



Development of Augmented Reality Based Digital Teaching Module for the Human Reproductive System in Class XI Science

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Abstract: Biology learning on the topic of the reproductive system in high schools still faces challenges due to the limited availability of learning media that can visualize abstract concepts interactively and contextually. Commonly used learning media are conventional, resulting in low student engagement and a lack of conceptual understanding. This study aims to develop an Augmented Reality (AR)-based digital learning module for the reproductive system and to test its validity, practicality, and effectiveness in Biology learning. The novelty of this research lies in the integration of Augmented Reality technology into the Biology learning module to provide interactive three-dimensional visualizations of the structures and processes of the reproductive system. This study used a Research and Development (R&D) approach with the ADDIE development model. The subjects were 11th-grade students at SMA Negeri 23 Makassar. The research instruments consisted of expert validation sheets, teacher and student response questionnaires, and learning achievement tests in the form of pretests and posttests. Data were analyzed using Aiken's V-index to determine validity, percentage analysis to assess practicality, and N-Gain analysis to evaluate effectiveness. The research results show that the AR-based digital teaching module has very high validity, practicality, and effectiveness. Therefore, the developed module is suitable for use as an innovative learning medium in biology education.

Keywords: Augmented reality; Digital teaching module; Effectiveness; Practicality; Validity

Introduction

The use of technology in education has now shifted toward digital learning (Siskayanti et al., 2022), where material is delivered through an integration of text, images, and video, keeping up with current developments (Nadeak, 2024). Digital media is not only designed to broaden students' horizons (Umroh et al., 2025), but also serves as a tool for teachers to create more modern learning processes that meet the needs of today's generation (Fadhilah & Thahir, 2023). The use of interactive digital modules has been shown to help students understand the material more easily and can be used independently (Wulandari et al., 2021).

Haria et al. (2024) stated that although digital technology offers various advantages in the learning process, the reality in schools shows that the availability

of innovative digital learning modules is still limited. This results in a lack of variety in learning support devices (Wardani et al., 2024), resulting in a passive classroom atmosphere that is unable to fully encourage active student participation as expected in the Merdeka curriculum (Astuti et al., 2024).

Without the support of learning tools such as systematically designed digital teaching modules, teachers often struggle to convey material clearly (Indriani et al., 2022). This ultimately results in suboptimal student learning outcomes (Setiyadi et al., 2017). This is most often seen in biology, particularly in abstract material (Hajiriah et al., 2019). Understanding biological concepts, such as the reproductive system, becomes less engaging if learned solely through text due to the complex processes involved (Ramadhani et al., 2025; Sugianto et al., 2023). This limited visualization

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often leads to misconceptions among students (Aripin & Suryaningsih, 2019). Consequently, when students learn solely through illustrations in textbooks, their enthusiasm and curiosity for science are diminished (Alfitriani et al., 2021).

Based on the results of observations at SMA Negeri 23 Makassar, it can be identified that the learning process at the school is still relatively monotonous and less interactive. Learning activities are still dominated by conventional media such as books and PowerPoint, which are less capable of creating an enjoyable learning atmosphere and encouraging active student participation. Students also require interactive learning tools to enhance in-depth understanding of the material and to create more authentic learning experiences.

One concrete solution to address these challenges is the implementation of Augmented Reality (AR) technology (Budianti, 2022), which is capable of displaying three-dimensional (3D) virtual objects directly in students' real-world environments, thereby helping to clarify learning materials (Tamboo et al., 2024). The integration of AR into digital modules can transform materials that are difficult to visualize into more realistic representations, thus assisting students in remembering and understanding concepts more deeply (Kamaruddin & Thahir, 2021).

The use of Augmented Reality (AR) technology not only serves to enhance the quality of learning media presentation (Sari et al., 2025), but has also been proven to improve scientific literacy, develop creative thinking skills, and foster students' enthusiasm in participating in Biology learning processes (Naf'atuzzahrah et al., 2024).

This study presents novelty in the development of an Augmented Reality (AR)-based digital teaching module specifically designed for the reproductive system topic. In contrast to conventional approaches that rely solely on images in textbooks (Masrurroh et al., 2023; Kamilah, 2023; Karuni, 2021), this digital module allows students to visualize the organs of the reproductive system in three-dimensional form through an interactive digital module display. The use of AR visualization in the reproductive system material is intended because this topic involves numerous organs and complex processes that are difficult for students to understand (Listiawan et al., 2022). This innovation not only enhances student engagement and understanding, but also offers a practical and cost-effective learning solution for schools with limited laboratory facilities (Anzilni & Hayudinna, 2025).

This is also in line with the studies conducted by Anapia et al. (2024) and Mardiah et al. (2024) which both developed Augmented Reality (AR)-based digital teaching modules. These studies focused on the effectiveness of the media in improving students' critical thinking and problem-solving skills through three-

dimensional object visualization. In contrast, the present study offers a more advanced development by integrating a wider range of multimedia features, such as in-depth material presentation, the inclusion of relevant YouTube videos, and the use of interactive QR barcodes that can be accessed not only through manual scanning but also through direct clicking without a scanning process when used by students. These features are designed to facilitate student access while simultaneously deepening students' understanding of the reproductive system material in an interactive manner. Therefore, this study is expected to serve as an alternative solution to overcome limitations in learning tools and to support the creation of more meaningful learning processes.

Method

This study belongs to the type of development research, namely Research and Development (R&D). The study employed the ADDIE development model, which consists of Analysis, Design, Development, Implementation, and Evaluation (Siregar & Rhamayanti, 2025). Penelitian ini dilaksanakan pada 13-21 Januari 2026 semester genap tahun ajaran 2025/2026.

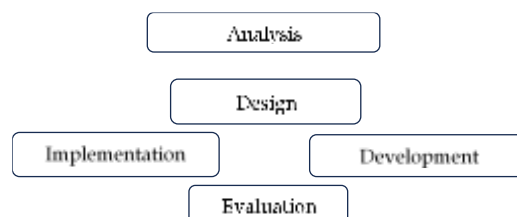


Figure 1. The ADDIE development model (Mulyasari et al., 2023)

The quality of the module was examined through a series of validation processes, in which product validity was determined based on in-depth evaluations conducted by two validators and a Biology subject-matter expert. The validity assessment in this study employed Aiken's scale, while the level of practicality was measured using response questionnaires completed by 34 students of Grade XI Merdeka 2 and one Grade XI Biology teacher (Anapia et al., 2024). Finally, the effectiveness of the media was evaluated by comparing learning outcomes from the pretest, posttest, and N-Gain analysis to determine the significance of AR use in improving students' conceptual understanding. The instruments used in this study included validation questionnaires for validators, teacher and student response questionnaires to measure practicality, and pretests and posttests to assess effectiveness. The data analysis technique for product validity was carried out

by scoring based on the results obtained from the scale. The scoring procedure for validity analysis is as follows:

$$V = \frac{\sum(r-I_0)}{n(C-1)} \tag{1}$$

Notes: r = Score given by the rater; I₀ = Lowest score; C = Highest score; N = Number of raters. The results were categorized according to the criteria presented in Table 1 as follows:

Table 1. Validity Criteria of Aiken’s Index (Kumawati et al., 2023)

Index Range	Category
V > 0.8	Very Valid
0.4 ≤ V ≤ 0.8	Valid
V < 0.4	Less Valid

Data analysis technique Product practicality is carried out by calculating the final value on the questionnaire using the following formula 1. Notes: P = Percentage; T_{se} = Total empirical score; T_{Sh} = Total expected score. Categorized according to the criteria in Table 2.

$$P = \frac{T_{Se}}{T_{Sh}} \times 100\% \tag{2}$$

Table 2. Practicality Categories (Marselina et al., 2024)

Practicality Criteria	Practicality Level
0% < x ≤ 20%	Impractical
20% < x ≤ 40%	Less practical
40% < x ≤ 60%	Quite Practical
60% < x ≤ 80%	Practical
80% < x ≤ 100%	Very Practical

The product effectiveness data analysis technique is carried out using the N-Gain test, the N-Gain test formula 2. Notes: g = Normal gain; Pretest Score = Total score before the trial; Posttest Score = Total score after the trial; Maximum Score = Highest total score. Categorized according to the criteria in Table 3.

$$g = \frac{\text{score posttest} - \text{score pretest}}{\text{score maximum} - \text{score pretest}} \tag{2}$$

Table 3. Effectiveness Category (Karim et al., 2021)

Interval	Criteria
0.70 < g ≤ 1.00	Very Effective
0.30 < g ≤ 0.70	Effective
0.00 ≤ g ≤ 0.30	Less Effective

Result and Discussion

Based on observations conducted at SMA Negeri 23 Makassar, it was found that Biology learning still employs an instructional pattern that tends to be rigid

and teacher-centered. The learning tools used are also limited, resulting in low levels of student enthusiasm toward the learning process. This condition leads to a classroom atmosphere that does not adequately reflect active student engagement, even though all Grade XI IPA Merdeka 2 students have been permitted to bring smartphones to school; however, these devices have not yet been functionally integrated into the learning process.

In response to these challenges, this study proposes an Augmented Reality (AR) based digital learning module as an innovative learning instrument. Unlike conventional figure-based media, AR has the advantage of presenting three-dimensional objects within students’ real-world environments. This advantage fosters high student enthusiasm in participating in Biology learning on the reproductive system topic, as detailed anatomical structure visualizations help students understand learning concepts more clearly and enjoyably.

Product Description

The Augmented Reality (AR)-based digital teaching module is presented in the form of an interactive flipbook, providing a reading experience that resembles a physical book while being enriched with digital features. This format allows students to navigate the pages flexibly using either smartphones or computers, making the learning process feel more modern, practical, and engaging.



Figure 2. Teaching module cover

The main page of the module displays the cover, as shown in Figure 2, which is designed with an attractive and communicative visual appearance to serve as the initial identity of the module, complemented by an appealing color combination. The cover design functions as a motivational trigger for students’ learning, as it

creates a positive first impression and stimulates students' curiosity about the material to be studied.

The subsequent page presents the information section of the digital teaching module, as shown in Figure 3. This module description provides a general overview of the module, enabling students to view the initial presentation of structured information before following the learning flow presented within the module.



Figure 3. Deskripsi modul ajar



Figure 4. AR QR code integration

This digital teaching module also features the integration of AR-based QR codes, as shown in Figure 4, which are embedded in each discussion section of the module, thereby eliminating the use of conventional static figures in the digital teaching module. This feature allows students to directly connect the material presented in the module with AR visualizations. The QR

codes create a more authentic and interactive learning experience, as students not only read theoretical concepts but also visually explore the material.

Augmented Reality display when used by students. Figure 5 shows the interaction between textual material and visualization to clarify the concept of the reproductive system.

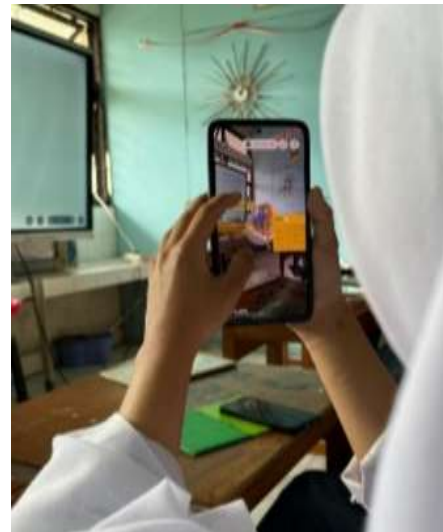


Figure 5. Student integration accesses AR QR code



Figure 6. Display of you tube

Furthermore, as shown in Figure 6, the module includes learning videos from YouTube that can be watched directly without requiring access to the YouTube application. These learning videos serve as varied supporting media in the presentation of the learning material.



Figure 7. Assignments in modules

As shown in Figure 7, the module presents an assignment section designed based on Augmented Reality (AR). This assignment encourages students to actively participate in the learning process. Through this approach, students are not only engaged in completing tasks passively, but are also trained to think critically and creatively. The AR-based assignment provides a challenging yet enjoyable learning experience, thereby enhancing students’ motivation and engagement throughout the learning process.

Empirically, this development research aligns with the principle that a digital learning medium must meet technical and pedagogical feasibility criteria before being widely implemented (Zamsiswaya et al., 2024). Systematic testing was conducted covering aspects of validity, practicality, and effectiveness in the learning process. The results of each of these evaluations are described as follows:

Validity Test Results

The evaluation stage of the AR-based digital teaching module began with a validity test conducted by two subject-matter expert validators. Based on the assessment results, an Aiken’s V coefficient score of 1.0 was obtained.

Table 4. Results of the Digital Teaching Module Validity Test

Number of validators	$\Sigma (r - l_0)$	$N(c-1)$	Aiken’s V	Category
2	144	132	1.00	Very Valid

Based on Table 4, the evaluation of each validation aspect falls into the *Very Valid* category, with the average validity score based on Aiken’s coefficient reaching 1.00. This level of validity indicates that the Augmented Reality (AR)-based digital teaching module has met the

technical standards of modern learning media. This finding supports the argument by (Cahyadi, 2019) that teaching materials designed with a systematic approach not only function as sources of information but also serve as methodologically feasible instructional instruments.

Practicality Test Results

After passing the validation stage by experts, the next aspect is the practicality of using the Augmented Reality (AR)-based digital teaching module, which is measured by collecting usage responses from 34 students and 1 teacher at the school.

Table 5. Results of the Practicality Test of the Teaching Module

Respondents	Persentase	Category
Students	81.40%	Very Practical
Teacher	95%	Very Practical

The practicality test of the learning media was conducted to measure the level of practicality of the developed digital teaching module (Dwiranata et al., 2019). Based on the practicality trial, the AR-based digital teaching module obtained an average practicality score of 81.40%, which falls into the Very Practical category based on the student questionnaire results. Meanwhile, the teacher response questionnaire yielded an average practicality score of 95%, which is also categorized as Very Practical. These practicality results indicate that the AR-based digital teaching module is very easy to use and access by both teachers and students in schools.

Effectiveness Test of the Digital Teaching Module

The developed AR-based digital teaching module has undergone validation and practicality testing. Subsequently, the effectiveness of this module was evaluated using the N-Gain score to measure its success. When the pretest and posttest results are compared using N-Gain analysis, a score indicating improvement in learning outcomes after the use of the digital teaching module can be obtained. Based on the results of statistical data analysis using the N-Gain test, the following results were obtained.

Based on the data presented in Table 6, the average N-Gain score obtained was 0.8893. Referring to the effectiveness criteria, this score falls within the range of $0.70 < g \leq 1.00$, indicating that the Augmented Reality (AR)-based digital teaching module demonstrates a level of effectiveness categorized as *Very Effective*. This achievement confirms that the use of the digital teaching module significantly improves students’ learning outcomes on the reproductive system topic.

Table 6. Results of the N-Gain test

	N	Minimum	Maximum	Mean	Std. Dvt
NGain_Score	34	0.09	1.00	0.8893	0.21074
NGain_Persen	34	18.18	200.00	177.8527	42.14873
Valid N (listwise)	34				

Discussion

The development of an Augmented Reality (AR)-based digital teaching module on the reproductive system topic represents a systematic effort to create a learning module that effectively addresses classroom challenges (Handika, 2023). The primary objective of this study is to produce a module that is not only innovative and interactive, but also scientifically valid, practical in its use, and effective in improving students' learning outcomes (Putra & Sentia, 2023; Euis et al., 2025). To achieve these objectives, this study applied the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Rustandi & Rismayanti, 2021).

At the Analysis stage, the researchers conducted observations to identify the challenges commonly experienced by Grade XI IPA Merdeka 2 students when learning abstract Biology concepts. This step was crucial to ensure that the developed product aligns with the characteristics and needs of students at the school. Moving to the Design stage, the module framework was developed by considering the sequence of learning materials and learning outcomes. At this stage, the researchers designed the digital teaching module in the form of an interactive flipbook, complete with guidelines for using Augmented Reality. Whereas previous learning relied solely on printed textbooks or PowerPoint presentations, this digital teaching module was designed as a more flexible self-learning resource.

Next, at the Development stage, AR technology was embedded into the module through QR codes, enabling students to view the anatomy of reproductive organs in three-dimensional form. To ensure its quality, based on the analysis of Aiken's V index, the developed module achieved a maximum value of 1.0, indicating that all aspects of the digital teaching module were well validated. At the Implementation stage, the module was directly tested to examine its level of practicality, in which student responses reached 81.40% and teacher responses reached 95%, both of which fall into the *Very Practical* category. These results indicate that the module is easy for both students and teachers to use in the classroom, in line with the findings of Pitri et al. (2023) which emphasize that the use of interactive digital modules based on the ADDIE model is able to create an interactive learning environment with ease of access and systematic material presentation. This high level of practicality highlights the importance of integrating

Augmented Reality in facilitating teachers and students to engage in Biology learning more efficiently.

The final stage was Evaluation, which was measured by examining the effectiveness of students' learning outcomes after using the module. The results showed an average N-Gain score of 0.8893, which falls into the category of "High Effectiveness." These findings demonstrate that the integration of AR visualization was able to enhance students' understanding and learning outcomes of the reproductive system material, indicating that the module is suitable for use as a Biology learning resource. This result is in line with the findings of Fatih et al. (2024) who reported that Augmented Reality-based learning modules significantly improve students' scientific literacy and critical thinking skills through interactive and enjoyable learning experiences.

Conclusion

This study successfully developed an Augmented Reality (AR)-based digital teaching module for the Grade XI science reproductive system topic, presented in an interactive flipbook format. The digital module has been empirically tested and meets the criteria of being highly valid, practical, and effective. Based on these criteria, the implementation of this module supports the transformation of modern education in alignment with the Merdeka Curriculum, enabling teachers to use the module as a supplementary learning resource.

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Author Contributions

Formal analysis, investigation, resources, data curation, writing—original draft preparation, N.A.; writing—review and editing, visualization, conceptualization, methodology, validation, R.T. and N.M. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The author declares no conflict of interest.

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