrated with local wisdom and augmented Reality.

Practicality analysis data based on student responses to the use of the student book on biodiversity integrated with local wisdom and assisted by augmented Reality. Student response data to the use of the student book can be presented in Figure 3.

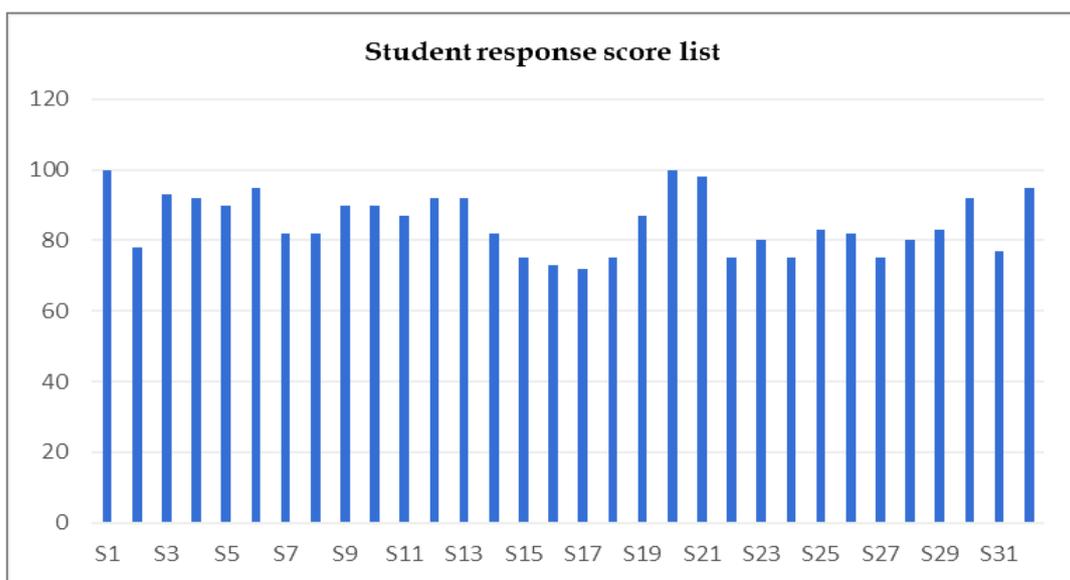


Figure 3. Student response scores

DISCUSSION

The average was 93.65% according to media and material specialists' validation reports. This demonstrates that the augmented reality-assisted human sensory system instruction module is classified as extremely feasible/very valid. Similarly, 96.13% (very valid) of the conservation literacy questions were validated. This is consistent with by Sholikha et al. (2024) findings on the development of Augmented Reality Learning Media, which shows that this AR product is well-suited for learning. Additionally, this is consistent with studies carried out by Iwan et al., (2024) about the development of interactive e-modules on protist material to improve student learning outcomes and the development of augmented reality-assisted modules to improve student learning outcomes (Iwan et al., 2024)

The practicality of the student book, based on local wisdom-oriented, problem-based learning assisted by Augmented Reality, is evident from students' responses to learning with it. The results of the student responses show an average of 85% in the convenient category. This student book makes it very easy and helps students in the learning process. This aligns with what Ilona-Elfertyja et al. (2020) conveyed: the potential benefits of AR integration in the learning process are very interesting and offer an opportunity for the future.

In the learning process, teachers, as sources of information, need to process various information so that students can receive it correctly and clearly; therefore, an aid in the form of augmented reality learning media is needed. (Fitrianingsih et al., 2023). Research results (Law & Heintz, 2021) show that of 714 articles, 42 explain

the importance of implementing AR technology in learning. Current developments are experiencing an increase in efforts to implement augmented reality technology in education. Augmented Reality is a new technology connected to the information system (Aslan, 2021).

The effectiveness test results, with a student conservation literacy $\text{sig} < 0.05$, indicate a difference in average conservation literacy before and after learning. Students' conservation literacy can be effectively increased by using the PBL learning approach in conjunction with augmented reality technology and local knowledge. The average student conservation literacy in the experimental group was significantly higher than in the control group, demonstrating this outcome. Students are encouraged to think critically and comprehend the significance of biodiversity protection through the use of PBL, which offers a more engaging, pertinent, and contextual learning experience (Ardoin et al., 2020; Hijra et al., 2025).

PBL integration can help low-ability biology students develop their critical thinking skills (Muhfahroyin et al., 2023). Students' performance in biology in Nigerian secondary schools can be raised by implementing the problem-based learning paradigm. Students' learning achievement in biology differs significantly, with the experimental group outperforming the control group.

(Usman et al., 2023). According to research results (Cardoso-Espinosa et al., 2024), The Efficiency of Problem-Based Learning in Developing Mathematical Proficiency Research by Iwan, Sumitro, Ibrohim, and Rohman (2024) regarding how the Problem Based Learning approach affects students' capacity for critical thought in conservation biology classes (Iwan et al., 2025b)

Research results by Purnamasari et al. (2016) show that the application of augmented Reality affects student learning achievement. Augmented Reality-based Assemblr EDU media can improve student learning outcomes (Lino Padang et al., 2022). By implementing this technology, it is hoped that it will become an attraction for students in learning (Hadi et al., 2022). Research results by Aripin & Suryaningsih (2019) show that Biology learning with AR media developed is quite effective and can improve students' learning achievement (Arulanand et al., 2020). Research result (Suharti et al., 2024) Augmented Reality influences students' critical thinking skills (Garzón et al., 2020). The media developed can improve students' science learning outcomes across cognitive, affective, and psychomotor domains (Fakhrudin et al., 2019). The application of AR-based media improves learning in Biology classes (Ciloglu & Ustun, 2023; Dehghani et al., 2023). Augmented Reality can introduce new forms and methods, and its capabilities will make classes more interactive (Garzón et al., 2020) ; Tamam & Qomaria, 2023). The application of Augmented Reality encourages students to be interactive (Kharchenko et al., 2021; Sharma et al., 2022).

The use of 3D technology in learning can improve students' understanding of the material (Bliznakova et al., 2024). The use of VR and gamification in environmental education enhances students' knowledge and skills, thereby improving the quality of future education (Asmak Ismail et al., 2024). The Use of Augmented Reality Mobile App Influences Students' Self-Competence (Hidayat et al., 2024). This research paves the way for optimizing VR-based learning environments to promote higher levels of reading comprehension among students. (Çoban et al., 2024). Learning through augmented Reality has a positive effect on students' academic achievement (Canbaz & Yalçın, 2024). The use of augmented reality-based card games can be an effective way to improve students' mathematical competence. This study serves as a call to action for prospective developers and educators to improve the integration of AR in mathematics education in the future (Ahmad & Junaini, 2022). Research results (İslim et al., 2024) show that Augmented Reality positively influences students' attitudes and interests in motivation, spatial ability, and creative thinking skills. To increase technology acceptance, teachers and technology developers should prioritize increasing ease of use and strengthening social factors (Yusuf, 2024; Kocak et al., 2023).

The integration of local wisdom into learning is crucial for enhancing students' environmental awareness and conservation attitudes. This aligns with research by Alshehri (2024), This illustrates that information received from formal environmental education can promote an attitude of care for nature. Preschool environmental awareness attitudes demonstrate a substantial difference between the average pretest and posttest environmental values of the experimental group (Güvenir & Türkmen, 2024). Increasing students' ecological awareness to prevent environmental pollution (Yilmaz, 2024; Oz & Isik, 2024). incorporating local culture into the comprehension of scientific ideas to enhance science education in schools and scientific literacy

in society (Suprpto et al., 2024). Students' comprehension of common things can be enhanced by incorporating local culture into physics learning projects (Rahmat et al., 2024). Research result (Fitriani et al., 2024) demonstrates how plant anatomy textbooks can help aspiring biology instructors develop their critical analytical abilities. Research results by Iwan et al. (2020) on the creation of PBL-based instructional materials including tifa local knowledge in Papua and the impact of doing so on problem-based learning to enhance students' problem-solving skills (Iwan et al., 2024; Iwan et al., 2025a).

CONCLUSION

The research satisfies the requirements of validity (96,13%), practicality (85%), and effectiveness in raising students' conservation literacy based on the findings of the study on the creation of student books on biodiversity-oriented problem-based learning integrated with local wisdom aided by augmented reality. The paired sample test yielded a Sig. (2-tailed) value of $0.00 < 0.05$. This demonstrates that there is a change in students' conservation literacy before and after using student books that focus on problem-based learning, include local knowledge, and use augmented reality to help with biodiversity content. The study's findings are intended to provide suggestions for creating and putting into practice a problem-based learning model that incorporates local knowledge and is enhanced by augmented reality in order to conservation literacy regarding materials other than biodiversity, fostering a caring attitude and conservation attitude towards natural resources.

ACKNOWLEDGMENT

This research was conducted under a research contract with the Indonesian Ministry of Research, Technology and Higher Education (DRTPM) in 2024, funded through the Basic Fundamental Research Scheme in Higher Education (No: SP-33/UN42.15/PG/2024).

REFERENCES

- Abdullah, A., Sayuti, A., Hasanuddin, H., Affan, M., & Wilson, G. (2019). People's perceptions of elephant conservation and the human-elephant conflict in Aceh Jaya, Sumatra, Indonesia. *European Journal of Wildlife Research*, 65(5). <https://doi.org/10.1007/s10344-019-1307-1>
- Agustina, D. W., Rachmadiarti, F., & Kuntjoro, S. (2023). Development of Environmental Pollution Handling Flipbook Based on Surabaya Local Wisdom to Train Students' Ethno-conservation. *IJORER: International Journal of Recent Educational Research*, 4(1), 16–30. <https://doi.org/10.46245/ijorer.v4i1.268>
- Al Balushi, H. M., & Ambusaidi, A. K. (2023). The influence of environmental education on Omani students' self-reported environmental attitudes and behaviours. *International Research in Geographical and Environmental Education*, 32(2), 90–106. doi:10.1080/10382046.2022.2154976
- Ahmad, N. I. N., & Junaini, S. N. (2022). PrismAR: A Mobile Augmented Reality Mathematics Card Game for Learning Prism. *International Journal of Computing and Digital Systems*, 11(1), 217–225. <https://doi.org/10.12785/ijcds/110118>
- Alshehri, S. Z. (2024). Exploring students' perceptions of pro-environmental knowledge and behaviour: a mixed-methods investigation. *Journal of Turkish Science Education*, 21(3), 389–409. <https://doi.org/10.36681/tused.2024.021>
- Anapia, S., Husain, I. H., Mardin, H., Mamu, H. D., & Akbar, M. N. (2024). Pengembangan Modul Pembelajaran Berbasis Augmented Reality Pada Materi Sel Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik SMA Negeri 1 Tibawa. 13(2).
- Anwar, R. I. Y., Maulani, J., & Alfah, R. (2023). Prototype Aplikasi Media Pembelajaran Berbasis Digital Mata Pelajaran Biologi Untuk Pengenalan Organ Tubuh Manusia. *Technologia: Jurnal Ilmiah*, 14(1), 1. <https://doi.org/10.31602/tji.v14i1.8051>
- Aprilinda, Y., Endra, R. Y., Afandi, F. N., Ariani, F., Cucus, A., & Lusi, D. S. (2020). Implementasi Augmented Reality untuk Media Pembelajaran Biologi di Sekolah Menengah Pertama. *Explore: Jurnal Sistem Informasi Dan Telematika*, 11(2), 124. <https://doi.org/10.36448/jsit.v11i2.1591>

- Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, 241(July 2019), 108224. <https://doi.org/10.1016/j.biocon.2019.108224>
- Aripin, I., & Suryaningsih, Y. (2019). Pengembangan Media Pembelajaran Biologi Menggunakan Teknologi Augmented Reality (AR) Berbasis Android pada Konsep Sistem Saraf. *Sainsmat: Jurnal Ilmiah Ilmu Pengetahuan Alam*, 8(2), 47. <https://doi.org/10.35580/sainsmat82107192019>
- Arulanand, N., RameshBabu, A., & Rajesh, P. K. (2020). Enriched learning experience using an augmented reality framework in engineering education. *Procedia Computer Science*, 172(2019), 937–942. <https://doi.org/10.1016/j.procs.2020.05.135>
- Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers and Education*, 171(May), 104237. <https://doi.org/10.1016/j.compedu.2021.104237>
- Asmak Ismail, N. H., B. Awwad, S. A., Thinakaran, R., Quah, W. B., & Muniandy, M. (2024). Virtual Reality and Gamification in Hospitality Education at the Front Desk. *TEM Journal*, 13(3), 1973–1980. <https://doi.org/10.18421/tem133-25>
- Bliznakova, K., Dukov, N., Tsekova, K., Kuppenova, M., Milev, M., & Bliznakov, Z. (2024). Analysing Student Feedback on the Integration of 3D Printing in the Teaching of Mammography for Radiologic Technologists. *TEM Journal*, 13(3), 1735–1742. <https://doi.org/10.18421/tem133-01>
- Branch, R. M. (2009). Approach, Instructional Design: The ADDIE. In *Department of Educational Psychology and Instructional Technology, University of Georgia* (Vol. 53, Issue 9).
- Canbaz, B., & Yalçın, N. (2024). The Effect of Mathematics Teaching with Mobile Augmented Reality Technology on Secondary School Students' Attitudes and Academic Achievements. *Participatory Educational Research*, 11(4), 59–76. <https://doi.org/10.17275/per.24.49.11.4>
- Cardoso-Espinosa, E. O., Cortes-Ruiz, J. A., & Zepeda-Hurtado, M. E. (2024). Effectiveness of Problem-Based Learning to Develop Mathematical Competencies at the Postgraduate Level. *TEM Journal*, 13(3), 2127–2132. <https://doi.org/10.18421/tem133-40>
- Ciloglu, T., & Ustun, A. B. (2023). The Effects of Mobile AR-based Biology Learning Experience on Students' Motivation, Self-Efficacy, and Attitudes in Online Learning. *Journal of Science Education and Technology*, 32(3), 309–337. <https://doi.org/10.1007/s10956-023-10030-7>
- Çoban, M., Topuz, A. C., Karabulut, A., & Chiu, T. K. F. (2024). Comparing Realities: A Study on the Impact of Virtual Reality versus Paper-Based Reading on Higher Education Students' Comprehension Skills. *Participatory Educational Research*, 11(4), 19–36. <https://doi.org/10.17275/per.24.47.11.4>
- Damopolii, I., Nunaki, J. H., Jeni, J., Rampheri, M. B., & Ambusaidi, A. K. (2024). An Integration of local wisdom into a problem-based student book to Empower Students' Conservation Attitudes. *Participatory Educational Research*, 11(1), 158–177. <https://doi.org/10.17275/per.24.10.11.1>
- Dehghani, M., Mohammadhasani, N., Hoseinzade Ghalevandi, M., & Azimi, E. (2023). Applying AR-based infographics to enhance learning of the heart and cardiac cycle in biology class. *Interactive Learning Environments*, 31(1), 185–200. <https://doi.org/10.1080/10494820.2020.1765394>
- Endang Purnama, Suroso Mukti Leksono, Adi Nestiadi, & Septi Kurniasih. (2024). Pengembangan E-LKPD Tema Keaneakragaman Hayati Berbasis Hasil Riset untuk Meningkatkan Kemampuan Literasi Konservasi Siswa SMP Kelas VII. *Jurnal Pendidikan Mipa*, 14(1), 194–199. <https://doi.org/10.37630/jpm.v14i1.1484>
- Fakhrudin, A., Sri, Y., & Riyadi, R. (2019). Implementation of Augmented Reality Technology in Natural Sciences Learning in Elementary Schools to Optimize the Students' Learning Results. *IJJET (International Journal of Indonesian Education and Teaching)*, 3(1), 1–10. <https://doi.org/10.24071/ijjet.v3i1.814>
- Fitriani, H., Asy'ari, M., Zubaidah, S., Mahanal, S., & Samsuri, T. (2024). Enhancing prospective biology teachers' critical analysis skills: an evaluation of the effects of a plant anatomy and development textbook. *Journal of Turkish Science Education*, 21(3), 533–548. <https://doi.org/10.36681/tused.2024.028>
- Fitrianingsih, R., Sudiarti, D., Hakim, M., & Author, C. (2023). Penerapan Media Augmented Reality Untuk

- Meningkatkan Minat Dan Hasil Belajar Ipa Pada Materi Sistem Ekskresi Application of Augmented Reality Media To Increase Interest and Results in Science Study in Excretion System Materials. *Jurnal Biologi Dan Konservasi*, 5(1).
- Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented Reality on education? A meta-analysis and research synthesis. *Educational Research Review*, 31, 100334. <https://doi.org/10.1016/j.edurev.2020.100334>
- Güvenir, Z., & Türkmen, L. (2024). The examination of preschool children's environmental attitudes and awareness. *Journal of Turkish Science Education*, 21(3), 430–447. <https://doi.org/10.36681/tused.2024.023>
- Harahap, R. D., Bangun, B., & Siregar, S. U. (2025). *The effectiveness of IMLO Biology media in enhancing students' learning motivation under the Merdeka Curriculum*. 8(2), 184–191. DOI : 10.30821/biolokus.v8i2.4796
- Harahap, R. D., & Hasibuan, R. (2025). *Efektioitas Penggunaan Media Sosial Tiktok Untuk Pembelajaran Biologi di SMA Negeri 1 Rantau Utara*. 13(2), 1200–1207.
- Hidayat, H., M. Tanucan, J. C., Harmanto, D., Dewi, F. K., Dewi, I. P., Anori, S., & Agustiarimi, W. (2024). The Influence of Augmented Reality Mobile App on Electronics Engineering Students' Self-Competence. *TEM Journal*, 13(3), 2310–2318. <https://doi.org/10.18421/tem133-58>
- Hijra, N., Iwan, I., & Jeni, J. (2025). *Integration of local wisdom and augmented Reality into PBL biodiversity worksheets: The impact on students' conservation literacy*. 1(1), 27–36.
- Ilona-Elefteyja, L., Meletiou-Mavrotheris, M., & Katzis, K. (2020). Augmented Reality in lower secondary education: A teacher professional development program in Cyprus and Greece. *Education Sciences*, 10(4). <https://doi.org/10.3390/educsci10040121>
- Indrasvari, M., Harahap, R. D., & Harahap, D. A. (2021). Analysis of the impact of smartphone use on adolescent social interactions during COVID-19. *Jurnal Penelitian Pendidikan IPA*, 7(2), 167–172. <https://doi.org/10.29303/jppipa.v7i2.622>
- İslim, Ö. F., Namli, Ş., Sevim Çirak, N., Özçakir, B., & Lavicza, Z. (2024). Augmented Reality in Mathematics Education: A Systematic Review. *Participatory Educational Research*, 11(4), 115–139. <https://doi.org/10.17275/per.24.52.11.4>
- Iwan, I., Istisaroh, I., Sirait, S. H. K., & Damopolii, I. (2020). The development of teaching materials oriented to problem-based learning, integrating Tifa to train students' critical thinking skills. *AIP Conference Proceedings*, 2215(April). <https://doi.org/10.1063/5.0000587>
- Iwan*, I., Sirait, S. H. K., & Fahmi, D. (2024). Development of an Interactive E-Module Based On Flipbook Protista Material To Improve Student Biology Learning Outcomes. *Jurnal IPA & Pembelajaran IPA*, 8(2), 131–142. <https://doi.org/10.24815/jipi.v8i2.38478>
- Iwan, I., Hanna, S., Sirait, K., & Rumlolas, N. (2024). *Development of augmented Reality-assisted teaching modules for the human sensory system to improve student learning outcomes*.
- Iwan, I., Sumitro, S. B., Ibrohim, I., Rohman, F., Sciences, N., Sciences, N., & Sciences, N. (2024). *The Effect of Pbl Integrated with Igya Ser Hanjob's Local Wisdom To Improve Students' Problem-Solving*. 11(1), 20–32.
- Iwan, Sumitro, S. B., Ibrohim, & Rohman, F. (2024). The Effectiveness of the Problem-Based Learning Model to Enhance Students' Critical Thinking Skills on Conservation Biology Courses. *Jurnal Penelitian Pendidikan IPA*, 10(8), 4641–4649. <https://doi.org/10.29303/jppipa.v10i8.6959>
- Iwan, I., Jeni, J., & Nurfathurrahmah, N. (2025a). *Biodiversity Module Based on Problem-Based Learning Local Wisdom Assisted by Augmented Reality : Improving Students' Critical Thinking*. 12(2), 497–510.
- Iwan, I., Jeni, J., & Nurfathurrahmah, N. (2025b). Strengthening Conservation Literacy through Integrating Local Wisdom into Problem-Based Learning in Secondary School Students. *Participatory Educational Research*, 12(6), 108–122. <https://doi.org/10.17275/per.25.81.12.6>
- Kartini, K. S., Tri, I. N., & Putra, A. (2020). *Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android*. 4(1), 12–19.
- Kharchenko, Y. V., Babenko, O. M., & Kiv, A. E. (2021). Using Blippar to create augmented Reality in chemistry education. *CEUR Workshop Proceedings*, 2898, 213–229.
- Kocak, E., Yalcin-Celik, A., & Uluyol, C. (2023). Pre-service Teachers' Environmental Literacy: The Role of

- STEM-Based Environmental Education with Microcontrollers. *Participatory Educational Research*, 10(5), 233-247. <https://doi.org/10.17275/per.23.84.10.5>
- Kumalasari, S. M., & Fikroh*, R. A. (2023). Development of Android-based Augmented Reality Learning Media on Atomic Matter. *Jurnal Pendidikan Sains Indonesia*, 11(3), 683-696. <https://doi.org/10.24815/jpsi.v11i3.30960>
- Law, E. L. C., & Heintz, M. (2021). Augmented reality applications for K-12 education: A systematic review from the usability and user experience perspective. *International Journal of Child-Computer Interaction*, 30, 100321. <https://doi.org/10.1016/j.ijcci.2021.100321>
- Lino Padang, F. A., Ramlawati, R., & Yunus, S. R. (2022). Media Assemblr Edu Berbasis Augmented Reality Untuk Meningkatkan Hasil Belajar Materi Sistem Organisasi Kehidupan Makhhluk Hidup. *Diklabio: Jurnal Pendidikan Dan Pembelajaran Biologi*, 6(1), 38-46. <https://doi.org/10.33369/diklabio.6.1.38-46>
- Lintangesukmanjaya, R. T., Prahani*, B. K., Marianus, M., Wibowo, F. C., Costu, B., & Arymbekov, B. (2024). Profile of Students' Critical Thinking Skills in 3D Module Learning Material on Gas Kinetic Theory with Inquiry Model. *Jurnal Pendidikan Sains Indonesia*, 12(1), 77-94. <https://doi.org/10.24815/jpsi.v12i1.33877>
- Lubis, S. P. W., Suryadarma, I. G. P., Paidi, & Yanto, B. E. (2022). The Effectiveness of Problem-based learning with Local Wisdom oriented to Socio-Scientific Issues. *International Journal of Instruction*, 15(2), 455-472. <https://doi.org/10.29333/iji.2022.15225a>
- Muhfahroyin, M., Rachmadiarti, F., Mahanal, S., Zubaidah, S., & Siagiyanto, B. E. (2023). Improving the critical thinking of low-ability students through TPS and PBL integration in biology learning. *Journal of Turkish Science Education*, 20(4), 606-618. <https://doi.org/10.36681/tused.2023.034>
- Oz, T., & Isik, A. (2024). The Opportunities for Mathematical Reasoning Skills That Teachers Provide for Their Students in The Learning Environment. *Participatory Educational Research*, 11(3), 1-21. <https://doi.org/10.17275/per.24.31.11.3>
- Purnamasari, D., Sudarisman, S., & Dwiastuti, S. (2016). Pengaruh Penerapan Media Augmented Reality Berbasis Discovery Learning Terhadap Hasil Belajar Pada Materi Darah. *Bio-Pedagogi*, 5(2), 7. <https://doi.org/10.20961/bio-pedagogi.v5i2.5416>
- Rahma Sari, A., Okra, R., Antoni Musril, H., & Derta, S. (2023). Perancangan Media Pembelajaran Biologi Berbasis Augmented Reality (Ar) Menggunakan Assemblr Edu Di Sma Negeri 1 Bukittinggi. *JATI (Jurnal Mahasiswa Teknik Informatika)*, 7(2), 1387-1394. <https://doi.org/10.36040/jati.v7i2.7247>
- Rahmat, A. D., Kuswanto, H., Wilujeng, I., & Daud, A. N. M. (2024). Local Culture Integration in Physics Experiments: Exploring Angklung with Arduino-Enhanced Frequency Measurement. *TEM Journal*, 13(2), 1248-1255. <https://doi.org/10.18421/TEM132-38>
- Ratnasari, D., Mahrawi, M., Wahyuni, I., & Risdatika, V. (2022). Pengaruh Augmented Reality Berbasis Web Dengan Model Problem Based Learning Terhadap Sikap Konservasi Peserta Didik. *Al-Ulum: Jurnal Sains Dan Teknologi*, 8(1), 6. <https://doi.org/10.31602/ajst.v8i1.7904>
- Regala, G. (2019). Problem-Based Learning Module in the Conservation of Ecosystem. *4th International Congress on Action Research, Action Learning, March*. <https://www.researchgate.net/publication/369542640>
- Sholikha, A. M., Bachrib, B. S., & Dewi, U. (2024). Pengembangan Media Pembelajaran Augmented Reality Berbasis Problem Based Learning dalam Materi Virus Biologi. *JiIP - Jurnal Ilmiah Ilmu Pendidikan*, 7(3), 2663-2668. <https://doi.org/10.54371/jiip.v7i3.3549>
- Sharma, S., Tuli, N., & Mantri, A. (2022). Augmented Reality in Educational Environments: A Systematic Review. *Journal of Engineering Education Transformations*, 36(2), 7-19. <https://doi.org/10.16920/jeet/2022/v36i2/22149>
- Sugiyono. (2015). *Metode Penelitian Pendidikan : Pendekatan Kuantitatif, Kualitatif, Dan R&D*.
- Suharti, P., Asyari, A., & Wikanta, W. (2024). Augmented Reality-integrated educational game using a problem-based learning model to improve critical thinking skills. *Research and Development in Education (RaDEn)*, 4(1), 320-336. <https://doi.org/10.22219/raden.v4i1.32026>

- Suprpto, N., Rizki, I. A., Saphira, H. V., Alfarizy, Y., & Jannah, S. N. (2024). Exploration of science concepts in Indonesian indigenous culture: actualization of the Indonesian curriculum. *Journal of Turkish Science Education*, 21(3), 410–429. <https://doi.org/10.36681/tused.2024.022>
- Tamam, B., & Qomaria, N. (2023). Implementation of Augmented Reality In Biology Learning: Its Effect on Learning Motivation and Retention. *Journal of Education Research and Evaluation*, 7(1), 17–22. <https://doi.org/10.23887/jere.v7i1.59038>
- Thenu, E. C., Iwan, I., & Jeni, J. (2025). *Pengembangan Buku Siswa Keanekaragaman Hayati Berorientasi Problem-Based Learning Terintegrasi Kearifan Lokal Dan Berbantuan Augmented Reality Untuk Melatih Kemampuan Berpikir Kritis Siswa*. 6(1), 11–19.
- Tresnawati, N., Tarmidzi, & Siroj, N. (2021). Pelatihan Skill Dimension Bagi Siswa Sd Melalui Program Edukasi Literasi Konservasi Mangrove Berbasis Etnosains Di Sdn 3 Ambulu Kabupaten Cirebon. *Abdimas Awang Long*, 4(1), 41–50. <https://doi.org/10.56301/awal.v4i1.124>
- Usman, G. B. T., Ali, M. N., & Ahmad, M. Z. (2023). Effectiveness of self learning modules on achievement in biology among secondary school students. *Journal of Turkish Science Education*, 20(3), 453–467.
- Yilmaz, A. (2024). Enhancing the Professional Skills Development Project (MESGEP): An Attempt to Facilitate Ecological Awareness. *Participatory Educational Research*, 11(1), 16–31. <https://doi.org/10.17275/per.24.2.11.1>
- Yusuf, I. (2024). *The Frontier Areas ' Student Acceptance of Physics Fun-based Mobile Application : Incorporating the Process-Oriented Guided-Inquiry Learning (POGIL) Strategy Punaji SETYOSARI Dedi KUSWANDI Saida ULFA*. 11(November), 152–171.