

# Development of a Research-Based E-Module to Enhance Laboratory Skills in Animal Development for Biology Education Students

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**Abstract:** The integration of digital learning resources in higher education necessitates innovative instructional materials to enhance students' laboratory competencies. This study aims to develop a research-based e-module for the Animal Development course and evaluate its validity, feasibility, and effectiveness. The research employed the 4D development model—Define, Design, Develop, and Disseminate, focusing on expert validation and small-group trials. Validation results indicate a high validity score (93.28), while student feasibility assessments show strong acceptance (84.2%). An N-Gain test involving 27 students demonstrates a substantial improvement in laboratory skills (N-Gain = 0.79). These findings confirm that the research-based e-module enhances conceptual understanding, improves laboratory practices, and strengthens students' data analysis abilities. Overall, the developed e-module serves as an effective digital resource for improving laboratory-based learning in Biology Education.

**Keywords:** Animal development; Biology Education; e-module development; Laboratory skills; Research-based learning

## Introduction

Biology education not only emphasizes theoretical comprehension but also requires the development of practical skills, particularly in laboratory settings (Scott et al., 2018) (Jongsma et al., 2024). The Animal Development course plays a crucial role in this context by providing students with opportunities to explore developmental processes in organisms and conduct laboratory experiments to observe and analyze these phenomena. However, students often struggle to develop adequate laboratory skills due to limited laboratory time, inadequate facilities, and the absence of comprehensive resources that integrate theory with practice (Abrahams & Millar, 2008) ; (Oliveira & Bonito, 2023). The lack of effective and innovative learning media further complicates students' ability to conduct

detailed observations and gain hands-on experience in animal development (Shana & Abulibdeh, 2020).

To master laboratory skills, students must demonstrate proficiency in using laboratory tools, making accurate observations, and critically analyzing experimental data (Gobaw et al., 2016); (Hofstein & Lunetta, 2020). Additionally, they are expected to design and execute experiments following appropriate methodologies, present their findings clearly, and integrate technology and digital resources to enhance their learning (Haleem et al., 2022) (Lohr et al., 2024). Beyond technical proficiency, collaboration with peers, adherence to safety protocols, and the application of critical thinking in solving experimental challenges are essential competencies for cultivating well-rounded laboratory skills (Walker et al., 2016) (Connor et al., 2023). These capabilities are fundamental for preparing students to engage in scientific research and teaching within the field of biology education.

## How to Cite:

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Despite these requirements, many students still exhibit low mastery of laboratory procedures and analytical skills, indicating that existing instructional materials have not adequately supported the development of practical competencies. According to constructivist learning theory, students learn more effectively when they actively construct knowledge through direct experience and reflection, emphasizing the need for instructional approaches that support experiential and inquiry-based learning (Kim, 2005); (Amineh & Asl, 2015). Therefore, instructional media that facilitate hands-on exploration, experimentation, and research-based learning are essential for promoting deeper understanding and skill acquisition. Furthermore, the integration of digital learning resources aligns with self-regulated learning theory, which highlights learners' ability to plan, monitor, and evaluate their own learning processes through structured, accessible, and interactive materials (Panadero, 2017).

Recent advancements in educational technology offer potential solutions to these challenges through the integration of research-based e-modules (Purwasih et al., 2022) (Istiqoma et al., 2023). These digital learning resources enable students to engage in self-directed learning, providing flexible access to course materials while strengthening their conceptual understanding (Istiqoma et al., 2023). A research-based approach to e-modules allows students to contextualize theoretical knowledge and apply recent scientific findings in laboratory experiments (Fitriyati et al., 2015); (Luh & Karang, 2021). These modules are specifically designed to enhance laboratory skills by guiding students through experimental techniques in animal development, thereby improving their ability to analyze and interpret experimental data. Several studies have demonstrated

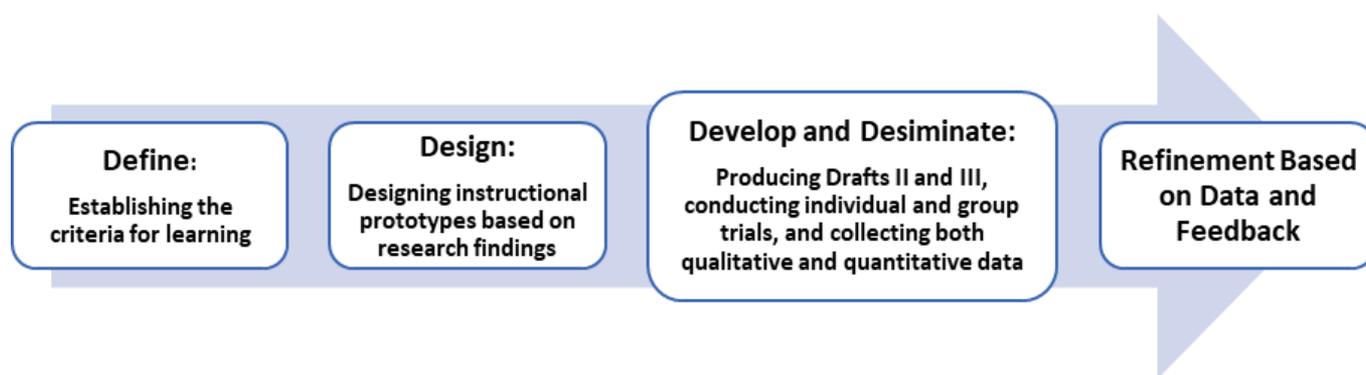
that research-based e-modules can significantly improve laboratory skills, creative thinking, and scientific process skills in biology education (Purnamasari et al., 2024) (Raviqah et al., 2023) (Biggs, 1996); (Jalil et al., 2024)

Given the gap between the expected laboratory competencies and students' actual performance, there is a strong need to develop instructional media that not only deliver content but also cultivate scientific process skills. Additionally, the absence of research-based digital resources specifically tailored to the Animal Development course indicates a clear research opportunity. Developing a research-based e-module is therefore justified as a strategic effort to address learning limitations, support the development of laboratory skills, and enhance students' readiness for scientific research in biology education (Anugra Rahma Shafira, Wiwit Alwi, 2023); (Kurnia et al., 2024)

Based on these considerations, this study was conducted to develop and validate a research-based e-module for the Animal Development course, aiming to provide an innovative and effective solution for improving students' laboratory competencies through structured, research-integrated, and digitally accessible learning materials.

## Method

This study employed the 4D development model, initially introduced by Thiagarajan et al. (1974), which comprises four phases: Define, Design, Develop, and Disseminate. However, this research primarily focused on the Develop phase, particularly small-group trials to evaluate the e-module's effectiveness. The procedural flow of these stages, adapted from the 4D model, is illustrated in Figure 1.



**Figure 1.** Flowchart of the Instructional Material Development Process Following the 4D Model.

### Define Stage

At this stage, the learning needs for the e-module were analyzed based on students' academic requirements, course objectives, and curriculum alignment. This analysis guided the determination of the

e-module's scope and content, ensuring it effectively integrates theoretical concepts with practical laboratory applications.

### Design Stage

In this phase, an initial prototype of the e-module was developed by incorporating research-based instructional materials. The design aimed to provide structured learning content, combining conceptual frameworks with interactive research-based activities to enhance student engagement and independent learning.

*Develop Stage*

The Develop phase involved a rigorous validation and revision process to ensure the e-module’s scientific accuracy, instructional quality, and usability. This phase consisted of:

1. Expert validation:

Subject matter experts assessed the content accuracy, depth, and alignment with course learning objectives. Media specialists evaluated the interface, usability, and interactivity for an optimal digital learning experience.

2. Small-group trials:

A limited number of students tested the e-module and provided structured feedback on its effectiveness and usability.

3. Data Collection & Analysis:

Qualitative data were derived from expert recommendations, focusing on content refinement and instructional improvements.

Quantitative data were collected through validation scores and student questionnaires to measure feasibility, usability, and user satisfaction. To determine the e-module’s effectiveness in enhancing students’ laboratory skills, an N-Gain analysis was conducted by comparing pre-test and post-test scores, assessing the degree of improvement of learning. The validity of the e-module was measured using descriptive percentage analysis.

*Disseminate Stage*

After validation and testing, the e-module was implemented in the Animal Development course as a digital instructional tool. Since previous evaluations confirmed its validity and pedagogical effectiveness, no further large-scale testing was required. Instead, the e-module was directly integrated into the curriculum, expanding its accessibility within Biology Education programs. This stage aimed to broaden its adoption across educational institutions, promoting innovative and research-based digital learning methodologies in biology instruction.

**Result and Discussion**

This section presents the findings from expert evaluations and small-group trials. The analysis incorporates both qualitative and quantitative data to

assess the validity, feasibility, and effectiveness of the developed research-based e-module.

*Expert Evaluation Results*

*Material Expert Validation*

The content validation process was conducted by a subject matter expert from the Biology Education Program at PMIPA FKIP Tadulako University. The primary objective was to evaluate the accuracy, relevance, and pedagogical quality of the e-module content. A summary of the quantitative validation results is presented in Table 1.

**Table 1.** Summary of Material Expert Evaluation Results

Product	Assessment V1	Assessment V2	Average	Category
Instructional Module	96.04	90.53	93.28	Highly Valid

Additionally, the expert provided several recommendations for improvement, including:

- Adding the phrase "Research-Based" to the module’s cover page to enhance clarity and alignment with its instructional framework.
- Refining the introductory section, as the existing description was deemed too broad and lacked specificity.
- Enhancing the clarity and relevance of images and illustrations to ensure better alignment with the module's instructional content and improve student comprehension.

*Media Expert Validation*

The media and instructional design expert assessed the visual design, layout, and usability of the e-module. A summary of the evaluation results is presented in Table 2. The expert provided several recommendations for improvement, including:

- Repositioning the logo on the cover page to enhance visual balance.
- Adjusting the size of the cover image to achieve better proportionality.
- Refining text alignment and enabling automatic hyphenation to improve readability and overall presentation.
- Ensuring proper binding of the module to facilitate ease of use and durability.

Student evaluations of the e-module were conducted following a small group trial involving 10 participants. The assessment focused on the feasibility, usability, and effectiveness of the module in supporting student learning. A summary of the quantitative

evaluation results is presented in Table 3. The average feasibility percentage was calculated at 84.2%, indicating that the majority of students found the e-module highly feasible and beneficial for enhancing their understanding of animal development.

**Table 2.** Summary of Media Expert Evaluation Results for the Animal Development E-Module

Aspects Evaluated	Rating	Comments/Suggestions for Improvement
Design (Visual)	4.0	Overall design is visually appealing and aligns well with learning objectives.
Text Readability	3.8	Font selection and size should be adjusted in certain sections for better readability.
Layout Organization	4.0	Layout is well-structured, clear, and easy to navigate.
Alignment with Learning Objectives	4.5	Content is well-integrated with learning objectives, enhancing student comprehension
Interactivity and Navigation	3.7	Navigation should be refined to ensure smoother transitions between sections.
Average Rating	4.0	(Very Good)

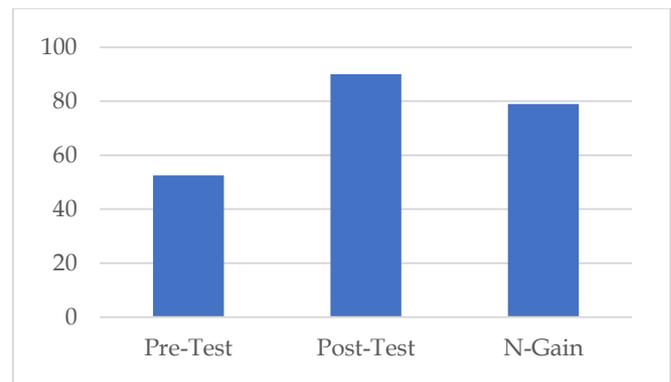
**Table 3.** Small Group Student Evaluation Data

Student	Score	Number of Descriptors	Feasibility Interval (%)	Category
Student 1	82	23	100	Highly Feasible
Student 2	86	23	100	Highly Feasible
Student 3	73	23	100	Highly Feasible
Student 4	81	23	100	Highly Feasible
Student 5	92	23	100	Highly Feasible
Student 6	81	23	100	Highly Feasible
Student 7	79	23	100	Highly Feasible
Student 8	86	23	100	Highly Feasible
Student 9	92	23	100	Highly Feasible
Student 10	90	23	100	Highly Feasible
Average Feasibility Percentage			84.2	Highly Feasible

The student evaluation results reveal that most participants provided high ratings for the e-module, with scores ranging from 73 to 92 and an average score of 84.2%. These findings indicate that the research-based e-module effectively supports students' comprehension of the subject matter and enhances their learning experience.

*N-Gain Analysis*

To evaluate the enhancement of laboratory skills after implementing the developed e-module, an N-Gain test was conducted using pre-test and post-test data from 27 students. The results, illustrated in Figure 2, indicate an average N-Gain score of 0.79 (79%), signifying a substantial improvement in students' laboratory competencies. This finding demonstrates that the research-based e-module effectively reinforces students' practical skills and conceptual understanding in the Animal Development course.



**Figure 2.** Pre-Test and Post-Test N-Gain Test Results

The results of this study indicate that the development of a research-based e-module for the course on animal development has undergone several validation and trial stages involving subject matter experts, media experts, and instructional design specialists, as well as students as end-users. Based on the findings, this e-module has been proven to be highly valid and suitable for use as teaching material. Previous research has similarly demonstrated that research-based e-modules can significantly improve learning outcomes in science education. For instance, problem-based learning (PBL)-based e-modules have been shown to enhance scientific literacy skills (Melyastiti et al., 2023) (Barokah et al., 2023) and biology learning outcomes (Pramana, 2020). This is consistent with the research conducted by (Anugra Rahma Shafira, Wiwit Alwi, 2023), who developed a research-based e-module to stimulate students' higher-order thinking on the topic of the physical and chemical properties of water. Their study demonstrated that research-based e-modules are effective in enhancing critical and analytical thinking skills among students, a finding highly relevant to the application of research-based e-modules in the animal development course.

The expert evaluation by the subject matter specialists revealed that the developed e-module holds a very high validity level, with an average score of 93.28, categorizing it as "Highly Valid." This validation primarily focused on the content and substance of the e-module's material. While some suggestions for

refinement were provided such as adjusting the wording on the cover and improving the overall introductory description the material was deemed appropriate for the learning objectives and sufficiently comprehensive. This e-module effectively presents research-based, detailed content, which supports students' understanding of animal development. These results are in line with the findings of (Nur Hikmah, 2023), which showed that an e-module developed for basic chemistry practicals could enhance students' ability to describe laboratory equipment and understand safety protocols. This suggests that the research-based e-module developed in this study also holds potential to improve students' laboratory skills within the context of animal development (Ramadansur et al., 2024) (Permadani & Sukmawati, 2021) (Liska et al., 2025). (Faridah et al., 2023).

Furthermore, these findings are consistent with research by (Fitriyati et al., 2015) (Liu et al., 2024), who demonstrated that research-based modules can effectively connect theoretical understanding with practical laboratory activities, thereby improving students' mastery of scientific concepts and processes. This supports the outcome of the present study, showing that integrating research-based content into instructional materials can strengthen both conceptual depth and laboratory competencies. In addition, (Sari, 2024) found that research-based e-modules enhance higher-order thinking skills, which aligns with the increased analytical skills observed in students who used the developed e-module in this study.

The evaluation by media and instructional design experts aimed to assess the visual aspects and layout of the e-module. The evaluation results indicated that the e-module, overall, performed well, with an average score of 93.28. However, some suggestions for design improvements were made, including the placement of the logo being too close to the bottom edge of the cover page and the need for photo resizing to ensure better proportions. Furthermore, it was recommended to use left-right alignment for the paragraphs and activate automatic hyphenation to enhance readability. These modifications would improve the overall learning experience and make the e-module visually more appealing and comfortable to use. A study by (Siregar; Harahap, 2020)(Güney, 2019) also reported that an e-module developed with good design principles achieved a very high validity score, with an average rating of 3.64 out of 4 in terms of content, language, presentation, and graphics. This underscores the importance of design elements in improving the effectiveness of learning. These media-validation results are also supported by findings from ("Instructional Modules for Constructivist Environmental Learning in Science, Technology and Society (STS) Subject," 2025);

(Lau et al., 2021) (Peng et al., 2021) who noted that learning modules designed with clear structure, readability, and visual coherence significantly improve student engagement and comprehension. Similarly, (Adhayanti & Pakadang, 2025); (Pelizzari et al., 2025) reported that well-designed e-modules contribute to improved learning outcomes and student satisfaction, reinforcing the significance of strong visual and structural design elements in digital instructional materials.

The trial conducted with students demonstrated that the e-module is highly feasible for use in teaching. All students rated it as "Highly Feasible," with an average score of 84.2%, indicating that the e-module was well-received and effective in supporting their learning processes. The highest score recorded was 92, and the lowest was 73, still within the "Highly Feasible" category. This suggests that the research-based e-module effectively delivers content clearly and comprehensively, facilitating students' understanding of the material on animal development. A study by Kimianti & Prasetyo (2019) further supports this conclusion, indicating that PBL-based e-modules are highly effective in enhancing scientific literacy and improving science learning outcomes. Therefore, the results of this study suggest that the developed e-module has a substantial positive impact on students' understanding.

These results are consistent with the findings of (Purwasih et al., 2022), who showed that e-modules designed according to students' learning needs and styles could significantly increase user satisfaction and improve learning efficiency. Likewise, (Istiqoma et al., 2023) found that electronic modules support students' independent learning and enhance motivation, particularly when the modules are structured clearly and designed to facilitate self-paced study. This further strengthens the conclusion that the developed research-based e-module is both feasible and effective for enhancing student learning.

The effectiveness of the e-module was also assessed using the N-Gain test, which measures the improvement in students' learning outcomes before and after using the e-module. The N-Gain results showed significant improvement, with an average score of 0.79 (79%), indicating that the e-module effectively enhances students' laboratory skills and understanding. This substantial increase reflects that the research-based e-module facilitates deeper comprehension and practical abilities in the topic of animal development. (Siregar; Harahap, 2020) similarly reported a high N-Gain score of 0.78 for a PBL-based e-module, demonstrating a significant improvement in student achievement from pre-test to post-test.

At the disseminate stage, following the validation and trials, the e-module was directly implemented as teaching material in the animal development course. No further trials were deemed necessary, as the trial with 10 students showed that the e-module was already suitable for use in the learning process. This reflects the effectiveness of the module, which had been tested and refined based on expert feedback. A study by (Pramana, 2020) also highlighted that a PBL-based e-module, validated by experts, is of very high quality and highly suitable for teaching. This affirms that the e-module developed in this study can be effectively integrated into the animal development curriculum. Furthermore, (Delegiro & Cajandig, 2025) emphasized that a problem-solving approach in e-modules can foster active and meaningful learning, helping students gain a deeper and more contextual understanding of concepts.

## Conclusion

This study demonstrates that the research-based e-module developed for the Animal Development course is valid, feasible, and effective in improving students' conceptual understanding and laboratory skills. The expert validation results show high material and media validity, while the student feasibility test indicates strong acceptance of the e-module as a learning tool. The N-Gain score of 0.79 further confirms a significant increase in students' laboratory competencies after using the e-module. These findings align with previous studies on research-based digital learning resources and indicate that integrating research elements, structured content, and interactive features can enhance both theoretical comprehension and practical skills. Overall, the developed e-module provides a reliable and innovative instructional resource that supports laboratory-based learning in Biology Education.

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## Author Contributions

Sutrisnawati Mardin was responsible for conceptualization, methodology, software, validation, investigation, and writing—original draft preparation. Achmad Ramadhan contributed to methodology, data analysis, and project administration. Dwi Setyorini was involved in data analysis and project administration."

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## Conflicts of Interest

The authors confirm that there are no conflicts of interest to declare.

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