Jupiter: Jurnal Pendidikan Terapan
Homepage : https://journal.diginus.id/jupiter/index
Email: jurnalpendidikanterapan@gmail.com

p-ISSN : 2985-3214; e-ISSN : 2964-3171
Jupiter, Vol. 4, No. 3, July 2026
Page 337-348

Development and Evaluation of a Biology Learning Module Integrating Microlearning Videos for Teaching the Human Immune System

Andi Tirta Angraeni[1], Ismail[2*], Faisal[3], Firdaus Daud[4], Rachmawaty[5]
Universitas Negeri Makassar, Makassar, Indonesia

ARTICLE INFO

Article history:
Submitted: July 03, 2026
Final Revised: July 14, 2026
Accepted: July 21, 2026
Published: July 30, 2026

Keywords:
Biology Learning Module; Validity; Practicality; Effectiveness.

ABSTRACT

Purpose: This study was done to create and check a Biology learning module that uses videos to teach people about the human immune system. The goal was to see if this module is really good if it is useful and if it actually works. The study looked at the Biology learning module and the immune system to find this out. **Methods**: This study employed the ADDIE development model, consisting of Analysis, Design, Development, Implementation, and Evaluation. The research was conducted with Grade XI students at SMA Negeri 4 Bulukumba, Indonesia. The module was validated by two experts and evaluated for practicality through questionnaires completed by two biology teachers and 23 students. Its effectiveness was assessed with 41 students (23 in the experimental class and 18 in the control class). Data were analyzed using Gregory's validity coefficient, descriptive percentage analysis, and normalized gain (N-gain). The ADDIE model provided a systematic framework for developing a valid, practical, and effective biology learning module integrated with microlearning videos. **Findings**: The developed module achieved a Gregory validity coefficient of 1.00, indicating very high validity. Teacher and student practicality scores reached 91.88% and 80%, respectively, indicating that the module is practical for classroom use. Furthermore, the experimental class achieved a higher N-gain score (0.72, high) than the control class (0.49, moderate), demonstrating that integrating microlearning videos into the Biology module effectively improved students' learning outcomes on the human immune system. **Research Implications**: The findings suggest that the developed module can serve as an effective instructional resource for teaching abstract Biology concepts while supporting independent and technology-enhanced learning in senior high schools. **Originality**: Unlike previous studies that primarily examined microlearning videos as standalone instructional media, this study integrates microlearning videos into a systematically developed Biology learning module and comprehensively evaluates its validity, practicality, and effectiveness, thereby contributing to the development of innovative Biology teaching materials for senior high school education.

Doi: https://doi.org/10.61255/jupiter.v4i3.1542

INTRODUCTION

Education in this century requires a learning process that is more attentive to students' needs. Information technology must also be utilized to develop critical thinking, creativity, communication, and collaboration skills. Unfortunately, education in Indonesia still faces many challenges. According to the PISA 2022 report, Indonesian students' scientific literacy remains below the OECD average, with a science score of 383 compared to the OECD average of 485. These findings emphasize the importance of developing innovative learning resources that support students' conceptual understanding and scientific literacy (Kholid, 2026; Lobb, 2023; Papagiannis & Pallaris, 2024). This situation shows that we need innovation in learning to improve the quality of the process and student learning outcomes.

Learning materials play an important role in providing meaningful learning experiences for students. In biology education, learning modules support independent and self-paced learning (C. Cruz & C. Rivera, 2022). However, conventional text-based materials are often insufficient for explaining complex biological concepts. Therefore, biology

modules should integrate interactive and engaging learning resources to facilitate students' understanding of abstract and complex topics. One factor influencing learning success is the availability of appropriate learning materials for students. As noted by Setianingrum et al., (2023), learning materials not only provide information but also help students gain a more focused and meaningful learning experience. A module is a form of learning material that supports independent study. According to Sari et al., (2021), a module is a systematically designed self-study package that allows students to learn at their own pace and according to their individual abilities. As stated by Ilhami (2021), an effective module must be comprehensive, easy to use, and have characteristics that enable independent learning. As a result, students can utilize the module for independent study.

A preliminary needs analysis conducted at SMA Negeri 4 Bulukumba indicated the need for innovative Biology learning materials integrated with digital technology. The student questionnaire showed that most students preferred short instructional videos and considered modules containing text, images, and videos easier to understand than text-based materials alone. Students also reported difficulties in understanding Biology concepts when learning depended only on teacher explanations without supporting media. Furthermore, interviews with Biology teachers revealed that despite the availability of digital facilities, technology integration in classroom learning remained limited. Teachers also observed low student engagement, particularly in learning abstract topics such as the human immune system. These findings emphasize the importance of developing digital-based Biology learning materials that provide engaging and structured learning experiences.

One way to address this issue is to use microlearning videos. Microlearning is a learning strategy that presents material in small, focused segments, making it easier to understand and remember. According to Hlazunova et al., (2024), this approach allows learners to absorb information more easily. Microlearning videos are typically produced as short clips around five minutes in length structured around specific, narrow topics. As noted by Praherdhiono & Prihatmoko (2023), this format is well-suited for learners in the digital age. Another advantage of microlearning videos is that learners can learn anytime and anywhere using their digital devices.

The immune system is one of the Biology topics characterized by its abstract nature, as it involves complex defense mechanisms that occur at the cellular and molecular levels and cannot be directly observed by students (Putri et al., 2025). This characteristic makes it difficult for students to understand key concepts, including immune response mechanisms, interactions among immune cells, and the body's defense against pathogens. Consequently, these learning challenges often lead to lower learning, which may ultimately contribute to poor learning outcomes (Low & Lim, 2023). Therefore, instructional materials that can effectively visualize these abstract concepts through systematic, engaging, and digitally supported presentations are essential. Integrating microlearning videos into learning modules is expected to facilitate a more concrete understanding of immune system mechanisms, enhance students' engagement in the learning process, and improve both their learning academic achievement.

To address these challenges, effective instructional approaches are needed to facilitate students' understanding of abstract biological concepts. One promising strategy is the integration of microlearning videos into biology instruction (Howard & Miskowski, 2005). Microlearning delivers educational content in short, focused segments, allowing students to process information more effectively and learn at their own pace. This approach is supported by Mayer's Cognitive Theory of Multimedia Learning, which posits that students learn more effectively when verbal and visual information are presented together. The integration of text, images, animations, and videos promotes meaningful learning by reducing cognitive overload and enhancing conceptual understanding (Lailli et al., 2026). In addition, Cognitive Load Theory suggests that presenting information in manageable units helps learners process complex content more efficiently and prevents excessive cognitive burden (Maulidya et al., 2023). Therefore, incorporating microlearning videos into biology learning is expected to improve students' understanding of complex topics, such as the human immune system, while increasing their engagement, and academic achievement.

Previous studies have demonstrated the positive impact of microlearning on students' learning experiences and outcomes. Microlearning has been shown to improve academic performance, increase learner satisfaction, promote positive attitudes toward educational technology and strengthen conceptual understanding (Adnas, 2022; Alshammari, 2024; Beltran, 2021; Hlazunova et al., 2024). However, most existing studies have examined microlearning videos as standalone learning resources or within online learning environments. Limited attention has been given to their integration into biology learning modules, particularly for teaching complex topics such as the human immune system at the senior high school level (Ngou et al., 2022). Furthermore, few studies have comprehensively evaluated the validity, practicality, and effectiveness of such instructional materials. Therefore, this study aimed to develop a biology learning module integrated with microlearning videos and evaluate its validity, practicality, and effectiveness in improving students' and learning outcomes. By addressing these research gaps, this study is expected to contribute to the development of innovative and evidence-based instructional materials for biology education.

Despite the growing body of literature on microlearning, several research gaps remain. First, previous studies have primarily focused on using microlearning videos as standalone instructional media or within e-learning environments rather than integrating them into systematically developed Biology learning modules. Second, only a limited number of studies have comprehensively evaluated the developed instructional modules in terms of their validity, practicality, and effectiveness. Third, research investigating integrated microlearning-based Biology modules for teaching the human immune system at the senior high school level remains scarce. Addressing these gaps, the present study develops a Biology learning module integrated with microlearning videos and evaluates its validity, practicality, and effectiveness in improving students' learning outcomes.

Therefore, this study aimed to develop and evaluate a Biology learning module integrating microlearning videos for teaching the human immune system by assessing its validity, practicality, and effectiveness in improving students' learning outcomes. This study contributes to biology education by developing a technology-enhanced learning module and providing empirical evidence of its validity, practicality, and effectiveness. The findings are expected to support the development of innovative instructional materials for teaching abstract biological concepts, particularly the human immune system. Furthermore, this study offers practical implications for educators seeking to integrate digital learning resources into biology instruction to promote meaningful learning and improve students' conceptual understanding and learning outcomes.

METHOD

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. To evaluate the effectiveness of the developed module, a quasi-experimental approach employing a pretest–posttest control group design was conducted. The experimental class learned using the Biology learning module integrating microlearning videos, whereas the control class received conventional instruction using the learning materials commonly used by the teacher.

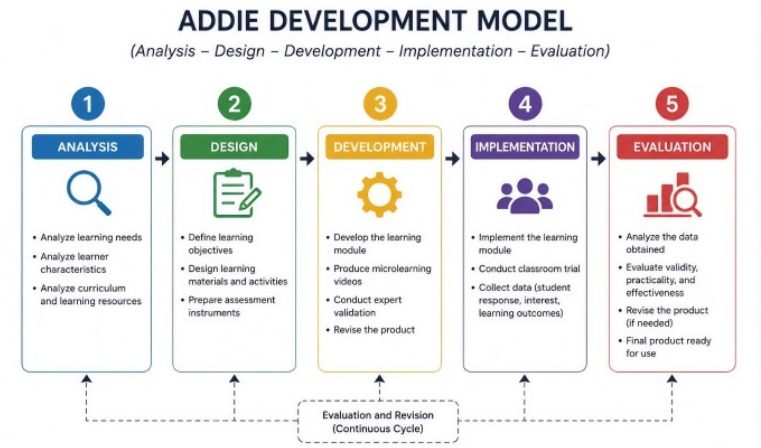

Figure 1. ADDIE Model Development Stages

The development process followed the five stages of the ADDIE model, namely Analysis, Design, Development, Implementation, and Evaluation, as presented in Figure 1. During the analysis stage, a needs analysis was conducted through classroom observations, interviews with Biology teachers, and questionnaires distributed to students. In addition, curriculum content and learning objectives related to the human immune system were analyzed to identify students' learning needs and determine the appropriate instructional content for the module. At the design stage, the framework of the Biology learning module was developed by determining the learning objectives, organizing the instructional materials, designing learning activities, assessment instruments, and integrating microlearning videos through QR codes. The module consisted of learning objectives, instructional materials, exercises, summaries, evaluations, and QR codes that directed students to the corresponding microlearning videos. During the development stage, the Biology learning module, microlearning videos, and research instruments were produced and subsequently validated by experts. The module and instruments were revised based on the validators' comments and suggestions until they fulfilled the required validity criteria. The implementation stage involved applying the validated module in classroom learning. The experimental class received instruction using the Biology learning module integrating microlearning videos, whereas the control class received conventional instruction. Practicality was evaluated through

teacher and student response questionnaires, while effectiveness was assessed using students' pretest and posttest learning outcomes. Finally, the evaluation stage was conducted throughout the development process to review the results of the validity, practicality, and effectiveness assessments. Feedback obtained from expert validation and classroom implementation was used to refine the module before producing the final version.

The study was conducted at SMA Negeri 4 Bulukumba, South Sulawesi, Indonesia, during the 2025/2026 academic year. The participants were selected using purposive sampling. Among the four Grade XI classes, two classes were selected in consultation with the Biology teacher based on the suitability of the research objectives and the implementation schedule of the human immune system topic. The participants consisted of 23 students in the experimental class and 18 students in the control class. In addition, two Biology teachers participated in evaluating the practicality of the developed module.

Four research instruments were employed in this study: expert validation sheets, teacher response questionnaires, student response questionnaires, and learning achievement tests. The expert validation sheets were used to evaluate the content, presentation, language, and graphical aspects of the developed Biology learning module as well as the research instruments. Teacher and student response questionnaires were administered to evaluate the practicality of the module after implementation. The effectiveness of the developed module was assessed using a learning achievement test consisting of pretest and posttest administered to both the experimental and control classes.

Table 1. Validity Instrument for modules integrated with Microlearning videos by expert validators.

Aspect	Indicator
Content Suitability	Coverage of material, Up-to-dateness of material, Integration of microlearning videos into teaching
Presentation Suitability	Presentation techniques, Instructional delivery, Presentation completeness
Language Compatibility	Alignment with student development, Quality of communication, Logical flow and coherence
Graphic Compatibility	Module and cover design, Visual design & microlearning video integration

Prior to classroom implementation, the developed Biology learning module and research instruments were validated by two expert validators using Gregory's content validity coefficient. Suggestions provided by the validators were incorporated into the revision process until the module fulfilled the required validity criteria.

$$VC = \frac{D}{A+B+C+D}$$ (Wesnawa et al., 2022)

Table 2. Validity Category

Mark	Description
0.8 – 1	Very high validity
0.60 – 0.79	High validity
0.40 – 0.59	Moderate validity
0.20 – 0.39	Low validity
0.00 – 0.19	Very low validity

(Suastrawan et al., 2021)

The validity coefficient calculation results determine the validity standards of the research instrument. An instrument is considered suitable if it has a strong level of content relevance and a validity value of at least 0.75. The calculation results indicate that the developed module meets the feasibility standards in terms of content, presentation, language, and graphics, so it can be used without significant changes. If the validity coefficient value is in the medium or low category (≤ 0.59), the module must be modified to meet the needs of students and the objectives of biology learning.

Table 3. Practical Instrument of Teacher Response for Integrated Biology Learning Module Microlearning Video

Content Suitability Aspect	Alignment of learning objectives with Learning Outcomes (CP)
	The order of presentation of material is in accordance with basic competencies
	Microlearning video integration supports understanding of biology concepts
	Activities in the module encourage student engagement
Learning Aspects	Presentation of material encourages students' thinking skills

	The module helps teachers explain abstract concepts of biology.
Graphic Aspects	The quality of the video display (images, animations, and audio) is appropriate to the material.
	The layout of the module (layout, font, color) attracts the attention of students.
	The presentation of text, images and videos is consistent and proportional.
Linguistic Aspects	Simple and easy to understand module language
	Communicative and engaging microlearning video language
Benefit	The module makes it easier for teachers to learn
	Modules help students learn independently

Meanwhile, the aspects and indicators in the student questionnaire used to evaluate the practicality of the integrated video microlearning module can be seen in Table 4.

Table 4. Practical Instrument of Student Responses for Integrated Biology Learning Modules with Microlearning Videos

Content Eligibility	Suitability of material to learning objectives
Appearance	The attractiveness of the module and video displays
Language	Clarity of language and ease of understanding
Benefit	Increase learning outcomes

Teachers and students have different perspectives. To understand these perspectives, the practicality percentages based on the teachers' and students' views were calculated. The following formula was used to determine the respondents' assessment percentages:

$$P = \frac{\sum x}{\sum xi}\ x\ 100\% \qquad \text{(Lodang et al., 2023)}$$

Comment:
P = Percentage value
$\sum x$ = Total score obtained from respondents
$\sum x_i$ = Total maximum expected value

After obtaining the percentage scores for the respondent statement indicators, the practicality criteria were adjusted based on Milala et al., (2021) , as shown in the following table:

Table 5. Practicality Assessment Categories for Microlearning Video Integrated Biology Learning Modules

Mark	Information
81% - 100%	Very practical
61% - 80%	Practical
41% - 60%	Quite practical
21% - 40%	Less practical
0 – 20%	Not practical

The practicality of the developed module was evaluated separately based on teachers' and students' responses to obtain a comprehensive assessment of its usability in classroom learning. The effectiveness of the developed Biology learning module was evaluated by comparing students' pretest and posttest scores. The improvement in students' learning outcomes was determined using normalized gain (N-gain) analysis, using the N-gain formula as follows:

$$\text{Ngain} = \frac{\text{Skor posttest} + \text{skor pretest}}{\text{Skor ideal} - \text{skor pretest}}$$

Then it is categorized based on the N-gain value obtained using N-gain using the category by (Safitri et al ., 2023).

RESULTS

Student needs analysis is the first step in the analysis phase of the ADDIE development model. The goal is to understand students, their needs in learning biology. This includes understanding the challenges they face while learning. This information will then be used to create biology learning modules integrated with microlearning videos. The results of the questionnaire showed that 83% of students were very interested in learning Biology if it was presented through short, clear and interesting videos. In addition, 78% of students stated that it was easier to understand

material through video displays than through long texts. In fact, 87% of students want Biology material to be presented in an attractive and easy-to-understand manner. They also stated that videos with simple language helped them better understand the material. This suggests that students tend to need learning media that combine visual and audio elements to support their learning process.

The development stage is the stage of changing the results of analysis and design into products that are ready to be used in learning. At this stage, the module, integrated with microlearning videos about the Immune System, is being developed according to the previously established plan. Furthermore, product quality is being ensured through a validation and revision process based on expert input. Revisions are being made in stages until the product is ready for use. After analyzing the content and determining the learning objectives for the Immune System material, a material framework is created based on Learning Outcomes and learning objectives that students must achieve. The material in the module is supported by microlearning videos designed to convey information in a concise, focused, and easy-to-understand manner. By combining microlearning modules and videos, it is hoped that students can learn independently, and achieve optimal learning outcomes.

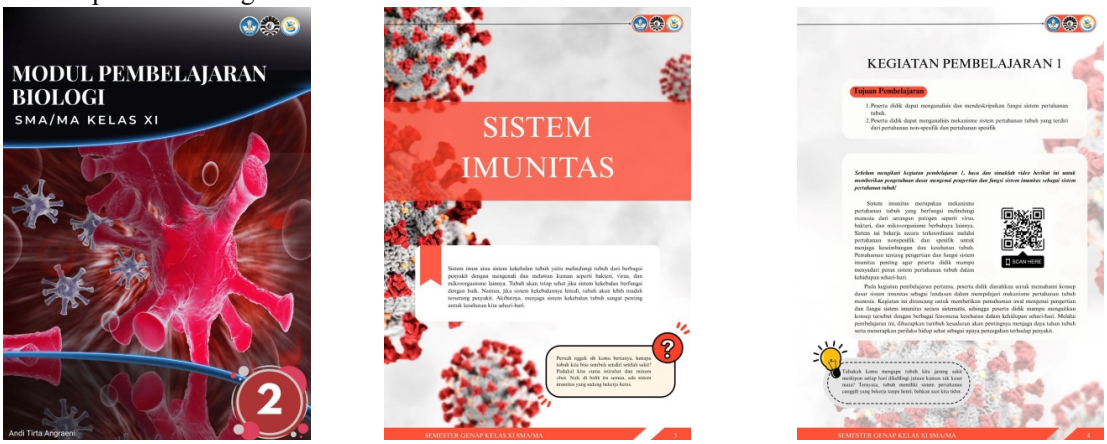

Figure 2. Design of a Biology Learning Module Integrated with Microlearning Videos

Next, the researcher wanted to know whether the integrated video microlearning module developed was practical and effective. For this reason, trials were conducted on students and teachers at the implementation stage.

$$\text{CV} = \frac{30}{0+0+0+30} = 1$$

The expert validation results showed that the biology learning module integrating microlearning videos achieved a Gregory content validity coefficient of 1.00, indicating very high validity. This result demonstrates that the developed module fulfilled the required standards across all validation aspects. The content aspect was rated highly because the learning materials were aligned with the learning outcomes, learning objectives, and scientific concepts related to the human immune system. The presentation aspect received positive evaluations due to the systematic organization of the learning materials, clear instructional sequence, and well-structured learning activities. The language aspect was considered appropriate because the module employed clear, communicative, and student-friendly language that facilitated comprehension. Furthermore, the graphical aspect was rated very highly as the layout, illustrations, color composition, and QR-code integration of the microlearning videos effectively supported students' engagement and understanding of abstract biological concepts. Overall, these findings indicate that the developed module is suitable for classroom implementation without requiring major revisions.

Table 6. Results of the Analysis of Teacher Response Questionnaires Regarding the Integrated Biology Learning Module with Microlearning Videos

Aspect	Percentage (%)	Category
Content suitability	90.63	Very Practical
Learning Aspect	91.67	Very Practical
Graphics	95.83	Very Practical
Language	93.75	Very Practical
Benefit	87.5	Very Practical
Average	91.88	Very Practical

The teacher response questionnaire indicated that the developed Biology learning module was highly practical for classroom implementation. The graphical aspect received the highest evaluation because the module integrates an attractive layout, clear illustrations, consistent visual design, and QR-code-linked microlearning videos that facilitate the explanation of abstract Biology concepts. The language and learning aspects were also evaluated positively, indicating that the module is easy to understand, supports instructional delivery, and assists teachers in conducting more engaging learning activities. Although the benefit aspect received a slightly lower score than the other aspects, it still demonstrated that the module effectively supports teaching, promotes students' independent learning, and contributes to improving learning outcomes.

Table 7. Results of the Analysis of Student Response Questionnaires for the Integrated Biology Learning Module with Microlearning Videos

Aspect	Percentage (%)	Category
Content Eligibility	80	Practical
Appearance	81	Very Practical
Language	82	Very Practical
Benefit	78	Practical
Average	80	Practical

Student responses indicated that the developed module was practical and well accepted during the learning process. The language aspect received the highest evaluation because the module used simple, communicative, and easy-to-understand language, enabling students to follow the learning materials independently. The appearance aspect was also highly rated, reflecting students' positive perceptions of the attractive visual design and the integration of microlearning videos through QR codes. Meanwhile, the benefit aspect obtained a slightly lower score, suggesting that although students perceived the module as helpful, differences in individual learning preferences and adaptation to a new learning approach may have influenced their overall perceptions of its usefulness.

Table 8. Frequency and Percentage Data Analysis of N-gain Value Categories of Student Learning Outcomes

Category	Experimental Class		Control Class	
	Frequency	Percentage (%)	Frequency	Percentage (%)
High	12	52.2	1	5.6
Moderate	10	43.5	13	72.2
Low	1	4.3	4	22.2
Total	**23**	**100**	**18**	**100**
Pretest	11.9		8.9	
Posttest	21.4		16.7	
N-gain	0.72		0.49	
Category	**High**		**Moderate**	

Therefore, this study contributes to biology education by developing a biology learning module integrated with microlearning videos and providing empirical evidence of its validity, practicality, and effectiveness. The findings are expected to support the development of technology-enhanced instructional materials for teaching abstract biological concepts, particularly the human immune system. Furthermore, this study provides practical guidance for educators in integrating digital learning resources into biology instruction to promote meaningful learning, improve students' conceptual understanding, and enhance learning outcomes. To provide a clearer illustration of students' learning improvement after the implementation of the learning intervention, the mean N-gain scores of the experimental and control classes are presented in Figure 3.

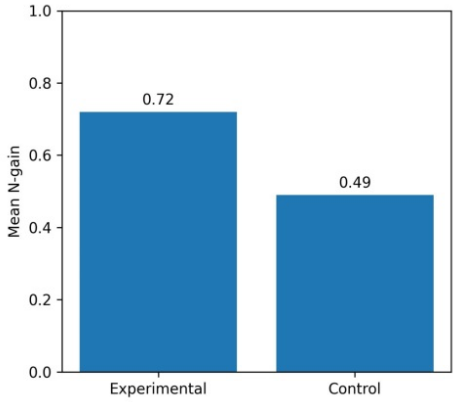

Figure 3. Comparison of the Mean N-gain Scores between the Experimental and Control Classes

As shown in Figure 3, the experimental class achieved a mean N-gain score of 0.72, whereas the control class obtained a mean score of 0.49. These results indicate that the improvement in students' learning outcomes was greater in the experimental class than in the control class. According to the N-gain classification criteria, a score of 0.72 falls into the high category, while a score of 0.49 is classified as moderate. Therefore, the learning model implemented in the experimental class was more effective in improving students' learning outcomes than the instructional approach used in the control class.

DISCUSSION

The Biology learning module integrating microlearning videos demonstrated very high validity, indicating that its content, presentation, language, and graphical components were well aligned with the intended learning outcomes and students' learning needs. This result can be attributed to the systematic development process following the ADDIE model, in which every component of the module was designed based on curriculum requirements, expert feedback, and students' characteristics. The integration of QR-code-based microlearning videos further enhanced the instructional quality by providing visual explanations of immune system mechanisms that are difficult to observe directly through conventional printed materials.

The high validity of the module suggests that the learning materials were not merely scientifically accurate but also pedagogically appropriate for senior high school students. The combination of concise textual explanations, illustrations, and short instructional videos enabled the module to present abstract biological concepts in a more accessible manner. According to Mayer's Cognitive Theory of Multimedia Learning, students understand complex concepts more effectively when verbal information is combined with relevant visual representations because both verbal and visual processing channels are activated simultaneously. Likewise, Cognitive Load Theory explains that organizing information into manageable learning units reduces unnecessary cognitive burden and facilitates meaningful learning. The high validity also reflects the coherence among learning objectives, instructional content, learning activities, and assessment. Such alignment ensures that students receive learning experiences that directly support the intended competencies while facilitating concept acquisition through multimodal learning resources.

These findings are consistent with Setianingrum et al., (2023) who emphasized that effective instructional materials should be systematically organized to support competency achievement. They also support the findings of Hlazunova et al., (2024), who reported that well-designed microlearning videos improve instructional quality by presenting information in concise, focused, and easily digestible segments.

The teacher responses indicated that the developed module was highly practical for classroom implementation. This finding suggests that the module successfully met teachers' instructional needs by providing well-organized learning materials supported by digital learning resources. The embedded QR codes enabled teachers to access instructional videos instantly without requiring additional learning platforms, thereby simplifying lesson implementation and reducing preparation time.

The practicality of the module may also have been influenced by contextual factors within the school environment. Teachers were already familiar with smartphone-assisted instruction, and most students had access to mobile devices capable of scanning QR codes. These conditions enabled the microlearning videos to be accessed without substantial technical barriers, thereby supporting smooth classroom implementation.

Another factor contributing to the high practicality score was the ability of the module to assist teachers in explaining complex biological processes. The immune system involves numerous cellular interactions that are difficult to visualize through verbal explanation alone. The integration of short instructional videos allowed these invisible biological processes to be represented visually, making classroom explanations clearer and more efficient.

Students also perceived the module as practical because the learning materials were presented through concise explanations, attractive illustrations, and short videos that could be accessed repeatedly whenever needed. This learning flexibility encouraged independent learning and reduced students' dependence on teacher explanations. Such characteristics are particularly important for Biology learning because many concepts require repeated observation and visualization before they can be fully understood. These findings support Ilhami, (2021), who argued that effective learning modules should facilitate self-directed learning. Furthermore, they are consistent with Alshammari, (2024), who found that video-based microlearning enhances learners' satisfaction, technology acceptance, and engagement by providing flexible learning experiences that are easy to access.

The developed Biology learning module integrating microlearning videos effectively improved students' learning outcomes, as demonstrated by the higher N-gain score achieved by the experimental class compared with the control class. This result indicates that integrating microlearning videos into printed learning modules provides additional instructional support beyond conventional teaching materials.

One possible explanation for this finding is the nature of the human immune system itself. The topic contains many abstract processes occurring at the cellular and molecular levels, making it difficult for students to construct accurate mental models using text alone. The microlearning videos transformed these abstract concepts into dynamic visual representations, enabling students to observe immune responses, interactions among immune cells, and defense mechanisms more concretely.

Another important factor is the segmentation of learning materials into short instructional units. According to Cognitive Load Theory, presenting information in smaller learning segments reduces extraneous cognitive load and allows students to process complex information more efficiently. In addition, Mayer's Cognitive Theory of Multimedia Learning suggests that integrating verbal explanations with visual representations promotes deeper conceptual understanding because students actively organize and integrate information from multiple channels. Consequently, students experienced fewer conceptual difficulties, became more engaged during learning activities, and achieved better cognitive learning outcomes.

The findings also indicate that the effectiveness of the module was influenced not only by the quality of its instructional content but also by the learning experience created through multimedia integration. The opportunity to replay videos, review learning materials independently, and connect textual explanations with visual demonstrations encouraged active learning and strengthened conceptual retention.

These findings are consistent with Low & Lim (2023), who reported that visual and interactive learning environments facilitate students' understanding of immunology concepts that are inherently abstract. Similarly, Hlazunova et al., (2024) concluded that microlearning technology improves conceptual understanding by presenting concise learning content in highly focused instructional segments. The present study extends these previous findings by demonstrating that microlearning videos become more effective when systematically integrated into Biology learning modules rather than being used as standalone instructional media. This integration provides students with a structured learning pathway that supports independent learning while simultaneously improving conceptual understanding and academic achievement.

Beyond its practical contribution, this study also provides theoretical support for Mayer's Cognitive Theory of Multimedia Learning by demonstrating that integrating text, illustrations, and microlearning videos within a single instructional module facilitates students' conceptual understanding. In addition, the findings extend Cognitive Load Theory by showing that presenting Biology content through segmented microlearning videos reduces unnecessary cognitive load and supports more effective knowledge construction.

From a practical perspective, the developed module can serve as an alternative instructional resource for Biology teachers implementing the Merdeka Curriculum. The integration of QR-code-based microlearning videos may also be adopted in other Biology topics involving abstract concepts, thereby supporting blended learning and promoting students' independent learning.

This study has several limitations. First, it was conducted in only one senior high school, limiting the generalizability of the findings. Second, the developed module focused exclusively on the human immune system topic. Third, the effectiveness evaluation was limited to students' cognitive learning outcomes and did not assess long-term retention, motivation, or higher-order thinking skills. Future studies should involve more diverse educational settings and investigate the long-term impact of microlearning-integrated modules on broader learning outcomes.

CONCLUSION

This study demonstrates that integrating microlearning videos into Biology learning modules can produce instructional materials that are valid, practical, and effective in facilitating students' understanding of abstract biological concepts. Beyond the development of a high-quality learning resource, the study provides empirical evidence that systematically integrating multimedia elements into printed modules through the ADDIE model enhances instructional quality and supports meaningful learning. Collectively, these results contribute to the growing body of research on multimedia-supported instructional materials and offer evidence for the effective integration of microlearning strategies in secondary Biology education.

From a practical perspective, the developed module offers valuable implications for Biology education. Biology teachers may use the module as a complementary instructional resource in face-to-face, blended, or technology-enhanced learning environments to facilitate the teaching of abstract biological concepts. The instructional design, which integrates QR-code-based microlearning videos into printed learning materials, may also serve as a practical reference for instructional material developers seeking to design similar resources for other Biology topics. In addition, schools and educational institutions may consider adopting comparable multimedia-supported learning materials to foster students' independent learning, digital literacy, and more meaningful learning experiences. These findings may also support the implementation of the Merdeka Curriculum by providing an example of how multimedia-integrated instructional materials can promote active, independent, and student-centered learning.

This study has several limitations that should be considered when interpreting the findings. It was conducted in a single senior high school and focused only on the human immune system topic, which may limit the transferability of the findings to other educational settings. In addition, the effectiveness of the module was evaluated solely through students' cognitive learning outcomes. Therefore, future research should investigate the implementation of similar modules across different Biology topics, educational levels, and more diverse educational contexts while examining additional outcomes such as learning motivation, critical thinking, and long-term knowledge retention.

REFERENCE

Adnas, D. A. (2022). Perancangan dan Pengembangan Jalur Pembelajaran pada E-Learning Menggunakan Micro-Learning. *Journal of Information System and Technology*, *03*(03), 304.

Alshammari, F. L. (2024). Video-based microlearning and the impact on programming skills and technology acceptance. *Journal of Education and E-Learning Research*, *11*(1), 155–165. https://doi.org/10.20448/jeelr.v11i1.5399

Beltran, R. S. (2021). Effectiveness of Modular and Video Lessons in Mathematics to The Performance of Grade 5 Pupils. *International Journal of Advanced Multidisciplinary Studies*, *1*(4), 1–10.

C. Cruz, L. I., & C. Rivera, K. (2022). Development And Validation Of Project-Based Module For Selected Topics In Biology. *International Journal of Educational Research & Social Sciences*, *3*(3), 1124–1137. https://doi.org/10.51601/ijersc.v3i3.374

Hlazunova, O. H., Schlauderer, R., Korolchuk, V. I., Voloshyna, T. V., & Saiapina, T. P. (2024). Microlearning technology based on video content: Advantages, methodology and quality factors. *Journal of Physics: Conference Series*, *2871*(1). https://doi.org/10.1088/1742-6596/2871/1/012028

Howard, D. R., & Miskowski, J. A. (2005). Using a module-based laboratory to incorporate inquiry into a large cell biology course. *Cell Biology Education*, *4*(FALL), 249–260. https://doi.org/10.1187/cbe.04-09-0052

Ilhami, S. (2021). Pengembangan Modul Pembelajaran Biologi Berorientasi Model Siklus Belajar Untuk Siswa Sma/Ma Kelas X. *PAEDAGOGY : Jurnal Ilmu Pendidikan Dan Psikologi*, *1*(2), 149–161. https://doi.org/10.51878/paedagogy.v1i2.805

Kholid, I. (2026). *Technology-Enhanced Co-Creative Pedagogies : Transforming Collaboration , Critical Thinking , and Innovation in STEAM Education*. *9*, 379–401.

Lailli, A. N., Qanita, E., Birzah, F., & Bilqis, M. (2026). *Analisis Karakteristik Media Pembelajaran Digital Melalui Perspektif Prinsip Multimedia*. *3*(2), 976–989.

Lobb, A. (2023). PISA 2022 Results (Volume I): The State of Learning and Equity in Education. In *OECD Publishing* (Vol. 46, Number 183).

Lodang, H., Saleh, A. R., & Tajusman, M. (2023). Analisis Kebutuhan Pengembangan Modul Ajar Berbasis Saintifik Materi Inovasi Teknologi Biologi Fase E. *Inovasi Sains Dan Pembelajaran*, *11*, 72–81.

Low, P.-Y., & Lim, G.-B. (2023). Scientific Articulation during Collaborative Digital Game-Based Learning Enhances Learning of Immunology. *ImmunoHorizons*, *7*(11), 718–728. https://doi.org/10.4049/immunohorizons.2300004

Maulidya, Rifi, Safitri, Desy, Istiqomah, & Nurul. (2023). Edukasi IPS. *Edukasi IPS*, *7*(1), 27–35. file:///C:/Users/ASUS/Downloads/sujarwo,+rifi4.pdf

Milala, H. F., Endryansyah, E., Joko, J., & Agung, A. I. (2021). Keefektifan Dan Kepraktisan Media Pembelajaran Menggunakan Adobe Flash Player. *Jurnal Pendidikan Teknik Elektro*, *11*(02), 195–202. https://doi.org/10.26740/jpte.v11n02.p195-202

Ngou, B. P. M., Ding, P., & Jones, J. D. G. (2022). Thirty years of resistance: Zig-zag through the plant immune system. *Plant Cell*, *34*(5), 1447–1478. https://doi.org/10.1093/plcell/koac041

Papagiannis, P., & Pallaris, G. (2024). *Evaluating 21st Century Skills Development through Makerspace Workshops in Computer Science Education*. http://arxiv.org/abs/2411.05012

Praherdhiono, H., & Prihatmoko, Y. (2023). Optimization of web-based physics learning technology through on-demand microlearning video download facility in an internet accessibility variation case. *Momentum: Physics Education Journal*, *7*(2), 290–298. https://doi.org/10.21067/mpej.v7i2.8527

Putri, D. E., Istiana, R., Herawati, D., & Zahwa, D. K. (2025). *Development of a Problem-Based E-Module on the Immune System Material to Enhance Systemic Thinking Skills*. *6*(2), 167–175. https://doi.org/10.55215/jber.v6i2.39

Safitri, A., Dama, L., & Ahmad, J. (2023). Pengembangan Instrumen Evaluasi Melalui Aplikasi Quizizz Untuk Meningkatkan Hasil Belajar Peserta Didik Pada Materi Perubahan Lingkungan Di SMA Negeri 2 Gorontalo. *Jurnal Pendidikan*, *11*(1), 61–79. https://doi.org/10.36232/pendidikan.v11i1.2272

Sari, I. P., Abadi, S., & Nawawi, S. (2021). *Pengembangan Modul Pembelajaran Biologi Berbasis Problem Solving Pada Materi Ekologi Sari Ike Puspita , Abadi Suyud , Nawawi Sulton : Pengembangan Modul Pembelajaran Biologi Pendahuluan 1 . Latar Belakang Pendidikan adalah suatu proses dalam rangka mempen*. *4*(1), 25–31.

Setianingrum, D. A., Matahari, D. B., Jumadi, J., & Wilujeng, I. (2023). *Development of Science e-Book Containing Gamelan ' s Local Wisdom Based on STEAM-POE to Facilitate Students ' Love of Local Culture*. *9*(6), 4791–4800. https://doi.org/10.29303/jppipa.v9i6.3760

Suastrawan, K. E., Suardana, I. N., & Sudiatmika, A. A. I. A. R. (2021). Pengembangan E-Modul Ipa Smp Kelas Vii Dengan Model Process Oriented Guided Inquiry Learning Berbasis Isu-Isu Sosial Sains Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa. *Quantum: Jurnal Inovasi Pendidikan Sains*, *12*(2), 199. https://doi.org/10.20527/quantum.v12i2.11228

Wesnawa, I. G. A., Kartowagiran, B., Jaedun, A., Hamdi, S., Hadi, S., Susantini, E., Sunendar, D., Laliyo, L. A. R., Christiawan, P. I., & Divayana, D. G. H. (2022). Content Validation of Digital Instrument for Measurement of Pedagogic Competence for Social Science Teacher Candidates in the Industrial Revolution 4.0 Era in Indonesia. *International Journal of Information and Education Technology*, *12*(12), 1424–1430. https://doi.org/10.18178/ijiet.2022.12.12.1767

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the principal, biology teachers, and Grade XI students of SMA Negeri 4 Bulukumba for their valuable cooperation and active participation throughout this study. The authors also extend their appreciation to the expert validators for their constructive feedback and valuable suggestions, which contributed significantly to the improvement of the developed biology module integrated with microlearning videos. The authors are also grateful to the Master's Program in Biology Education, Universitas Negeri Makassar, for providing academic guidance and support throughout the research process and the preparation of this manuscript.

AUTHOR CONTRIBUTION STATEMENT

AA conceptualized the study, developed the biology module, collected and analyzed the data, and prepared the original manuscript. IS and FA supervised the research, provided methodological and academic guidance, reviewed and edited the manuscript, and contributed to the interpretation of the findings. FD and RA validated the developed module and provided critical feedback to improve its quality. IS served as the corresponding author. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used ChatGPT (OpenAI) and QuillBot during the preparation of this manuscript to assist with language editing, paraphrasing, grammar improvement, and enhancing the clarity of the writing. The study design, data collection, data analysis, interpretation of the findings, and conclusions were performed entirely by the authors. All

AI-assisted content was carefully reviewed, revised, and verified by the authors, who take full responsibility for the final content of this manuscript.

Andi Tirta Angraeni
Department of Biology Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar,
Jl. A. P. Pettarani, Makassar 90222, South Sulawesi, Indonesia
Email: anditirtaangraeni@gmail.com

***Ismail (Corresponding Author)**
Department of Biology Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar,
Jl. A. P. Pettarani, Makassar 90222, South Sulawesi, Indonesia
Email: ismail6131@unm.ac.id

Faisal
Department of Biology Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar,
Jl. A. P. Pettarani, Makassar 90222, South Sulawesi, Indonesia
Email:

Firdaus Daud
Department of Biology Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar,
Jl. A. P. Pettarani, Makassar 90222, South Sulawesi, Indonesia
Email: firdaus.daud@unm.ac.id

Rachmawaty
Department of Biology Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar,
Jl. A. P. Pettarani, Makassar 90222, South Sulawesi, Indonesia
Email: rachmawaty@unm.ac.id