RESEARCH ARTICLE

Development of project-based modules to improve learning outcomes, critical thinking and problem-solving skills

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Abstract: In the 21st century, students must have high knowledge and thinking skills which can be achieved through learning activities. This study aimed to develop a Project-Based Module (PBM) on the topic of determination, differentiation, and organogenesis that is feasible and effective in improving students' cognitive learning outcomes (CLO), critical thinking (CTS), and problem-solving skills (PSS). The module used the 4D developmental model consisting of define, design, develop, and disseminate, which then underwent validation and student response for its feasibility in terms of material adequacy, learning process, and layout design. The module was also tested for its effectiveness in improving CLO, CTS, and PSS. The result showed that the module was tested valid and categorized as "very worthy" as 91.6 % by material expert, learning expert, and layout expert. Students gave excellent responses to the module as 87.77 % with a very worthy category. Moreover, the independent t-test results show a significant difference in CLO (P = 0.00), CTS (P = 0.00), and PSS (P= 0.00) between the control and experimental posttest results. Thus, the project-based module improves student's CLO, CTS, and PSS in the animal development course. Further research needs to be extended for wider-scale trials to obtain maximum results.

Keywords: animal development; cognitive ability; learning resource; PjBL

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Article history:
Received: 30 March 2024
Revised: 2 July 2024
Accepted: 8 July 2024
Published: 23 July 2024

10.22219/jpbi.v10i2.32958

p-ISSN: 2442-3750
e-ISSN: 2537-6204

How to cite:
Tampubolon, M. L. V. & Sipahutar, H. (2024). Development of project-based modules to improve learning outcomes, critical thinking and problem-solving skills. *JPBI (Jurnal Pendidikan Biologi Indonesia), 10*(2), 531-541. https://doi.org/10.22219/jpbi.v10i2.32958

Introduction

In the face of future working life, students must have various appropriate skills in the 21st century, known as the 4Cs skill, including critical thinking and problem-solving skills (González-Pérez & Ramírez-Montoya, 2022). Based on the PISA (the program for international student assessment) 2018 database, students in Indonesia scored lower than the average score in the reading, mathematics, and science categories (OECD, 2019).

Critical thinking skills play a significant role in student performance in PISA assessments (Yanto et al., 2023). Some findings showed that students' critical thinking skills still need to improve in the learning process. A study showed that the skills of biology education students were poor (Rahmatika et al., 2020). Other research results showed that biology education students' skills were in the medium category (Iwan et al., 2023). These findings showed that the skills of students were still critical. It was due to (1) a lack of analyzing a problem, (2) difficulty doing high-level questions (C4-C6), and (3) It is difficulty in connecting concepts and problems and expressing opinions (Saputri et al., 2019). Critical thinking and problem-solving are closely related.

Problem-solving is a competence or skill in reasoning and cognitive processing to understand and solve problem situations (Helmold, 2023; Mayer, 2023; Pizlo, 2022). Unfortunately, students' problem-solving skills are still categorized as low and need to be improved as in the pre-research results on Biology Education students showed a total score of students' problem-solving skills was categorized as "bad" (Harahap et al., 2018). It happens due to a lack of student role during the learning process (Permata et al., 2022) and a lack of activity empowering students' thinking skills (Kawuwung & Mamahit, 2023).

Lack of critical thinking and problem-solving skills showed the student's cognitive ability of high order thinking skills (HOTS) were low. The result of a preliminary study on biology education students showed that the cognitive learning outcomes were categorized as poor (Rahmatika et al., 2020). A similar preliminary study showed the student cognitive learning outcome is in the low category (Sari et al., 2020). It happens due to the complexity of the learning material, so students need help understanding (Rahmatika et al., 2020).

Learning resources are essential in optimizing learning by facilitating students to learn independently (Njoroge, 2019). Modules are ones that can be used because it systematically designed based on specific learning models that have learning objectives, materials, and worksheets/evaluation sheets (Priantini & Widiastuti, 2021; Putra et al., 2018). The PJBL model is suitable to be implemented into modules. The module is designed systematically by integrating the syntax of project-based learning and providing project activity as a task that students must do. Students can strengthen their knowledge by conducting investigations collaboratively through project activities (Pakpahan et al., 2021; Purba et al., 2019).

The higher a student's cognitive ability, the higher the learning outcomes to show that the learning process is successful. Students need to have high-level cognitive processes (HOTS) such as analyzing (C4), evaluating (C5), and creating (C6) (Ramdiah et al., 2019). Critical thinking skills are high-order thinking skills that can make students think reflectively and respond to the learning topics conveyed by the teacher by providing arguments accompanied by logical reasons. There are five indicators of critical thinking skills, according to Facione, including: 1) interpretation, 2) analysis, 3) evaluation, 4) inference, and 5) explanation (Seventika et al., 2018). Another higher-order thinking ability is problem-solving; students find the best answer to overcome a problem by integrating their knowledge. There are four indicators of problem-solving skills, according to Polya, namely 1) understanding the problem, 2) designing a suitable strategy, 3) solving the problem, and 4) examining the problem (Harahap et al., 2018).

Implementing this learning model into the module has several good impacts and is effective for the lecture process (Hsin & Wu, 2023) and at the same time can help improve student's thinking skills, especially critical thinking skills (Baidowi et al., 2023) and problem-solving (Chiang & Lee, 2016). This at the same time can increase student's learning outcomes (Saleh & Triyono, 2022). Experiencing this module makes students get higher achievement in the learning process. The development of modules that integrate project-based learning models has been carried out by several researchers, but none have focused on cell determination and differentiation and also endoderm organogenesis: digestive tract and glands in the Animal Development course. Moreover, there has been no research that specifically examines the impact of the development of the module on cognitive learning outcomes, critical thinking skills, and problem-solving skills at once.

The formulation of the problem that is the focus of this research is: 1) how is the feasibility of the module based on validators and student responses? 2) how the module affects cognitive learning outcomes (CLO)? 3) how the module affects critical thinking skills (CTS)? and 4) how the module affects critical thinking skills (PSS)? Then, this research aims to 1) develop project-based modules (PBM) that are feasible in terms of construction and substance, then determine the effect of PBM on 2) CLO, 3) CTS, and 4) PSS.

Method

Module Development

This study was conducted from March 2023 until November 2023 at the Department of Biology, Faculty of Mathematics and Natural Science, Universitas Negeri Medan. The samples were 50 students of the Biology Education Study Program (BESP) 2022 from classes BESP A (25 students) as the experimental class and BESP C (25 students) as the control class, which is taking the Animal Development course in the third semester. The samples were taken purposively, and both classes must have equal initial ability. The research data were collected using 1) the non-test containing the questionnaire for validation that was addressed to material, learning, and layout experts, and for student response trials that were only carried out in the experimental class, which is the small groups (9 students) and limited groups (16 people); and 2) test containing 20 essay questions for determining the effect of PBM on the CLO, CTS, and PSS.

This study used Thiagarajan's 4-D development model, which consists of four stages (Thiagarajan et al., 1974): (1) Define stage identified problems and learning objectives; (2) Design stage obtained the initial module, instrument of expert validation for material, learning, and layout experts, and instrument of trial development in student response form for small and limited groups from class of BESP A; (3) Development stage produce the product development, the project-based module, after expert validation and student's response trial which has been reviewed based on the feasibility assessment standards of the National Education Standards Agency (NESA) then revised and tested in terms of material adequacy, learning process, layout design; (4) Disseminate stage obtained the promotion and distribution of product developed.

Module Testing

The product implementation is conducted to measure the effect of PBM on the CLO, CTS, and PSS through pretest-posttest in the learning process, which lasted for three meetings (Figure 1) with two different treatments carried out, including (1) BESP C 2022 (the control class) uses conventional learning methods, only utilizing textbooks; (2) BESP A 2022 (the experimental class) uses a project-based learning model (PjBL) with the project-based module. At the first meeting in the experimental class, the learning process began with conducting a pretest by doing 20 essay questions, then continued with the explanation of the first project task which is "Paper Determination and Cell Differentiation," that will be carried out by students independently at home (individually). The project task is explained per stage according to the PjBL syntax, namely 1) problem identification, 2) project planning design, 3) preparation of project schedules, 4) project monitoring, 5) collection of project results, and 6) project evaluation. Syntax 1 to 3 is done briefly in this first meeting, but Syntax 4 is done online, where students are monitored and asked about their progress through the WhatsApp application. Then, they are welcome to ask questions and convey obstacles and project progress. While syntax 5 and 6 are performed in separate meetings. After the explanation of project activities, learning was continued by displaying material in the module by discussing (question-and-answer) and connecting the material with the project task to be carried out.

Then, at the second meeting, researchers began the learning process by explaining the next project task in the form of "Intestinal Rotation Props (Midgut)." The project activities are explained per stage according to the PjBL syntax as in the first meeting and the project will be carried out by students independently at home (individually). After the explanation of project activities, learning was continued by displaying material in the module by discussing (question-and-answer) and connecting the material with the project task to be carried out. Then, at the third meeting, further project activities were carried out, namely the fifth and sixth syntax of PjBL, and the collection, presentations, and evaluations of project results were carried out. After that, a posttest is carried out with the same 20 essay questions as in the pretest, which aims to see the ability and final knowledge and measure whether there is an improvement after this learning process is carried out.

At the first meeting in the control class, the pretest was carried out at the beginning of the learning and continued by explaining the material while discussing (question-and-answer) related to the material of determination and cell differentiation displayed on PowerPoint. The teaching resources used by students and researchers are textbooks provided by the lecture. At the second meeting, the researcher continued to explain the following material while discussing (question-and-answer). The learning process begins with questions that refer to the sub-material to be discussed, and then the basic concepts of the material are explained. Then, at the third meeting, a posttest is carried out, which aims to see the ability or final knowledge and measure whether there is an improvement after this learning process is carried out. The number and content of questions are the same for both the experimental class and the control class. The difference is only the use of learning models and learning resources.

Statistical Analysis

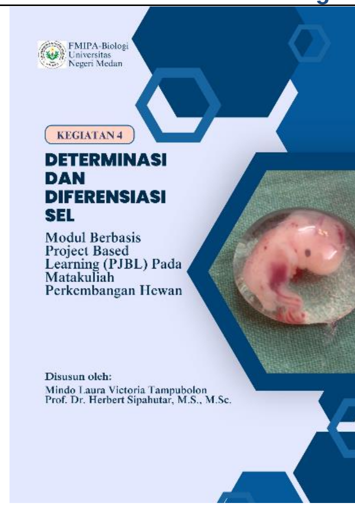
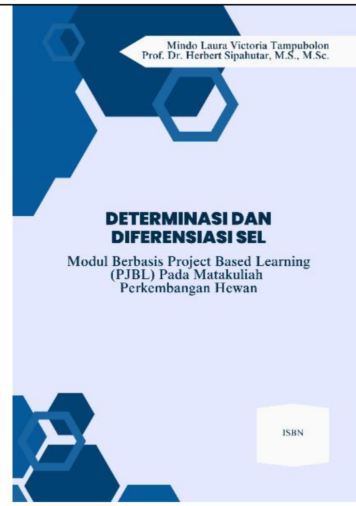
The pretest-posttest results are calculated to measure differences and improvements in CLO, CTS, and PSS, between the control and experimental classes and get to know which one is better after implementing the treatments in the learning process. The data were analyzed descriptively-quantitatively through independent t-test using software SPSS 23.0. The independent sample t-test aims to determine if there is a difference between the control and experimental classes' posttest results of cognitive learning outcomes, critical thinking, and problem-solving skills.

Results and Discussion

The project-based module was designed according to course learning achievement and objectives using the Canva application, which applies project-based learning model and consists of two topics (chapters), namely 1) Cell determination and differentiation, and 2) Endoderm derivatives: digestive tracts and glands. The components contained in the module include 1) content table, 2) introduction, 3) instructions for using modules, 4) learning outcomes in courses, 5) learning objectives, 6) concept map, 7) project activity sheet, 8) material content, 9) exercise, 10) summary, 11) evaluation, 12) case study, 13) glossary, and 14) bibliography. The project-based module has been revised and tested its feasibility based on validation from the material expert (a lecturer in Universitas Sumatera Utara), learning and layout experts (two lecturers in Universitas Negeri Medan), and student responses from the experiment class. Some of the parts contained in the final product can be seen in Table 1. Each chapter in the PBM begins by providing initial information (perception), such as "Did you know?" and then continues with a deeper discussion of the material. Then, after the discussion of the material is complete, the measurement of student understanding after studying the material through exercise, evaluation, and case study. To help students understand the material, the essence of the material content is explained briefly in the summary.

This also helps students hone their speed-reading skills (scanning).

Table 1. The parts of project-based module (PBM)

<table>
<tr><th>Parts of Module</th><th colspan="2">Figures</th></tr>
<tr><td>Front and Back Cover</td><td>
</td><td>
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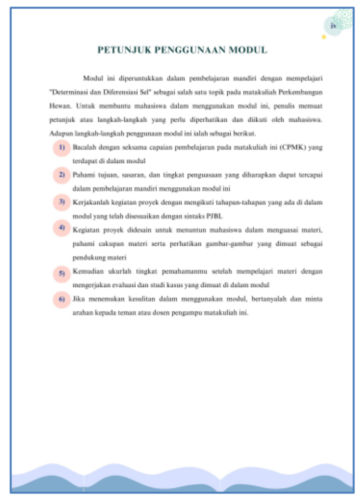
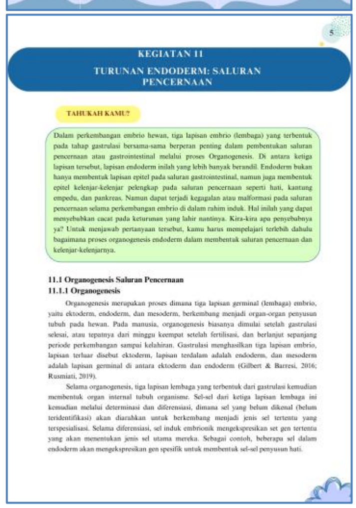
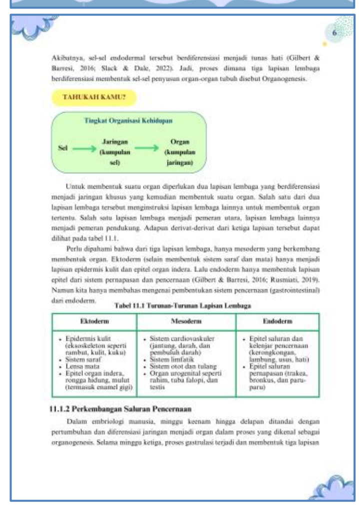
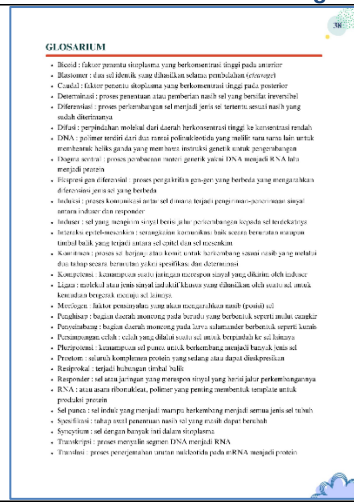
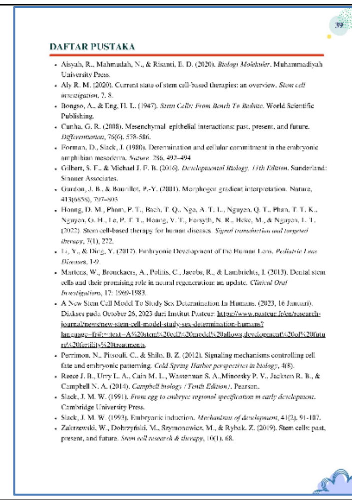
<tr><td>The opening section of the module contains 1) content table, 2) introduction, 3) instructions for using module, 4) learning outcomes in courses (CPMK), and 5) learning objectives.</td><td></td><td></td></tr>
<tr><td>Material Content</td><td></td><td></td></tr>
</table>

Parts of Module	Figures
Closing section is the final part of the module consisting of glossary and bibliography	 GLOSARIUM  DAFTAR PUSTAKA

In the PBM, there is a project activity sheet that integrates six syntaxes from PjBL. In the first syntax, students are invited to identify problems by answering questions based on information in the reading. Then, they will face questions that are the focus of the project task and are given directions to do a project that is the answer to these questions. There are two projects, namely making papers for the first material and making props for the second material. In the second syntax, students are guided to compile project designs, starting from collecting information and determining project needs such as tools and materials, designs, procedures, etc., and they are asked to provide temporary answers about their project designs. In the third syntax, students are asked to compile a project schedule, namely a logbook containing details of activities and the time of implementation. In the four syntaxes, students are asked to discuss progress and obstacles with researchers online. This aims to monitor the implementation of the project. In the fifth syntax and sixth syntax, students collect and present project results according to a predetermined schedule and evaluate the project results.
This developed product is reviewed by material expert, learning design expert, and layout design expert. The validity test result by all in Table 2 showed the PBM was tested valid and categorized as "very worthy" as 91.6 %.

Table 2. The result of validity test

Aspect	Validity Value (%)	Criteria
Material Content	86.5	Very Worthy
Learning	95.8	Very Worthy
Layout Design	92.5	Very Worthy
Average	91.6	Very Worthy

Then, the PBM is reviewed by students who used the module, namely the BESP A 2022 class (the experiment class). The student response was carried out on 25 students who were divided into two groups: a small group of 9 people and a limited group of 16 people. The result of the student's response trial in Table 3 showed that the PBM was worth using in the learning process and categorized as "very worthy" by 87.77 %.

Table 3. The result of student response

Student Response	Response Value (%)	Criteria
Small Group	87.12	Very Worthy
Limited Group	88.43	Very Worthy
Average Score	87.77	Very Worthy

After validation and response trials, the developed module was implemented in the learning process. The pretest-posttest was carried out to determine the effectiveness of the project-based module. The results were calculated to measure the effectiveness of the product in improving students' cognitive learning outcomes, critical thinking, and problem-solving skills through independent t-test. Before conducting the independent t-tests, all data were normally distributed (normality test; P. > 0.05) and declared homogeneous (homogeneity test; P. > 0.05). The independent t-test aims to determine if there is a difference between the control and experiment classes' posttest results as seen in Table 4, meanwhile both classes' posttest results can be seen in Figure 1, Figure 2, and Figure 3 so that it can be found which class gets the greater improvement in the learning process.

Table 4. The result of independent t-test

Variables	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Cognitive Learning Outcomes	2.36	.131	10.629	48	.000
Critical Thinking Skill	1.72	.195	10.769	48	.000
Problem-Solving Skill	2.24	.141	10.706	48	.000

Cognitive Learning Outcomes

In the cognitive learning outcomes, the independent t-test result in Table 4 show sig. value is lower than 0.05, which means Ha is accepted (P=0.00). It shows there is a difference in posttest scores of cognitive learning outcomes between the control class and the experiment class. Moreover, the average posttest result in Figure 1 showed that the experimental class that used the project-based module experienced a higher increase than the control class that used the textbook. The average posttest score of cognitive learning outcomes in the experimental and control class are 81.10 and 52.68, respectively.

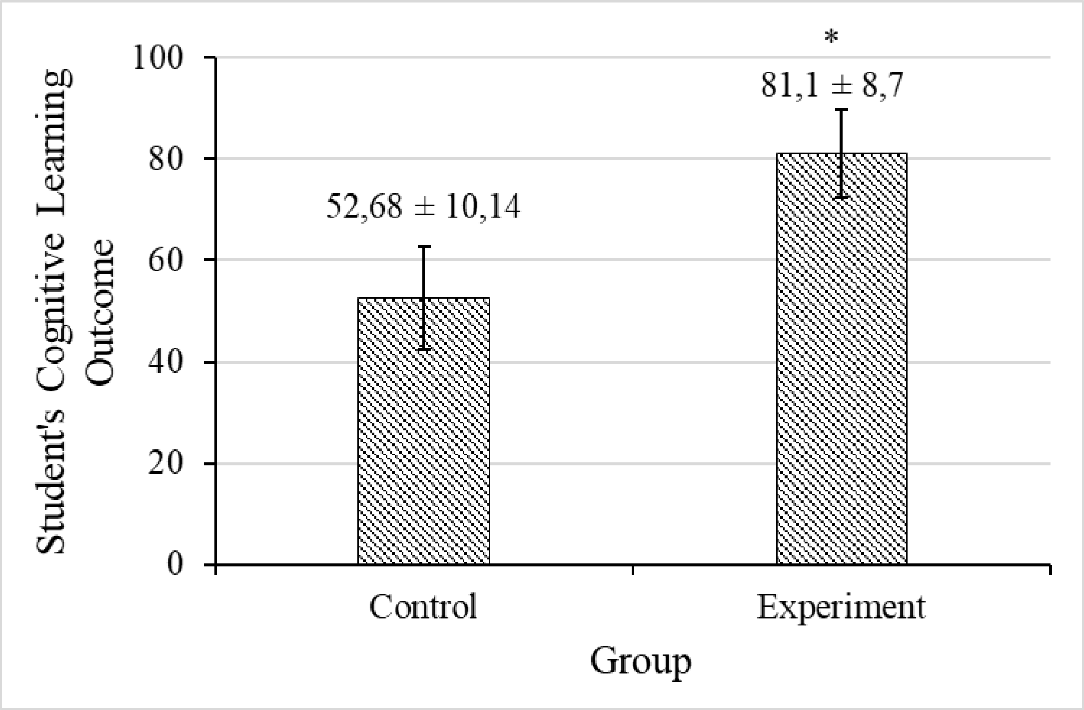


Figure 1. The PBM improve students' cognitive learning outcomes. The * indicates that the experimental class is significantly different from the control class (t-test, P=0.00). The experimental class uses project-based modules while the control class only uses textbooks

Critical Thinking Skills

Meanwhile, the independent t-test result of the critical thinking skills in Table 4 show sig. value is lower than 0.05, which means Ha is accepted (P=0.00). It shows there is a difference in posttest scores of critical thinking skills between the control class and the experiment class. Moreover, the average posttest result in Figure 2 showed that the experimental class that used the project-based module experienced a higher increase than the control class that used the textbook. The average posttest score of critical thinking skills in the experimental and control class are 80.85 and 52.10, respectively.

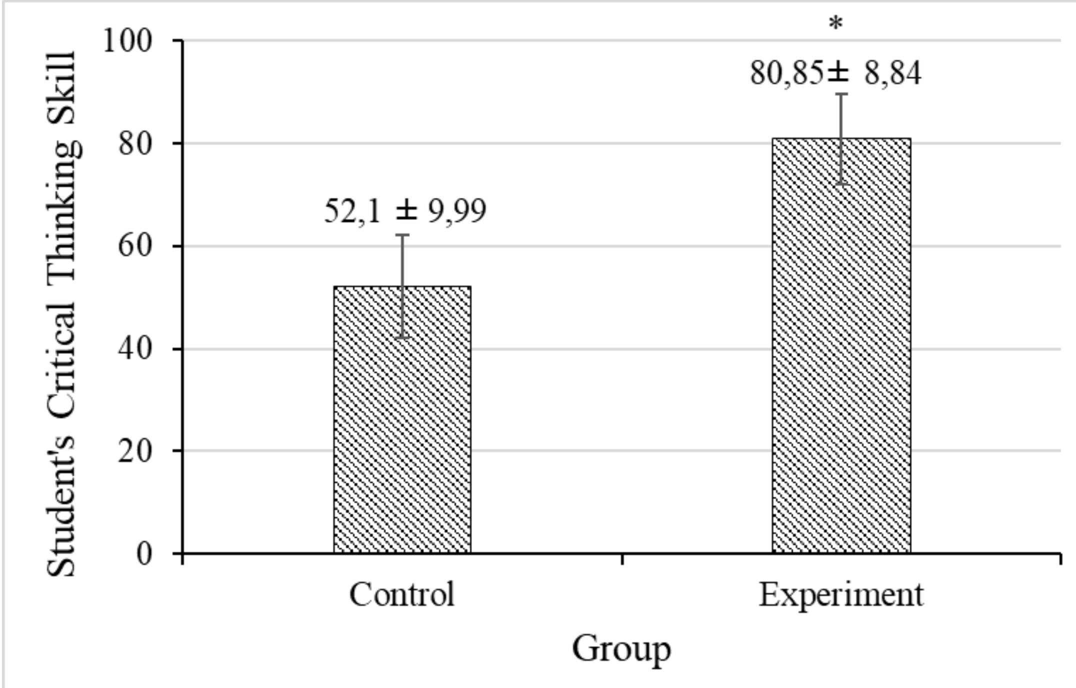


Figure 2. Project-based module improve critical thinking skills. The * indicates that the experimental class is significantly different from the control class (t-test, P=0.00). The experimental class uses project-based modules while the control class only uses textbooks

Problem-Solving Skills

In the problem-solving skills, the independent t-test result in Table 4 show sig. value is lower than 0.05, which means Ha is accepted (P=0.00). It shows there is a difference in posttest scores of problem-solving skills between the control class and the experiment class. Moreover, the average posttest result in Figure 3 showed that the experimental class that used the project-based module experienced a higher increase than the control class that used the textbook. The average posttest score of problem-solving skills in the experimental and control class are 80.70 and 51.85, respectively.

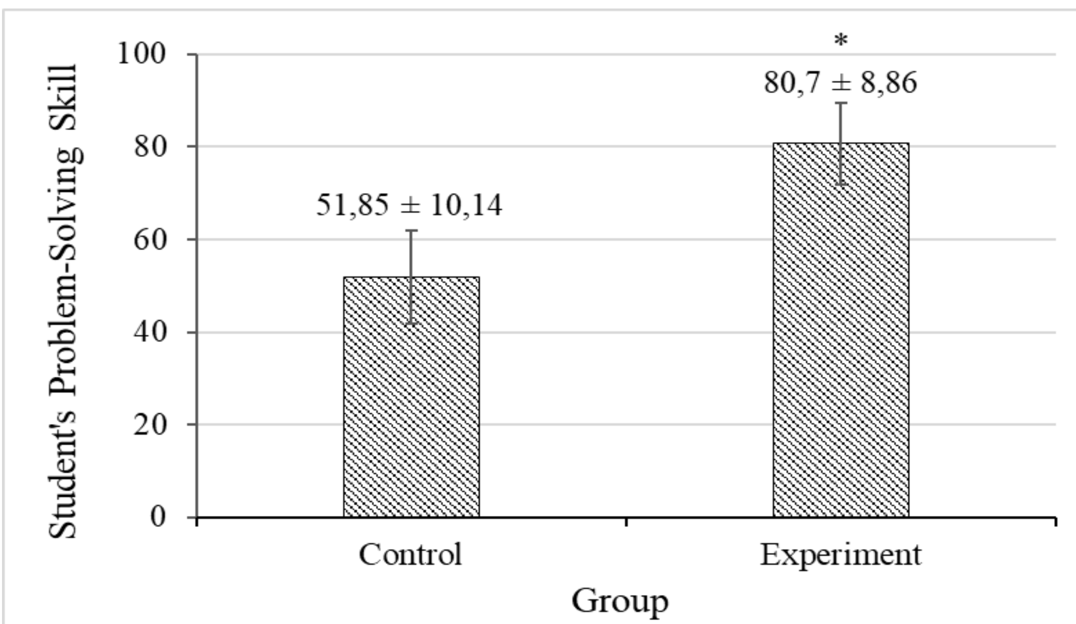


Figure 3. Project-based module improve problem-solving skills. The * indicates that the experimental class is significantly different from the control class (t-test, P=0.00). The experimental class uses project-based modules while the control class only uses textbooks

Based on all result, the experiment class get higher increased than the control class. It can be concluded that using a PBM effectively improves students' cognitive learning outcomes, critical thinking, and problem-solving skills.

Producing proper learning resources needs a series of stages that are carried out. Existing problems are identified, which then becomes a reference to find suitable solutions, which is the development of a project-based module that can be used in the Animal Development course. The project-based module consists of two learning topics, which are (1) cell determination and differentiation, and (2) endoderm derivatives: digestive tracts and glands. The preparation of the module draft pays attention not only to the suitability of the material content with learning achievement but also to the attractiveness of the module display.

The PBM have been revised according to suggestions from validators and students to improve their quality regarding material content, learning aspects, and appearance or layout. Based on the results of feasibility tests, both validation and response tests from this research showed that the PBM is good enough and feasible to be used as an additional learning media supporting the learning process. The material content in the module is presented well enough to make it easier for students to learn, understand, and improve their knowledge and thinking skills using the PBM. The material content in the module also entirely follows the learning achievement in the animal development course as contained in the semester learning plan. The module's appearance is varied and causes interest to readers by displaying consistent patterns, sharp and dynamic illustrations, contrasting colors, and easy-to-read writing that motivates readers to learn the contents of this module.

The results show that using PBM is more effective in increasing the understanding and the student's cognitive learning outcomes in studying cell determination and differentiation and endoderm derivatives: digestive tract and glands in animal development course. The implementation of the PBM has effectively increased student activities during the lecture process, showing increased learning outcomes (Saleh & Triyono, 2022). There was a difference in learning outcomes between the experimental class and the control class, where students who used the PBM (experimental class) obtained higher learning outcomes than students who did not use the project-based module. Project activity aims to increase students' understanding of the material by providing problems related to the material and being asked to solve these problems (Suwarno et al., 2020). During the project, students gain more understanding by searching, collecting, analyzing, and deciding the best solution for the problem.

Using this module is also more effective in improving students' critical thinking skills in studying animal development courses on the topics of cell determination and differentiation and endoderm derivatives: digestive tract and glands. In contrast, the critical thinking skill of the experimental class, which used the project-based module, was higher than that of the control class (Harahap et al., 2022). Thus, developing project-based module that are carried out effectively can foster students' critical thinking skills. This skill is essential and required to solve problems. Critical thinking skills direct individuals to solve problems logically and appropriately by evaluating evidence, assumptions, logic, and language that underlie other people's thoughts to make decisions based on what must be believed and done with a good knowledge base (Fitriani et al., 2020).

Using PBM can also more effectively increase students' problem-solving skills. The project activities in the module containing problem-solving indicators have proven to foster students' problem-solving skills effectively. The problems in the project-based module can attract students to solve the problems given (Chiang & Lee, 2016). The problem-solving process involves looking for specific answers to the problem situation at hand (Rahman, 2019). Applying the project-based learning model in the module stimulated students to be active in solving problems given through project activity. Students can habitually solve problems through exercises, evaluations, and case studies by finding the best answers to overcome problems by integrating their knowledge. Someone with good problem-solving skills can produce practical, creative, and innovative solutions and show independence and initiative in identifying and solving problems (Purwaningsih et al., 2020).

Integrating the project-based learning model shows better results than the conventional learning model. It is due to the student's role during the learning process, which is student-centered. It places teachers as motivators and facilitators who can direct and guide students to solve a problem that involves working on a project (Ánh, 2023). It can stimulate students' creativity in planning, communicating strategies, solving problems, and making decisions on the problem (Chen & Chan, 2021). Meanwhile the conventional approach make student less motivated to learn and think critically which lead decreasing the quality of learning process (Wale & Bishaw, 2020). Collaborating in doing projects can increase their interest and make the learning process more successful (Guo et al., 2020).

The syntax in the project-based learning model encourages students to think critically and be more able to solve problems. Students are given a problem where they have to design a suitable answer for the problem. It turned out they experienced critical thinking skills by evaluating their plans in making the product as the output to solve problems contextually in this learning model (Mutakinati et al., 2018). During this activity, there must be any differences in the analysis done by students when determining

the design, tools, material, and also procedure. It makes students more challenged to solve real problems. The depth of students thinking determines how the project shows their ability to think critically. Critical thinking skill influences problem-solving skills because someone who can think critically can process the information at hand and find the best solution to the problem (Fitarahmawati & Suhartini, 2021). Students gain knowledge and thinking skills through the project activity.
Thus, developing PBM is feasible and effective in encouraging students' cognitive learning outcomes and helping them think critically in solving problems on cell determination and differentiation, and endoderm derivatives: the digestive tract and its glands. It showed that the PBM can be used as an appropriate learning media in Animal Development course.

Conclusion

The project-based module (PBM) is designed according to course learning achievement which consists of two topics (chapters), namely 1) Cell determination and differentiation, and 2) Endoderm derivatives: digestive tracts and glands. Both validation and response tests from this research showed that the project-based module is good enough and feasible to be used as an additional learning media. Compared to the textbook, this module was tested more effectively in improving students' cognitive learning outcomes and students' thinking skills such as critical thinking and problem-solving. There is a significant difference between the control and experiment posttest results on CLO, CT, and PS. The experiment class that used this module got a higher posttest score than the control class. Based on the result of this study, it can be concluded that the PJBL-based module can be used as an appropriate and effective learning media in Animal Development course which can help students encourage their learning outcomes, critical thinking skills, and problem-solving skills. It can also help practitioners to provide better teaching material and at the same time gain their knowledge. Further research needs to be extended for wider-scale trials and complemented by the assessment of the learning process from the completion of the module worksheet to obtain maximum results on how the module impacts the learning process.

Acknowledgment

Respectful appreciation and gratitude were conveyed to experts from Universitas Negeri Medan and Universitas Sumatera Utara, students from the Department of Biology, Faculty of Mathematics and Natural Sciences Universitas Negeri Medan, and all parties involved in this research as much as possible.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

M. L. V. Tampubolon: methodology, analysis, and writing original draft preparation; and **H. Sipahutar:** review and editing.

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