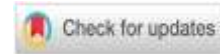




Development of augmented reality-based flashcard learning media for teaching leaf types



Dwi Aninditya Siregar ¹, Nabilah Siregar ², Sari Wahyuni Rozi Nasution³ Hanifah Nur Nasution⁴

^{1,3}Physics Education Department, Insitut Pendidikan Tapanuli Selatan. Indonesia

² Biology Education Departemen, Institut Pendidikan Tapanuli Selatan, Indonesia

⁴.Vokasional Informatika Education, Institut Penddiikan Tapanuli Selatan, Indonesia

* Corresponding author: dwi.aninditya@gmail.com

Article Info

Article History:

Received 28 September 2025

Revised 06 October 2025

Accepted 20 October 2025

Published 30 November 2025

Keywords:

Flashcard

Augmented Reality

Media Teaching

Leaf Types



ABSTRACT

The use of this medium is expected to help students better understand and retain information about leaves, thereby contributing to improved learning outcomes in biology as a whole. This study aims to develop an effective Augmented Reality (AR)-based flashcard learning medium for the topic of leaf types. The research employed a Research and Development (R&D) approach using the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The research subjects consisted of 25 biology education students who had completed the Plant Morphology course, selected through a purposive sampling technique. The validation results indicated that the AR flashcard learning medium demonstrated a very high level of feasibility. Media expert validation obtained a score of 89.3%, while material expert validation yielded a score of 90%, both categorized as “highly feasible.” Furthermore, the evaluation based on educators’ responses achieved a score of 100%, also classified as “highly feasible.” These findings suggest that the AR-based flashcard learning medium received highly positive responses and proved effective in enhancing students’ interest and motivation in learning plant morphology.

Copyright © 2025, Siregar et al

This is an open access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license



Citation: Siregar, A.D., Siregar, N., Nasution, S.W.R., & Nasution, H.N. (2025). Development of augmented reality-based flashcard learning media for teaching leaf types. *JPBIO (Jurnal Pendidikan Biologi)*, 10(2), 418-429. DOI: <https://doi.org/10.31932/jpbio.v10i2.5434>

INTRODUCTION

Biology education constitutes a fundamental aspect of learning, particularly in fostering students’ understanding of biodiversity in both plants and animals. Numerous topics within biology are highly relevant and engaging for students. Among these, the study of leaf types is a crucial component, as leaves play a vital role in photosynthesis and in maintaining plant ecosystem



functions. Furthermore, leaf-type identification is one of the core topics in plant morphology courses. Mastery of this material equips students with foundational knowledge essential for understanding more complex biological concepts (Eriawati, 2023).

Traditional teaching methods, however, face considerable challenges. Conventional instructional approaches often fail to capture students' attention, particularly when dealing with visually rich or abstract topics such as leaf types. Students tend to experience boredom and a lack of interest when learning is limited to textbooks or whiteboard explanations (Karanez, Rapti & Halimi, 2015). In response to this issue, the integration of technology in education has emerged as a promising solution. The rapid advancement of digital media provides opportunities to enhance teaching and learning processes (Zuoet et al, 2025). One innovative approach is the use of Augmented Reality (AR), which combines the real world with virtual three-dimensional objects to create an interactive learning environment (Munawarah, 2025).

In biology education, the topic of leaf types falls within the study of plant morphology, which requires direct observation of real objects. The morphological characteristics of leaves, such as shape, margin, venation, and arrangement, are highly visual and detailed, making them difficult to fully understand through two-dimensional images in textbooks or other conventional media (Masing & Sila, 2023). This limitation often leads to low student engagement and weak conceptual understanding of leaf structures. The implementation of AR allows students to visualize three-dimensional leaf models directly through mobile devices, thereby enriching their learning experiences and facilitating deeper comprehension of complex biological concepts (Helen et al., 2023).

Flashcards are visual learning media consisting of illustrated cards with brief textual descriptions, designed to facilitate quick recognition of concepts or terms. In the context of biology education, flashcards are considered effective because they provide direct visual representations of leaf forms and types, reinforce visual memory, and build associations between images and scientific terminology (Lismaya et al., 2024). This medium also promotes independent learning and allows for material repetition simply and engagingly. The integration of Augmented Reality (AR) with flashcards transforms them into more engaging and interactive learning tools, thereby increasing students' active participation in the learning process. A study conducted by Mardiani et al. (2024) demonstrated that AR-based flashcards significantly enhance students' memory retention and cognitive abilities compared to conventional flashcards. Similarly, research by Azzahra et al. (2024) found that the implementation of AR in biology education provides several advantages, including improved conceptual understanding, information retention, learning motivation, and student engagement. The combination of visual context and interactive media was identified as a key factor supporting these outcomes.

Therefore, the application of AR in biology learning can enhance students' understanding by providing real-world contexts that bridge theoretical knowledge with practical comprehension. Increased student engagement is widely recognized as a critical determinant of learning success, and interactive media such as AR-based flashcards can foster engagement in enjoyable and stimulating ways, ultimately contributing to improved learning outcomes.

The design of AR-based learning media must be carefully tailored to students' needs and the characteristics of the content being taught. Effective development requires thoughtful consideration of both content quality and technological features, including the integration of appropriate visual and interactive elements. Beyond improving students' understanding, AR has the potential to reshape how learners interact with educational materials. By offering a deeper and more immersive learning experience, AR can stimulate students' interest in biology, particularly in plant-related topics.

Although several previous studies have explored the use of flashcard media and Augmented Reality (AR) applications in science education, most of these studies have focused on general topics such as cells, animal classification, or other basic biological concepts, and have not emphasized specific morphological analyses such as leaf-type identification. The novelty of this study lies in the development of an AR-based flashcard that features high-resolution 3D models of leaf morphology, validated by both media and material experts. Previous research conducted by Utami, Rukiyah, and Andika (2021) only developed AR-based flashcards for the topic of starfish, while Tamboo et al. (2024) developed AR-based flashcards for the topic of cells. Earlier studies generally utilized simple two-dimensional images or basic visual models, with very few incorporating three-dimensional representations, and none presenting detailed morphological features such as leaf margins, venation, and arrangement.

This research aims to develop an effective AR-based flashcard learning medium for the topic of leaf types. It is anticipated that the use of this medium will enhance students' comprehension and retention of leaf-related information, thereby contributing to improved learning outcomes in biology as a whole (Hidayat & Kena, 2024).

RESEARCH METHODS

Research Design

This research uses the Research and Development (R&D) method with the ADDIE research model. According to Sugiyono (2009), the stages of ADDIE include Analysis, Design, Development, Implementation, and Evaluation.

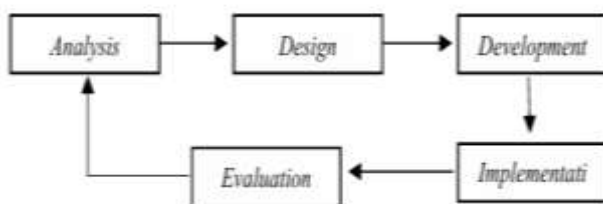


Figure 1. Research Design for the Development of Augmented Reality-Based Flashcard Learning Media for Teaching Leaf Types.

As shown in Figure 1, the implementation process follows the ADDIE model stages systematically. The development process of the Augmented Reality (AR)-based flashcard learning media on the topic of leaf types was carried out through five main stages, namely analysis, design, development, implementation, and evaluation. The analysis stage aimed to identify the need for developing AR-based flashcard learning media to help students easily recognize and understand various examples of leaf types. In the design stage, the structure and presentation of the AR-based flashcards were planned, emphasizing the accuracy and clarity of images and accompanying materials. The design process involved the use of Canva for visual creation and Assemblr Edu for AR integration (Marseli et al, 2023). During the development stage, the AR flashcard media were created based on the established design and then validated by media experts and subject matter experts using validation instruments prepared by the researchers. If the validation results did not meet the criteria of "feasible" or "highly feasible," revisions were made according to the experts' feedback and suggestions. Once the AR flashcards were deemed feasible, the media were tested on students from the Biology Education Study Program at the South Tapanuli Institute of Education to assess their effectiveness in supporting the learning process. The implementation stage focused on evaluating how well the AR-based flashcards enhanced students' understanding and engagement

during learning activities. Finally, the evaluation stage involved analyzing the trial results and refining the product based on the findings. Formative evaluation was also conducted at each stage to ensure that the developed learning media met the required feasibility criteria and could be effectively utilized in classroom learning.

Population and Samples

The population of this study consists of students of the Biology Education Study Program at the South Tapanuli Institute of Education, while the research sample comprises 25 fifth-semester students of the same program. The use of sampling techniques is non-probability sampling through a technique called purposive sampling, or a technique used in taking samples by considering several things. Fifth-semester students of the Biology Education Study Program have studied topics related to plant morphology, including various types of leaves. Therefore, they possess the foundational knowledge necessary to assess the feasibility and effectiveness of the developed AR Flashcard learning media.

Instruments

The instruments used in this research consisted of observation, questionnaires, documentation, and validation sheets. Observation was conducted systematically through both direct and indirect observation and recording. The researcher observed learning activities in the classroom to analyze the types of learning media used by lecturers to support instructional activities. The questionnaire was distributed to educators to obtain their responses and assess the feasibility of using AR-based flashcard learning media on the topic of leaf types. Documentation was collected in the form of photographs, videos, and experimental data records to support the analysis process. Meanwhile, validation sheets were provided to material experts and media experts containing statements related to the feasibility of the developed learning media. These statements assessed various aspects, including the physical form of the media, language use, learning components, and material quality.

Procedures

The AR flashcard learning media was developed using the ADDIE development model. The ADDIE model comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. At the analysis stage, a needs assessment was conducted, and the instructional content to be developed for the AR flashcard learning media was determined. Identifying the content is the initial step in the development process. The content developed in this AR flashcard is the various forms of leaves. The design stage involves the planning and preparation of the initial draft of the AR flashcard product. The development stage is the phase in which the feasibility of the product is evaluated by subject-matter experts and media experts. The purpose of validation is to obtain feedback and evaluations on the product to inform necessary revisions. The implementation stage consists of applying the prepared AR flashcard product in real classroom settings so that the intended learning objectives can be achieved. The evaluation stage is the final phase of the ADDIE model, aimed at assessing the quality of both the product and the learning process.

Data Analysis

Data has the most important position in research, because data is a description of the variables being studied, and serves as a means of proving hypotheses. Therefore, whether the data is true or not, it is very important to determine the quality of the research results. And whether it is true or not, it also depends on whether the data collection instrument is good or not. The data analysis techniques used in this study are validated with validation data from material experts,



media experts, and student responses. The data from the validation by the validator and the data from the teacher's response are then analyzed. In this study, a Likert scale is used, which is compiled in the form of a statement. The measured statement indicators were given a score of 1-5, namely: (5) very feasible, (4) feasible, (3) quite feasible, (2) not feasible, and (1) very unfeasible. The percentage of validation results of the expert team and teacher responses can be calculated using the formula: Pratiwi, et al. (2021).

$$P = \frac{\sum x}{\sum X} \times 100\%$$

Information:

Q: Percentage searched

$\sum x$: Total score given by validators

$\sum X$: Total score

To determine the feasibility of the learning media developed by the researcher using the validation assessment criteria by experts, it can be seen in the following Table I.

Table I. Media Eligibility Criteria

Yes	Present (%)	Criterion
1	81-100%	Highly Worth It
2	61-80%	Proper
3	41-60%	Quite Decent
4	21-40%	Not Eligible
5	0-20%	Very Unworthy

RESULTS

Analysis

At this stage, the primary activity was conducting a needs analysis. The results of the preliminary research carried out in the Biology Education Study Program served as the basis for developing the AR flashcard learning media. The analysis of student characteristics aimed to identify their skill levels. This information was obtained from a one-month pre-survey conducted by the researchers in the Biology Education Study Program. Based on the survey results, the students exhibited the following characteristics: (a) low understanding of the subject matter, and (b) boredom when learning materials were delivered using lecture methods and textbooks. From the needs analysis, the researchers decided to develop Augmented Reality (AR) flashcard learning media intended to foster enthusiasm and reduce student boredom during the learning process. AR flashcards combine pictorial cards with concise descriptions, making the learning material easier and faster for students to absorb compared to the sole use of textbooks (Dian et al. 2023).

Design

After identifying the students' needs and learning challenges, the next stage was the design of the AR-based flashcard learning media. The design process involved several key steps to ensure the functionality and visual appeal of the product. First, the size of the ethnopedagogy-based AR herbarium flashcards was determined, typically using A6 dimensions (10 × 15 cm). The development process utilized the Assemblr platform, which could be accessed through studio.assemblrworld.com or the mobile application. A new project was created by selecting “+



Create Project” and choosing “Blank Project.” Three-dimensional (3D) objects were then added by clicking “Insert” → “3D Object,” selecting from available 3D models, or uploading custom models in (.glb) or (.fbx) formats. The size, position, and rotation of these objects were adjusted to fit the AR canvas appropriately. Text elements were included by selecting “Insert” → “Text,” where captions describing the 3D objects were typed and customized in terms of font, color, and placement. Interactive features could also be configured, such as the “On Tap” option for displaying text upon user interaction or the “Always Show” option for continuous visibility. The AR content was then previewed using the “Preview” feature to ensure accuracy and alignment between visuals and text. Once finalized, the project was saved and published by selecting “Publish Project,” after which the Assemblr platform automatically generated a shareable link and QR code. The QR code was subsequently downloaded and incorporated into flashcard designs created using Canva, where the layout was arranged to include the QR code, an appropriate label such as “Scan to View AR,” and an optional AR icon. Finally, the completed flashcards were exported in PDF format for printing or in PNG/JPG formats for digital distribution. The flashcards are then ready for use: students can simply scan the QR code to open the AR link (Umar, et al ,2025).

Table 2. Product Revisions Based on Comments and Suggestions from Media Experts

Before Revision	After Revision
 <p>The images were unclear and the colors were not vivid</p>	 <p>The images are now clear, and the colors are more vivid</p>
 <p>Still in 2D format</p>	 <p>Converted into 3D format</p>
 <p>Classification was not properly arranged</p>	 <p>Classification is now organized vertically</p>
 <p>QR Code was in a basic format</p>	 <p>QR Code is now integrated in AR format</p>

Development

At the development stage, media validation was conducted to determine the feasibility of the AR flashcard learning media from a media-design perspective. Media experts evaluated aspects such as language, usability of the AR flashcards, and their physical features (Mardin, H 2025). The

validation process of the instructional media product was conducted by Mrs. Hanifah Nur Nasution, M.Kom., a lecturer in the Informatics Vocational Study Program at the South Tapanuli Institute of Education, who served as the media expert validator. Based on the validation data from the media expert, the AR-based flashcard learning media obtained an average score of 89.3%, which falls under the “Highly Feasible” category. Similar results were reported by Nurbayan, Rinjani, and Juhana (2024), whose study found that the material expert validation achieved a perfect score of 100 (classified as “Very Valid”), while the media expert validation reached a score of 97.5 (also classified as “Very Valid”), indicating that AR-based flashcard media demonstrate excellent validity and feasibility for educational use.

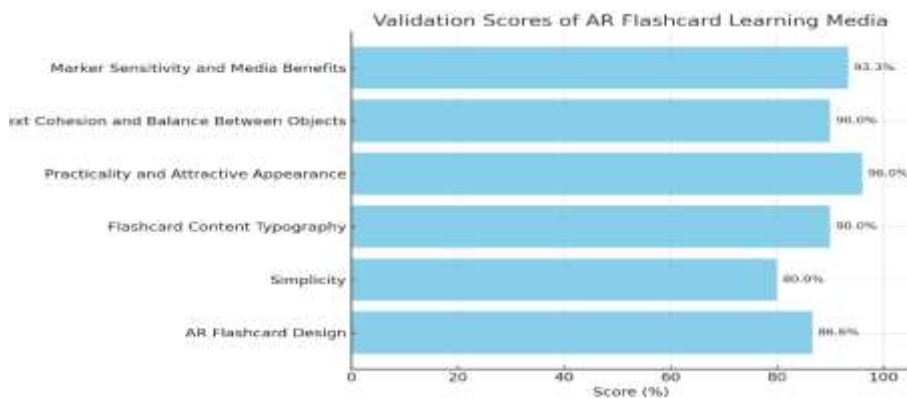


Figure 2. Score Graph of Media Expert Validation Results on the AR Flashcard Learning Media

From Figure 2 above, it can be seen that the validation results by media experts show that the AR Flashcard learning media obtained an average score of 89.3%, which falls under the Highly Feasible category. The material validation analysis was conducted to ensure that the AR Flashcard learning media is appropriate for use in terms of content quality. The material expert assessed the language accuracy, relevance of the material to students’ learning needs, and alignment of the content with the intended learning objectives. The validation of this instructional material was carried out by Mrs. Sri Rahmi Tanjung, S.Pd., M.Si., a lecturer in the Biology Education Study Program at the South Tapanuli Institute of Education, who served as the material expert validator.

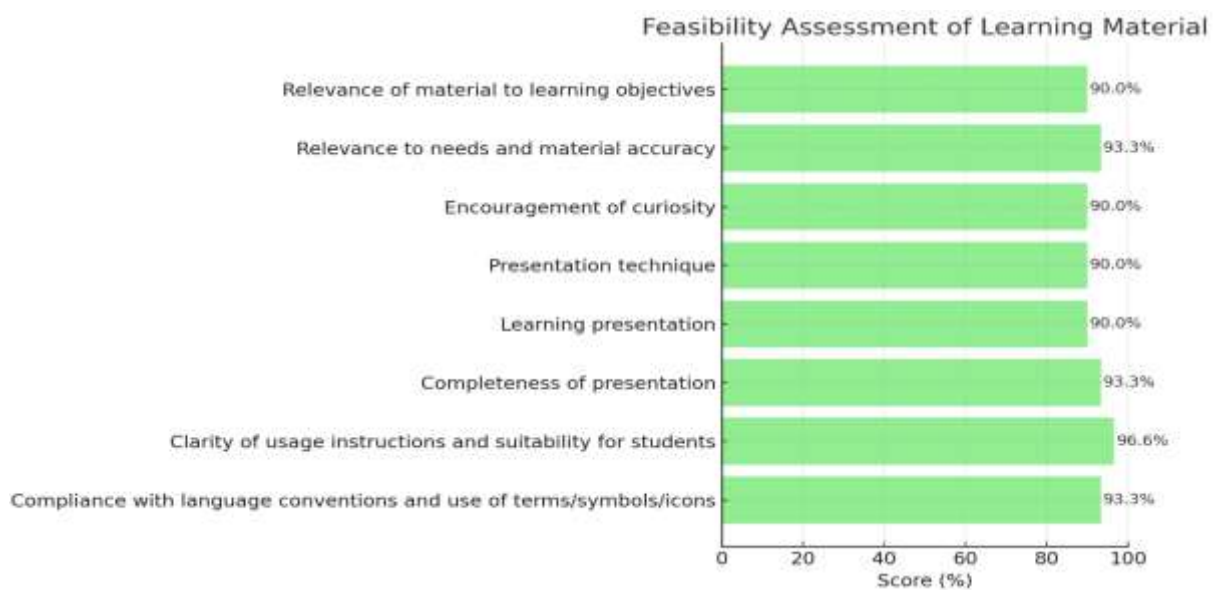


Figure 3. Score Graph of Material Expert Validation Results on the AR Flashcard Learning Media

From Figure 3 above, it can be seen that based on the results of validation by material experts, the AR Flashcard learning media obtained an average score of above 90%, categorized as Highly Feasible across all aspects of material and presentation assessment. These results indicate that the developed media is not only visually engaging but also possesses high-quality content that is well-suited to support the learning process.

Implementation

The trial of use in larger classes was carried out after a limited-scale field test was carried out. In this study, a trial of use was carried out on 25 students. This field trial was carried out to see whether or not the AR Flashcard learning media is feasible. The result of student response in the trial use was 88.6% so that the AR Flashcard learning media was categorized as very feasible to use. Based on the results of the use trials, it can also be concluded that Flashcard AR is very feasible to be developed as a learning medium. These results indicate that Flashcard AR media not only meet the feasibility standards in terms of design, content, and ease of use, but also succeed in attracting students' interest in learning and helping them understand contextual learning materials. Arsyad (2017) explained that good learning media must meet the principles of suitability with learning objectives, visual appeal, readability, and ease of use to increase students' motivation and learning outcomes.

Evaluation

Evaluation is the last stage of the ADDIE development model, because in this study only until the assessment of the teacher's response to the flashcard media developed, the evaluation referred to here is the evaluation of the implementation activities. So the results of the assessment obtained by the researcher on flashcard media are very feasible to use, according to the results of the implementation, with a percentage of 100%.

DISCUSSION

Analysis

Based on the preliminary analysis conducted in the Biology Study Program, it was found that students demonstrated a low level of understanding of the subject matter and expressed boredom when lessons were delivered using conventional lecture methods and textbooks. This condition is consistent with previous findings in the educational literature, which indicate that passive teaching approaches such as lectures tend to result in lower levels of student motivation and engagement (Cartono, 2022). In response to these characteristics, the development of Augmented Reality (AR)-based flashcard learning media represents an appropriate and innovative strategy. Interactive visual media such as AR make abstract concepts more concrete and engaging, thereby facilitating students' cognitive processing of learning content. Research on AR flashcards has demonstrated their high validity and effectiveness in improving students' conceptual understanding (Izzati & Kamaludin, 2024).

The AR flashcards developed in this study integrate images with simple textual descriptions that can be activated through Augmented Reality (AR) technology. This approach supports a multisensory learning strategy (visual and kinesthetic), which, according to multimedia learning and cognitive theories, enhances information processing, reduces cognitive load, and strengthens knowledge retention. Therefore, AR flashcards are not only expected to reduce students' boredom but also to improve their learning effectiveness in understanding topics such as leaf morphology. Similarly, the findings of Oktavia, A., Aeni, A. N., & Ismail, A. (2025) demonstrated a significant improvement in students' understanding when using AR flashcards (Sig. 0.004 < 0.05) with an effect size of 2.08 (large category). The N-Gain analysis also indicated a higher increase in



comprehension in the experimental group (0.57) compared to the control group (0.36). Overall, the needs analysis strongly supports the potential of AR-based flashcards to increase students' motivation, attention, and comprehension of biological material. This medium aligns with established principles of effective instructional design, including simplicity, relevance of content, and interactivity, which are essential for promoting meaningful learning experiences in higher education contexts.

Development

The validation results of the Augmented Reality (AR)-based flashcard learning media, as shown in Figure 1, indicate that the developed product meets high standards of feasibility across multiple criteria. The highest score was obtained for Practicality and Attractive Appearance (96.0%), suggesting that the AR flashcards are perceived as visually engaging and user-friendly, which is critical for sustaining students' attention during learning. This aligns with previous studies emphasizing that visually appealing and practical educational media increase student motivation and engagement (Izzati & Kamaludin, 2024).

Marker Sensitivity and Media Benefits also achieved a high score (93.3%), demonstrating that the AR flashcards function effectively when scanned, and that the media provide tangible benefits to the learning process. This is consistent with research indicating that smooth and reliable AR functionality enhances the learning experience by reducing technical barriers (Mardiani et al., 2024).

Text Cohesion and Balance Between Objects (90.0%) and Flashcard Content Typography (90.0%) reflect the clarity and readability of the flashcard content. According to cognitive load theory, well-structured and balanced visual-text elements help learners process information more efficiently and reduce extraneous cognitive load (Mayer, 2021).

The scores for AR Flashcard Design (86.6%) and Simplicity (80.0%) indicate that while the design and overall simplicity of the flashcards are considered feasible, these aspects may require further refinement. Ensuring a balance between interactive features and simplicity is crucial to avoid overwhelming learners, particularly when introducing new technologies such as AR in education.

Overall, the validation results confirm that the AR-based flashcards developed in this study are highly feasible for implementation in the classroom. The high scores across all validation criteria support their potential to improve students' motivation, engagement, and understanding of complex biological concepts, particularly those requiring visual representation such as leaf morphology.

The feasibility assessment of the developed learning material (Figure 2) demonstrates a high level of suitability across all evaluated criteria. The highest score was achieved in Clarity of usage instructions and suitability for students (96.6%), indicating that the material is not only user-friendly but also highly accessible to the intended learners. Clear instructions and appropriate content delivery are essential for ensuring that students can independently engage with and benefit from the material, as emphasized by Mayer (2021) in his multimedia learning principles.

The criteria of Relevance to needs and material accuracy, Completeness of presentation, and Compliance with language conventions and use of terms/symbols/icons each received a high score of 93.3%. These findings suggest that the learning material effectively addresses student needs, maintains high content accuracy, and adheres to linguistic and symbolic conventions, which is critical for fostering accurate understanding and minimizing misinterpretations (Clark & Mayer, 2016). Meanwhile, the Relevance of material to learning objectives, Encouragement of curiosity, Presentation technique, and Learning presentation scored 90.0%. While these values remain within the "very feasible" category, they indicate potential areas for further refinement, especially in improving the motivational aspects of the material and diversifying presentation techniques to further stimulate curiosity and deeper learning (Dicheva et al., 2015).

Overall, the high scores across all dimensions confirm that the learning material has met essential quality standards and is feasible for implementation in the learning process. These findings are consistent with previous studies showing that well-designed, contextually relevant, and clearly presented instructional materials contribute significantly to students' engagement and comprehension (Izzati & Kamaludin, 2024; Mardiani et al., 2024).

Implementation

The large-scale implementation trial was conducted following the completion of limited field testing. In this study, the trial involved 25 undergraduate students to assess the feasibility of the Augmented Reality (AR)-based Flashcard learning media. The results of the user trial showed a high student response rate of 88.6%, categorizing the AR Flashcard as "highly feasible" for classroom use. This finding indicates that the AR Flashcard not only meets essential standards in terms of design, content, and usability but also effectively attracts students' interest and supports contextual understanding of the learning material. Similarly, Adityas et al. (2024) revealed that AR-based flashcards are an effective learning tool for improving students' learning abilities and serve as a promising alternative for early literacy education.

The high feasibility score achieved in this study reflects the importance of integrating interactive and visually engaging learning tools to enhance students' motivation and comprehension. According to Arsyad (2017), effective instructional media should align with learning objectives, exhibit visual appeal, maintain readability, and ensure ease of use to improve both motivation and learning outcomes. These principles are clearly reflected in the AR Flashcard, which combines augmented reality features with visual aids to deliver complex content in a more accessible manner.

Furthermore, the positive responses obtained from students support previous studies indicating that the use of augmented reality-based flashcards can significantly improve learning engagement and concept mastery (Izzati et al., 2024; Mardiani et al., 2024). This suggests that the AR Flashcard has the potential to serve not only as a complementary learning tool but also as an innovative medium to contextualize learning materials, thereby making the learning process more meaningful.

Overall, the findings of this study demonstrate that the AR Flashcard is a highly feasible learning medium for larger-scale implementation. Its ability to combine interactivity, contextual relevance, and visual appeal positions it as an effective tool for modern teaching practices, especially in higher education settings.

CONCLUSION

The design of the AR Flashcard learning media successfully captured students' attention and fostered their interest in learning about leaf types. The feasibility of the AR Flashcard media was evaluated based on assessments from multiple validators. The validation conducted by media experts yielded a score of 89.3%, classified as "highly feasible," while the validation by subject-matter experts resulted in a score of 90%, also categorized as "highly feasible." In addition, the feasibility assessment based on educators' responses to the developed AR Flashcard media achieved a score of 100%, indicating a "highly feasible" classification. These findings demonstrate that the AR Flashcard learning media received highly positive responses, confirming its ability to engage students and enhance their motivation to learn.

ACKNOWLEDGMENT

The authors would like to sincerely thank KEMDIKTISAINTEK for providing financial support through the BIMA research grant scheme, which enabled the completion of this study. This article is part of the research project entitled "Development of Ethnopedagogical-Based



Augmented Reality Flashcard Learning Media for Biology Education Students.” The authors also wish to extend their appreciation to the Institut Pendidikan Tapanuli Selatan and collaborating partner institutions for their continuous support, valuable input, and facilitation during the research and development process.

REFERENCES

- Adityas, Aldina, A., Amaliyah, U., & Ahmad, B. (2024). Developing augmented reality-based flashcards for early readers of elementary school. *Jurnal JPSD (Jurnal Pendidikan Sekolah Dasar)*. <https://doi.org/10.26555/jpsd.v1i1i2.a30427>
- Arsyad, A. (2017). *Media Pembelajaran*. PT RajaGrafindo Persada.
- Azzahra, W.S., Diana, E., Nuraeni, D., Yusni, I., & Andriyatno. (2024). Integration of Augmented Reality (AR) in Biology Education: A Systematic Literature Review *The Eurasia Proceedings of Educational and Social Sciences*,
- Cartono. (2022). Use of Augmented Reality in Biology Learning. *Educare: Journal Educational and Multimedia*, 2(01), 72–76. Retrieved from <https://seaninstitute.or.id/bersinar/index.php/ducare/article/view/70>.
- Clark, R. C., & Mayer, R. E. (2016). *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning* (4th ed.). Wiley.
- Dian, R.S., Hidayanto, E., & Mashfufah, A. (2023). Flashcard Media Based on Augmented Reality in Building Spatial Materials to Improve Cognitive Learning Outcomes of Fifth- Grade Students in Elementary School. *Journal for Lesson and Learning Studies*, 6(2), 297–303. <https://doi.org/10.23887/jlls.v6i2.64126>
- Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). *Gamification in education: A systematic mapping study*. *Educational Technology & Society*, 18(3), 75–88.
- Eriawati. (2023). Karakteristik morfologi daun di Fakultas Tarbiyah dan Keguruan sebagai referensi morfologi tumbuhan. *Prosiding Seminar Nasional Biologi, Teknologi dan Kependidikan*. <https://doi.org/10.22373/pbio.v5i1.2107>
- Hidayat, & Kena. (2024). Pengembangan Flashcard Berbasis Augmented Reality Melalui Model ADDIE Guna Meningkatkan Keterampilan Berpikir Kritis Siswa SD”. *Jurnal Lingkar Mutu Pendidikan*, 22(1), 35–40. <https://jtmp.kemdikbud.go.id/index.php/jtmp/article/view/155>.
- Helen, H., Marlina, L., & Fathurohman, A. (2023). Penggunaan Media Flashcard Berbasis Augmented Reality untuk Meningkatkan Hasil Belajar Peserta Didik. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, 6(10), 7699-7702. <https://doi.org/10.54371/jiip.v6i10.289>.
- Izzati, L., Nand, A., & Kamaludin. (2024). Augmented reality-based flashcard media to improve students' concept understanding in chemistry learning. *IJSME*, 7(2), 252–266. [10.24042/ijsme.v7i2.20975](https://doi.org/10.24042/ijsme.v7i2.20975).
- Lismaya, L., Nurlaelah, I., & Handayani. (2024). Revolutionizing biology learning through AR: The case of Leafcapture application development. *Indonesian Journal Learning and Instruction*, 7(1), 23-34. <https://doi.org/10.25134/ijli.v7i1.9603>.
- Karanez, X., Rapti., E., & Halimi, G. (2015). Traditional and Modern Teaching Methodologies: Which One is More Successful and What are the Challenges?. *Academic Journal of Interdisciplinary Studies*, 4(2), 311. <https://doi.org/10.5901/ajis.2015.v4n2s2p311>
- Mardin, H., D. Mamu, H., Husain, I., & Yasser Arafat, M. (2025). Validitas Media Pembelajaran Flashcard Berbasis Augmented Reality Pada Materi Sel Kelas XI SMA. *Jurnal Biogenerasi*, 10(1), 796–802. <https://doi.org/10.30605/biogenerasi.v10i1.5378>

- Mardiani, E., Fujiono, Hanayanti, C. S., Lestari, N. C., & Hutauruk, T. L. (2024). Exploration of Augmented Reality-Based Flashcards as a Teaching Tool to Improve Children's Cognitive Ability. *Jurnal Scientia*, 5(1), 55–65. <https://doi.org/10.58471/scientia.v13i01.2173>
- Mayer, R. E. (2021). *Multimedia Learning* (4th ed.). Cambridge University Press.
- Masing, F. A., & Sila, V. U. R. (2023). The development of local plants e-module based on mobile learning for the subjects of botany and plant morphology. *Biosfer: Jurnal Pendidikan Biologi*, 16(1), 197–205. <https://doi.org/10.21009/biosferjpb.32900>
- Marseli, P., Adriani, W. N., & Inayah, N. (2023). Pengembangan Media Pembelajaran Visual Macam-macam Lengan Busana melalui Flashcard Berbasis AR Menggunakan Assemblr Edu. *Jurnal Pendas: Jurnal Ilmiah Pendidikan Dasar*, 10(3). <https://doi.org/10.23969/jp.v10i03.32339>
- Muhamad, N., Dian, R., & Agusjuhana. (2024). Perancangan Flashcard Berbasis AR Sebagai Media Pelatihan Desain Grafis Di SMPN 9 Sumedang. *Judikatif: Jurnal Desain Komunikasi Kreatif*, 6(2), 205–215. <https://doi.org/10.35134/judikatif.v6i2.210>
- Munawarah, S. (2025). Development of Augmented Reality-Based Learning Media in Science Learning on Plant Body Parts Material for Grade IV of Lasoani State Elementary School. *Journal of Educational Sciences*, 9(4), 2884–2894. <https://doi.org/10.31258/jes.9.4.p.2884-2894>
- Oktavia, A., Aeni, A. N., & Ismail, A. (2025). The Influence of Augmented Reality-Based Flashcards on the Understanding of the Concept of Grade V Students on The Material of Fauna Diversity In Indonesia. *Jurnal Cakrawala Pendas*, 11(2), 375–387. <https://doi.org/10.31949/jcp.v11i2.13156>
- Pratiwi, A. K., Makhrus, M., & Zuhdi, M. (2021). Pengembangan Perangkat Pembelajaran Berbasis Model Inkuiri terbimbing untuk Meningkatkan Kemampuan Literasi Sains dan Sikap Ilmiah Peserta Didik. *Jurnal Ilmiah Profesi Pendidikan*, 6(3), 290–295. <https://doi.org/10.29303/jipp.v6i3.240>
- Tambo, C.I., Herinda, M.I.H., Mustamin, I., & Nurul, F.U. (2024). Pengembangan Media Pembelajaran Flashcard Berbasis Augmented Reality Pada Materi Sel di Kelas XI SMA Negeri I Tibawa. Oryza. *Jurnal Pendidikan Biologi*. <https://doi.org/10.33627/oz.v13i2.2750>.
- Utami, F., Rukiyah, R., & Andika, W. D. (2021). Pengembangan Media Flashcard Berbasis Augmented Reality pada Materi Mengenal Binatang Laut. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, 5(2), 1718–1728. <https://doi.org/10.31004/obsesi.v5i2.933>.
- Umar, N., Husain, R., Pulukadang, W.T., Halidu, S., & Katili, S. (2025). Pengembangan Media Wordly Cards Berbasis Augmented Reality (AR) Melalui Aplikasi Assemblr Edu Pada Materi Kosakata Kelas IV di SDN. *EDUTECH : Jurnal Inovasi Pendidikan Berbantuan Teknologi*, 5(1), 76-90. <https://doi.org/10.51878/edutech.v5i1.4605>.
- Sugiyono. (2019). *Metode penelitian kualitatif dan R&D*. Bandung: Alfabeta.
- Zuo, R., Wenling, L., & Xuemei, Z. (2025). Augmented Reality and Student Motivation: A Systematic Review (2013-2024). *Journal of Computers for Science and Mathematics Learning*, 2(1), 38-52. <https://doi.org/10.70232/jcsml.v2i1.23>