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Analysis of Learning Outcomes, Process Skills and Perceptions of Biology Education Students at PGRI Silampari University in the Animal Development Course Based on Project Based Learning

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Abstract: The shift in the learning paradigm emphasizes the importance of active student involvement through project-based learning. This research was conducted at PGRI Silampari University with 32 students as research subjects. The problem of this research is how the data on process skills, learning outcomes and perceptions of Biology Education students at PGRI Silampari University after project-based learning. The purpose of this study was to determine the data on process skills, learning outcomes, and student perceptions after learning with a project-based learning model. This research method is a descriptive method with a quantitative approach. The research instruments are observation sheets, tests, and questionnaires. The results of this study are that students achieve learning outcomes in the high category after the implementation of Project-based learning, data on students' science process skills, namely observation indicators obtained 75.25%, interpretation 67%, classification 75%, experimental planning 75%, use of tools 81.25%, predicting 77%, application of concepts 80%, communicating 100%. The average score obtained was 78.75% with a high category. Student learning outcomes in the Animal Development Course show that in general the final achievement is in the good category. Based on the final grades of 32 students, the highest score was 95.4, while the lowest was 65, with an overall average score of 78.85, which is categorized as Good. The conclusion of this study is that most students were able to achieve learning outcomes well, acquire meaningful new knowledge through problem-solving, and think critically.

Keywords: Learning outcomes; Process skills; Project-based learning

Introduction

In the current increasingly developing digital era, it has caused significant transformations, especially regarding input and output in the learning process (Haleem et al., 2022; Sudirman & Yuhelman, 2025). One category of approaches that integrates argumentation in all classroom activities to support conceptual understanding in science (Fitria et al., 2025; Gogh & Kovari, 2025; Weiss et al., 2022).

In the 1980s, referring to constructivist learning theory, science education in the US emphasized an inquiry-based approach as a more authentic model of the scientific process, in line with the goals of scientific literacy that highlight critical thinking skills in the application of scientific methods (DeFeo et al., 2025). Science in Biology subjects is developing along with technology towards the Industrial Revolution Era 4.0. Education 4.0 integrates technology in learning. The goal of learning is to improve student skills, including critical

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thinking, communication, collaboration, creativity, innovation, and problem-solving skills. Problem-solving skills are important for students because they involve the use of knowledge, skills, and experience to solve problems (Zakia, 2025).

Biology courses in most colleges and universities have two mandatory components: lecture-related knowledge and laboratory work (DeFeo et al., 2025). This knowledge-based approach emphasizes that science instruction should support all learners, not in memorizing facts but in applying their knowledge in new and challenging situations (He et al., 2024). Scientists rely on principle-oriented, logically structured knowledge to solve problems and explain phenomena in various contexts (Dawson et al., 2024; Nahum et al., 2010). Therefore, the logical structure of scientific knowledge, which can be illustrated in a science concept map, is crucial for student learning. Scientists also conduct scientific inquiries involving observation, controlling variables, and making inferences (Jin et al., 2019).

The current learning paradigm emphasizes the need for active student involvement through learning that emphasizes hands-on experience, one of which is project-based learning. Scientific understanding in a project-based learning environment serves as a context for developing cognitive flexibility through social constructivism and meaningful problem-solving (Adah Miller et al., 2025). Project-based learning emphasizes an educational approach that aims to teach students by engaging them in finding solutions to problems through investigation (Firneno et al., 2023). Learning activities are encouraged to carry out projects that students carry out to answer questions or problems that they choose themselves or are posed by the lecturer. The result of this activity is usually a product or artifact that addresses the project's objectives. Typically, projects are complex tasks that involve students in design, problem-solving, decision-making, and resource management in a social context, that is, working together with peers to achieve a common goal.

An interesting characteristic of project-based learning is that the learning process and the final outcome cannot be fully determined in advance. This requires students and lecturers to continuously monitor, reflect, assess, and update their practices. They characterize project-based learning with the following principles: Engaging learning experiences that engage students in complex, real-world projects, through which they develop and apply skills and knowledge; Learning that requires students to draw from multiple sources of information and disciplines to solve problems; Learning where the curriculum outcomes can be predetermined, but the results of the student learning process are not predetermined or fully predictable experiences, through which students learn to manage and allocate resources such as time and materials (Chounta et al., 2017).

In the Biology Education Study Program at Universitas PGRI Silampari, the Animal Development course is one of the relevant courses using this model because it requires students to master conceptual material while applying science process skills in real life. Although Project Based Learning has been widely used in various learning contexts at Universitas PGRI Silampari, data regarding learning outcomes, process skills, and student perceptions in the Animal Development course are not yet known. Therefore, this research is important to answer the application of Project Based Learning can increase student activeness and develop science process skills periodically. In the context of Biology Education, students reported that Project Based Learning helped them develop critical and creative thinking skills (Nurulwati et al., 2021). In practical courses like Animal Development, project-based learning is considered effective in connecting theoretical concepts with students' empirical experiences (Kibet et al., 2024). However, there are still reports that some students are not yet accustomed to managing projects independently, resulting in suboptimal learning outcomes.

Method

Time and Location of the Research

This research was conducted from February to June 2025, during the even semester of the 2024/2025 academic year, in the Animal Development course. This research was conducted in the Biology Education Study Program, Faculty of Science and Technology, Universitas PGRI Silampari.

Types of Research

This research uses a qualitative descriptive approach with a case study design. This qualitative design was chosen to explore in-depth educational phenomena related to the implementation of Project Based Learning (Project based learning) in the Animal Development course. Through this design, researchers can gain a comprehensive understanding of students' experiences, learning processes, and perceptions. This approach was chosen to explore in-depth the educational phenomenon related to the implementation of Project-Based Learning in the Animal Development course in the Biology Education Study Program. This design allows researchers to comprehensively understand students' experiences in the learning process and their perceptions of the model's effectiveness.

Research Methods

The case study method was applied to focus on a single case the implementation of Project based learning in the Animal Development course. This method enabled the researcher to collect detailed and contextual data from multiple sources (observations, tests, and questionnaires).

Population and Sample

The population consisted of all Biology Education students who had taken the Animal Development course at PGRI Silampari University. The sample was selected purposively, involving 32 students who actively participated in Project based learning activities and were willing to provide reflective and detailed responses. The sample represented varied backgrounds and levels of achievement to capture a diverse range of experiences.

Research Stages

The research was carried out in several systematic stages as follows: 1) Preparation Stage, determining the research focus and objectives. Designing research instruments (observation sheet, test, questionnaire). Conducting instrument validation and trial. Coordinating with lecturers and students involved in the Animal Development course; 2) Implementation Stage, Introducing students to the concept and procedures of project based Learning. Organizing project based learning activities where students designed small-scale research related to animal development; 3) Data Collection Stage, observation data: collected throughout Project based learning implementation using process skill rubrics. Learning outcomes: collected from students' project reports and final exam results. Perception data: collected using questionnaires distributed after the learning activities concluded; 4) Data dnalysis and interpretation stage, quantitative scoring of process skills, learning outcomes, and perceptions. qualitative interpretation of students' reflections and open-ended questionnaire responses.

Data Analysis

Data collection began with coordination and information provided to participants regarding the research objectives. Students developed research projects related to the animal development course. Student learning outcomes were derived from final exam data, and perceptions regarding project based learning were collected after the lectures concluded. The following is the formula for scoring process skills, learning outcomes and analysis of perception data on project-based learning.

$$Pa = ax\ 100\%/N \quad (1)$$

Information: Pa = Percentage of student learning activities; a = Total score of the student's skills assessment components achieved; N = Maximum score from the student activity assessment component.

Table 1. Process Skills Criteria

Percentage	Category
80% - 100%	Very good
70% - 80%	Good
60 % -70%	Fair
50% - 60%	Weak
0% - 50%	Very weak

The formula for student learning outcome scores is:

$$Pa = n\ x\ 100\%/N \quad (2)$$

Information: P = percentage of improvement in learning outcomes; n = number of students increases; N = total number of students.

Table 2. Learning Outcomes Criteria

Score Range	Category
80-100	Very good
70 – 80	Good
60 – 70	Fair
50-60	Weak
0 – 50	Very weak

Result and Discussion

Student Process Skills Results

The results of the study indicate that the implementation of Project-Based Learning in the Animal Development course has a positive impact on three main aspects: learning outcomes, process skills, and student perceptions. Project based learning has been widely used in science education as a promising teaching approach to enhance learning in its cognitive, social, and emotional aspects. Project-based learning promotes in-depth collaborative multidisciplinary learning, engages students in authentic practice, and "builds an iterative culture in which students are constantly prototyping, reflecting, redesigning, revising, and evaluating" (Tsybulsky et al., 2021). In higher education, students need to be prepared for their future professions, and their professional competencies must encompass a wide range of complex skills (Holmes et al., 2021; Yi et al., 2024). The importance of 21st-century skills extends beyond secondary education and is also frequently discussed throughout higher education. Critical thinking, problem-solving, communication, and collaboration appear to be the most relevant skills that students must master throughout their education, alongside domain-specific knowledge and skills to be

able to make professional decisions and implement solutions (Finefter-Rosenbluh et al., 2023; Parlindungan et al., 2023)

From the quantitative data, most students achieved high grades. Meanwhile, from the qualitative data, it was found that students felt more motivated and actively involved in project activities. The results of the qualitative analysis produced three main themes: (1) Improved learning outcomes through direct experience, (2) Strengthening science process skills during project implementation, and (3) Positive student perceptions of the implementation of Project-Based Learning (Project based learning). Each theme is closely related to the research objective, which is to determine the impact of project-based learning comprehensively. Students stated that the project process made it easier for them to understand the concept of animal development. One student stated, "With this project, I understand better because I directly apply the material in real activities." Observations also showed that students actively collected data, discussed, and compiled reports collaboratively. The lecturer stated that "The implementation of Project-Based Learning (Project based learning) can increase students' independence and process skills." These findings are in line with research by Sutaryani et al. (2024) and Rehman et al. (2024), that Project based learning improves science process skills and student activeness. The findings also support Abas et al. (2024) that project-based learning can optimize conceptual understanding in biology courses. This shows that Project based learning not only improves academic achievement, but also helps students develop critical thinking skills.

There is a strong relationship between improved learning outcomes and process skills. Improved process skills during project work also broaden students' conceptual understanding, resulting in better learning outcomes. Students' positive perceptions also act as a motivating factor, strengthening their engagement during project implementation. Several external factors supporting the success of project-based learning include the availability of laboratory facilities and support from lecturers in facilitating the project. Furthermore, a collaborative work culture among students positively impacts project implementation. Although most students demonstrated positive outcomes, some students experienced difficulties in managing their time during project work. Several participants also stated that they needed more intensive guidance in the initial stages because they were unfamiliar with the project-based learning model.

Table 3. Results of the Process Skills of Biology Education Students at PGRI Silampari University in the Animal Development Course

No	Indicator	Theory	Activity Implementation	K-1	K-2	K-3	K-4
1.	Observation	The process of collecting data about a phenomenon or event using the senses	Conduct observations using all five senses to the maximum	√	√	√	√
			Observe the symptoms that appear in the right way	√	√	√	-
			Distinguish changes that appear in observation results (can connect between variables)	√	-	-	√
Indicator score				100%	67%	67%	67%
2.	Interpretation	Make temporary conclusions from the recorded data	Conducting observations obtained	√	√	√	√
			Finding patterns in a series of observations made	-	-	√	-
			Drawing conclusions based on the observation data obtained	√	√	-	√
Indicator score				67%	67%	67%	67%
3.	Classification	Systematics used to classify something based on certain conditions	Record each observation separately	√	√	√	√
			Look for differences and similarities from the observation results obtained	√	√	√	√
			Compare the observation results obtained with the theoretical results	√	-	-	√
			Finding the right basis for grouping or classifying observations	-	-	√	√
Indicator score				75%	50%	75%	100%
4.	Experimental Planning	Organized planning in testing hypotheses	Using appropriate tools and materials for appropriate experimental trials	√	√	√	√
			Design the experiment according to the things that need to be observed so that it is in accordance with the objectives of the experiment.	√	√	√	√
			Carrying out experimental procedures is done systematically	√	-	-	√

No	Indicator	Theory	Activity Implementation	K-1	K-2	K-3	K-4
			Using good, correct and logical language	-	-	√	√
Indicator score				75%	50%	75%	100%
5.	Using Tools	Skilled in using various tools in experimental activities	Know the name and function of the tools used	√	√	√	√
			Using materials correctly, efficiently and carefully	√	√	√	√
			Know the names and functions of the materials used	√	√	√	√
			Revealing what might happen in circumstances that have not been observed	-	-	-	√
Indicator score				75%	75%	75%	100%
6.	Predicting	The skill of making predictions about something that has not yet happened or has not been observed based on existing trends or patterns.	Predicting the experimental results that will be obtained	-	-	√	√
			Predicting the causes of inaccuracy in the results obtained	-	-	-	√
			Use learned concepts in new problems	√	√	√	√
Indicator score				33%	33%	67%	100%
7.	Applying the Concept	Use learned concepts in new situations or apply them to new experiences to explain what happened.	Explain the experiments carried out based on the concepts that have been studied	√	√	√	√
			Conduct experiments appropriately according to the concepts that have been studied	√	√	√	√
			Using concepts obtained from experimental results to answer questions	√	√	√	√
			ask questions about the experimental materials to lecturers and friends	-	-	-	√
			Discuss work steps or problems that arise during practice with group members.	-	√	√	√
Indicator score				60%	80%	80%	100%
8.	Communicate	Students are able to discuss in certain groups and compile and present reports on activities carried out systematically and clearly.	Discuss experimental data with a group of friends to get the right answer.	√	√	√	√
			Explaining experimental data in tables or graphs	√	√	√	√
			Reporting experimental results orally or in writing	√	√	√	√
			Explain the experimental results obtained	√	√	√	√
Indicator score				100%	100%	100%	100%

Group 1 (The effect of temperature on the opening and closing movements of the operculum in goldfish (Cyprinus caprio) fry)
Group 2 (Eating behavior of male and female hamsters (Mesocricetus auratus) towards 3 types of food)
Group 3 (Metamorphosis of fruit flies (Droshopila melanogaster))
Group 4 (Differences in the growth of tilapia (Oroechromis niloticus) with natural and factory-grown food

In general, all student groups demonstrated good development of science process skills across most indicators. This was evident in the “Communication” indicator score, which reached 100% across all groups, indicating that students were able to discuss, prepare reports, and present project results systematically and clearly. The “Observation” indicator also showed high achievement (100%) in group 1, and relatively stable (67%) in the other groups. This condition reflects that the Project based learning process encouraged students to conduct real-world observations of biological objects. The “Experiment Planning” and “Tool Use” indicators showed variation in scores between groups. Groups 1 and 3 scored 75%, while group 4 scored 100%, indicating that this group was able to systematically design experiments and use tools appropriately. Implementing projects in the context of biological experiments improved skills in planning and implementing practicum procedures effectively. Meanwhile, group 2 showed a lower score (50%) because they still needed guidance in designing experimental stages and ensuring the suitability of practicum objectives. The "Predicting" indicator showed a significant increase in scores, with Group 4 achieving 100%, while Groups 1 and 2 remained at 33%. This indicates that students who were more active in discussing and interpreting data were able to make better predictions about observed biological phenomena. The "Applying Concepts" indicator showed an increasing trend from Group 1 (60%) to Group 4 (100%). This indicates that through contextual project development, students were better able to apply animal development concepts to real-world situations. Overall, it can be concluded that groups that chose more complex and realistic project topics (e.g., tilapia growth in Group 4) tended to demonstrate higher process skills. This indicates that the success of Project based learning implementation is determined not only by the learning strategy but also by the relevance and appropriateness of the project to the course objectives.

These findings are supported by relevant research that suggests aligning instructional objectives with classroom assessments helps uncover important aspects of student learning, understand student learning, and promote the achievement of instructional objectives. Aligning instructional activities with classroom assessments clarifies instructors' instructions and helps them provide feedback to students that helps them achieve instructional objectives. When instructors' instructional objectives align with student activities and classroom assessments, teaching and learning are maximized, and student learning is enhanced. In addition to guiding instructional implementation, curriculum standards also determine the scope of academic-level examinations (Zhao et al., 2023).

Project based science pedagogy is built on five features used to design activities that: (a) engage students in investigating real-life questions or problems that drive the activity and organize concepts and principles; (b) result in students developing a series of artifacts, or products, that address the question or problem; (c) enable students to engage in inquiry; (d) engage students, faculty, and community members in a community of inquiry as they collaborate on the problem; and (e) encourage students' use of cognitive tools (Hasni et al., 2016).

Students' biological knowledge during learning can influence their learning. Therefore, one predictor is students' overall biological knowledge, as measured by posttest or learning outcomes (Zha et al., 2025). Furthermore, this framework empowers students by allowing them to receive feedback on their collaborative efforts, which encourages improved interaction skills. These findings have significant implications for the development and implementation of Project based Learning environments, offering valuable insights for educators to evaluate student progress and make strategic decisions (Hadyaoui & Cheniti-Belcadhi, 2023). Process skills are part of the scientific skills used to acquire, process, construct, and apply scientific theories. Process skills are not only useful in science learning but also in students' daily lives (Hartono et al., 2022). Science process skills are crucial for students to apply scientific methods and develop knowledge to acquire new knowledge or enrich existing knowledge. Science process skills can be facilitated through learning with a Project-Based Learning model (Napitupulu et al., 2024). Critical thinking is a skill or process that enables students to acquire new knowledge through problem-solving and collaboration. Critical thinking skills focus more on the learning process than simply acquiring knowledge. Critical thinking skills involve activities such as interpreting, analyzing, evaluating, concluding, explaining the results of one's thinking, and how to make decisions and apply new knowledge. Based on these reasons, student development (Pradana et al., 2020).

Student Learning Outcomes in the Animal Development Course

Figure 1, student learning outcomes in the Animal Development course showed that in general, the final achievement is in the good category. Based on the final grade data of 32 students, the highest score was 95.4, while the lowest score was 65.6, with an overall average of 78.85. This indicates that most students were able to achieve learning outcomes according to the expected targets after implementing the Project Based Learning model. Students who obtained high scores generally demonstrated active involvement during the project process, were able to integrate theory and practice, and completed assignments independently and collaboratively. In contrast, students with lower scores still experienced obstacles in managing time and integrating the concept of animal development into project activities.

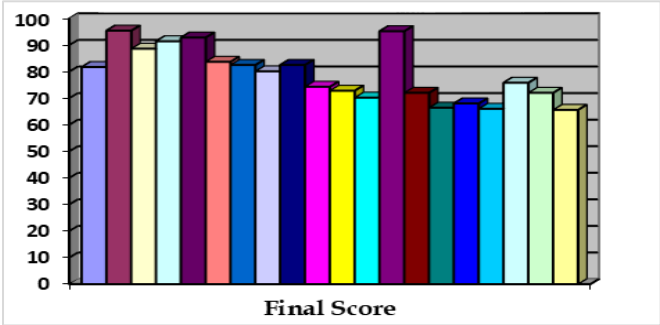

Figure 1. Final grade for the animal development course

Judging from the distribution of scores, more than half of the students scored above 80, indicating that project-based learning can improve conceptual understanding of animal development material. This finding is in line with research Dwiningsih et al. (2024) Project-based learning can be used to improve students' creative thinking skills. Critical thinking skills are mental processes for perceiving, analyzing, synthesizing, and evaluating information obtained from observation, experience, reflection, and reasoning. Critical thinking is related to learning-to-learn skills and is key to generating new ideas, organizing one's learning through efficient time and information management (Fontana-Rosa et al., 2025). Practice-based learning offers a promising approach to enabling prospective lecturers to acquire the skills they need to engage in complex classroom practice (Hoppe et al., 2025). Project-based learning is an educational approach that aims to teach students by engaging them in finding solutions to problems through investigation (Chounta et al., 2017; Fitri et al., 2024).

Student Perception Data Results Regarding Project Based Learning

The data in Figure 2 are interpreted as showing the habits carried out related to asking questions, namely curiosity, wanting to innovate, and being critical/reflective, which are carried out by students in the animal development course.

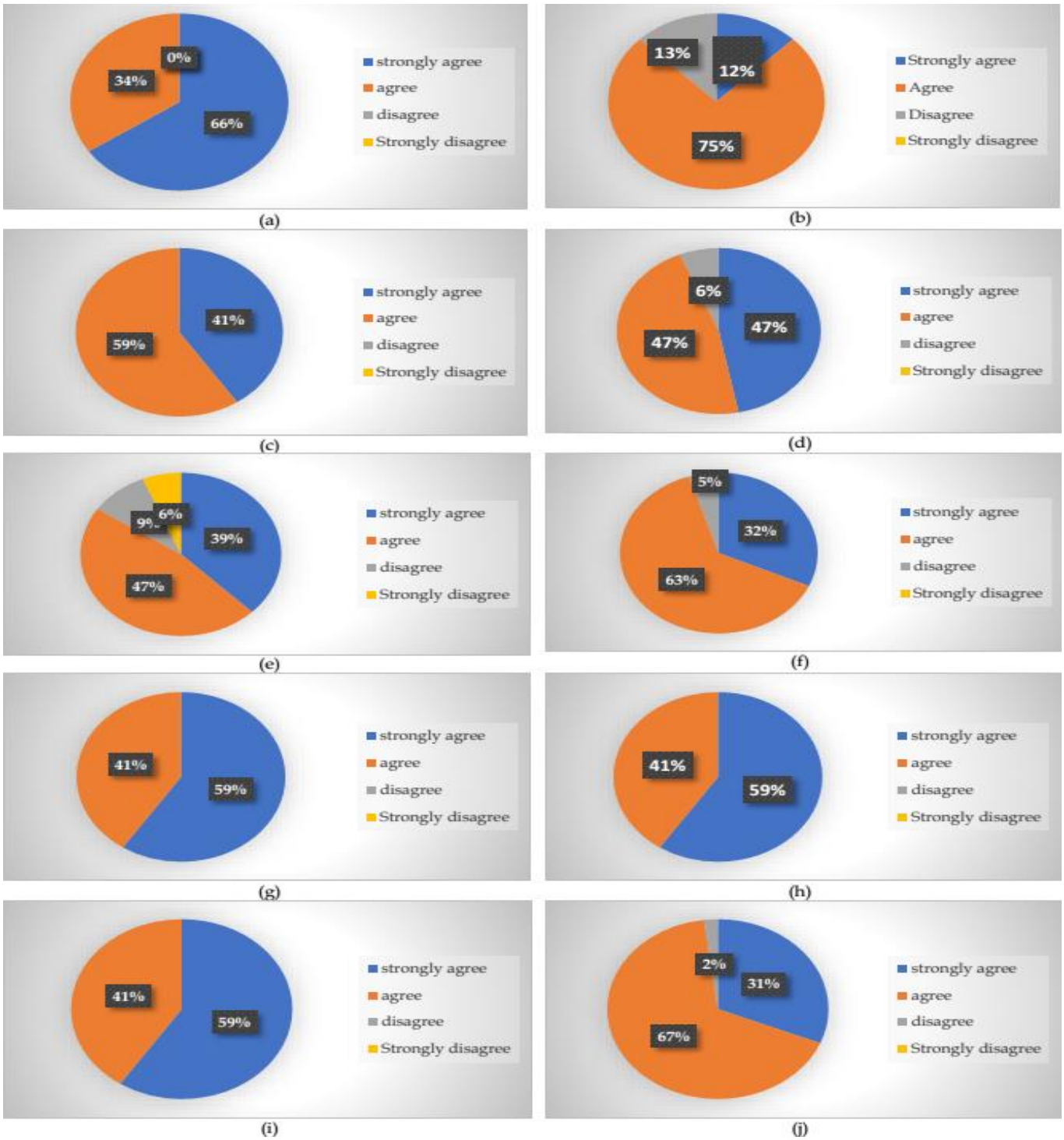

Figure 2. Student perception data on project based learning. (a) Interested in participating in project based animal development learning; (b) Remain enthusiastic even though the project I am working on is quite difficult; (c) Actively discuss and share ideas while working on the project; (d) Would like to find out more about the given project topic; (e) Took the initiative to complete the project assignment without waiting for the lecturer's instructions; (f) The project topic matches my interests and passions; (g) Feel satisfied when the project I am working on is completed well; (h) Enjoy working in groups when working on projects; (i) Interested in using technology (e.g. internet, software) in projects; (j) Have difficulty evaluating project results to improve my learning process

Their perceptions of the value of inquiry prospective lecturers related to these aspects when describing having a habit of thinking inquisitive, lecturer education Researchers most frequently mentioned that they were critical/reflective and curious (van Katwijk et al., 2022).

This study showed that students not only gained new ways to work collaboratively but also gained a better understanding of the technical principles of the course (Hadyaoui & Cheniti-Belcadhi, 2023). This study showed that the Project based learning teaching model was more effective than other teaching models in terms of improving clinical competence and student satisfaction (Zheng et al., 2023).

The project based learning model organizes learning around a project. A project consists of complex tasks, based on challenging questions or problems, that engage students in design, problem-solving, decision-making, or investigative activities; giving students the opportunity to work relatively independently over a long period of time; and culminating in a realistic product or presentation. Project based learning encompasses learning about authentic content, authentic evaluation, unsupervised faculty facilitation, explicit educational objectives, cooperative learning, reflection, and the incorporation of adult skills. PBL uses authentic (guided) questions, has an investigative community, and utilizes technology-based cognitive instruments as well as comprehensive, community-based, and multidisciplinary "expeditionary learning." Project based learning is a form of student-centered learning based on three constructivist principles: learning is context-specific; students are actively involved in the learning process; and they achieve goals through social interaction and the sharing of experiences, knowledge, and understanding. Project based learning is a specific type of inquiry-based learning in which the learning context is provided through authentic questions and problems in real-world practice that result in meaningful learning experiences (Santoso et al., 2023). In the project-based learning process, students' abilities can be enhanced by exploring ideas, reviewing possibilities, selecting topics and planning, producing and testing media, and presenting them.

Conclusion

The majority of students achieved learning outcomes in the high category after the implementation of Project based learning, data on students' science process skills, namely observation indicators obtained 75.25%, interpretation 67%, classification 75%, experimental planning 75%, using tools 81.25%, predicting 77%, applying concepts 80%, communicating 100%. The average score obtained was 78.75% with a high category. Student learning outcomes in the Animal Development course show that in general the final achievement is in the good category. Based on the final score data of 32 students, the highest score obtained was 95.4, while the lowest score was 65 with an overall average score of 78.85 included in the Good category. This indicates that most students are able to achieve learning outcomes according to the expected targets after the implementation of the Project Based Learning model. Students provide positive responses and perceptions towards the implementation of Project Based Learning in the Animal Development course.

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The authors declare no conflict of interest.

References

Abas, A., Amin, M., Ibrohim, I., & Indriwati, S. E. (2024). Integration of project-based learning to improve scientific process skills and conceptual understanding in the learning process of invertebrate zoology. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(2), 486–496. https://doi.org/10.22219/jpbi.v10i2.34305

Adah Miller, E., Li, T., Chen, I. C., Krajcik, J., & Codere Kelly, S. (2025). Designing for and investigating elementary students' cognitive flexibility, science, and literacy achievement in project-based science learning. *Disciplinary and Interdisciplinary Science Education Research*, *7*(1), 1–23. https://doi.org/10.1186/s43031-025-00131-1

Chounta, I. A., Manske, S., & Hoppe, H. U. (2017). Correction to: "From Making to Learning": introducing Dev Camps as an educational paradigm for Re-inventing Project-based Learning (International Journal of Educational Technology in Higher Education. *International Journal of Educational Technology in Higher Education*, *14*(1), 41239. https://doi.org/10.1186/s41239-017-0079-5

Dawson, C., Julku, H., Pihlajamäki, M., Kaakinen, J. K., Schooler, J. W., & Simola, J. (2024). Evidence-based scientific thinking and decision-making in everyday life. *Cognitive Research: Principles and Implications*, *9*(1), 50.

https://doi.org/10.1186/s41235-024-00578-2

DeFeo, D. J., Gerken, S., Tran, T. C., Khodyakov, D., & Fink, A. (2025). General education biology labs: a Delphi study of student learning outcomes. *Discover Education*, *4*(1). https://doi.org/10.1007/s44217-025-00428-3

Dwiningsih, K., & Aisy, N. (2024). Development of Project-Based Learning Oriented Student Worksheets to Improve Students' Creative Thinking Skills on Class X High School Nanotechnology Material. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 3640–3649. https://doi.org/10.29303/jppipa.v10i7.7821

Finefter-Rosenbluh, I., Berry, A., & Ryan, T. (2023). Acting Upon Student Voice-Based Teaching Assessment Initiatives: An Account of Participatory Action Research for Teacher Professional Learning. *Journal of Teacher Education*, *74*(5), 508–521. https://doi.org/10.1177/00224871231200278

Firneno, T. J., Welsh, G. T., Nimlos, P. J., & Larson, E. L. (2023). "I think": integrating project-based learning and case study to teach fundamentals of evolutionary tree-thinking. *Evolution: Education and Outreach*, *16*(1), 1–11. https://doi.org/10.1186/s12052-023-00192-8

Fitri, R., Lufri, L., Alberida, H., Amran, A., & Fachry, R. (2024). The project-based learning model and its contribution to student creativity: A review. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(1), 223–233. https://doi.org/10.22219/jpbi.v10i1.31499

Fitria, A. R., Hasnunidah, N., Fadiawati, N., & Suyatna, A. (2025). Enhancing Scientific Argumentation through the Integration of Argument-Driven Inquiry and STEM in E-Worksheets for Secondary Science Education. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 263–272. https://doi.org/10.29303/jppipa.v11i7.11603

Fontana-Rosa, N. S., González-de Paz, L., Codina-Rodríguez, A. C., Pérez-Riart, M., & Carrió-Llach, M. del M. (2025). Perspectives of medicine, human biology, and nursing undergraduates on transversal skills learning: a mixed-methods study. *BMC Medical Education*, *25*(1). https://doi.org/10.1186/s12909-025-06749-z

Gogh, E., & Kovari, A. (2025). Homework in the AI era: cheating, challenge, or change? *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1609518

Hadyaoui, A., & Cheniti-Belcadhi, L. (2023). Ontology-based group assessment analytics framework for performances prediction in project-based collaborative learning. *Smart Learning Environments*, *10*(1). https://doi.org/10.1186/s40561-023-00262-w

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, *3*(February), 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hartono, H., Susanti, R., & Ariska, M. (2022). Science Process Skills Analysis of Junior High School Students in South Sumatera Using Test Basic of Process Skill (BAPS). *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2184–2190. https://doi.org/10.29303/jppipa.v8i5.2276

Hasni, A., Bousadra, F., Belletête, V., Benabdallah, A., Nicole, M.-C., & Dumais, N. (2016). Trends in research on project-based science and technology teaching and learning at K–12 levels: a systematic review. *Studies in Science Education*, *52*(2), 199–231. https://doi.org/10.1080/03057267.2016.1226573

He, P., Krajcik, J., & Schneider, B. (2024). Correction to: Transforming standards into classrooms for knowledge-in-use: an effective and coherent project-based learning system. *Disciplinary and Interdisciplinary Science Education Research*, *6*(1). https://doi.org/10.1186/s43031-024-00107-7

Holmes, A. G. D., Polman Tuin, M., & Turner, S. L. (2021). Competence and competency in higher education, simple terms yet with complex meanings: Theoretical and practical issues for university teachers and assessors implementing Competency-Based Education (CBE). *Educational Process International Journal*, *10*(3). https://doi.org/10.22521/edupij.2021.103.3

Hoppe, T., Seidel, T., Renkl, A., & Rieß, W. (2025). Advancing Preservice Science Teachers' Skills to Assess Student Thinking On-the-Fly Through Practice-Based Learning. *Journal of Teacher Education*, *76*(1), 42–56. https://doi.org/10.1177/00224871241237497

Jin, H., Mikeska, J. N., Hokayem, H., & Mavronikolas, E. (2019). Toward coherence in curriculum, instruction, and assessment: A review of learning progression literature. *Science Education*, *103*(5), 1206–1234. https://doi.org/10.1002/sce.21525

Kibet, C. K., Entfellner, J. B. D., Jjingo, D., de Villiers, E. P., de Villiers, S., Wambui, K., Kinyanjui, S., & Masiga, D. (2024). Designing and delivering bioinformatics project-based learning in East Africa. *BMC Bioinformatics*, *25*(1), 1–16. https://doi.org/10.1186/s12859-024-05680-2

Luh Gede Sutaryani, Ni Made Pujani, & I Nyoman Tika. (2024). Project-Based Learning on Science Process Skills and Learning Outcomes in High School Physics: A Quasi-Experimental Study on the Topic of Fluids. *Journal of Education Research and Evaluation*, *8*(4), 806–815. https://doi.org/10.23887/jere.v8i4.83769

Nahum, T. L., Mamlok-Naaman, R., Hofstein, A., & Taber, K. S. (2010). Teaching and learning the concept of chemical bonding. *Studies in Science Education*, *46*(2), 179–207. https://doi.org/10.1080/03057267.2010.504548

Napitupulu, N. D., Hutahaean, J., & Fauziyyah, A. N. L. (2024). Trends Research Project Based Learning (PjBL) Model to Improve Science Process Skills in Students' Science Learning (2015-2024): A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 488–497. https://doi.org/10.29303/jppipa.v10i7.8577

Nurulwati, Herliana, F., Elisa, & Musdar. (2021). The Effectiveness of Project-Based Learning to Increase Science Process Skills in Static Fluids Topic. *AIP Conference Proceedings*, *2320*(January). https://doi.org/10.1063/5.0037628

Parlindungan, D., Yani, A. P., Karyadi, B., Ruyani, A., Samitra, D., & Destriani, S. N. (2023). *Project-Based Learning: Animal Diversity Survey in Turtle Conservation Area at Bengkulu University*. https://doi.org/10.2991/978-2-38476-012-1_35

Pradana, D., Nur, M., & Suprapto, N. (2020). Improving Critical Thinking Skill of Junior High School Students through Science Process Skills Based Learning. *Jurnal Penelitian Pendidikan IPA*, *6*(2), 166–172. https://doi.org/10.29303/jppipa.v6i2.428

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, *10*(23), e39988. https://doi.org/10.1016/j.heliyon.2024.e39988

Santoso, R. T. P. B., Priyanto, S. H., Junaedi, I. W. R., Santoso, D. S. S., & Sunaryanto, L. T. (2023). Project-based entrepreneurial learning (PBEL): a blended model for startup creations at higher education institutions. *Journal of Innovation and Entrepreneurship*, *12*(1), 1–22. https://doi.org/10.1186/s13731-023-00276-1

Sudirman, R. J., & Yuhelman, N. (2025). Development of Acid-Base E-Modules Based on Guided Discovery Learning Using React Native to Improve Problem Solving Skills of Phase F High School Students. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 934–946. https://doi.org/10.29303/jppipa.v11i7.12212

Tsybulsky, D., & Muchnik-Rozanov, Y. (2021). Project-based learning in science-teacher pedagogical practicum: the role of emotional experiences in building preservice teachers' competencies. *Disciplinary and Interdisciplinary Science Education Research*, *3*(1). https://doi.org/10.1186/s43031-021-00037-8

van Katwijk, L., Jansen, E., & van Veen, K. (2022). Development of an Inquiry Stance? Perceptions of Preservice Teachers and Teacher Educators Toward Preservice Teacher Inquiry in Dutch Primary Teacher Education. *Journal of Teacher Education*, *73*(3), 286–300. https://doi.org/10.1177/00224871211013750

Weiss, K. A., McDermott, M. A., & Hand, B. (2022). Characterising immersive argument-based inquiry learning environments in school-based education: a systematic literature review. *Studies in Science Education*, *58*(1), 15–47. https://doi.org/10.1080/03057267.2021.1897931

Yi, E., & Park, D.-H. (2024). The effect of core competencies of university students on employment and first year salary level based on school activity log. *Heliyon*, *10*(7), e28474. https://doi.org/10.1016/j.heliyon.2024.e28474

Zakia, T. (2025). The Effect of Implementing Problem Based Learning (PBL) Learning Model Assisted by Interactive Media on Improving Problem Solving Skills and Self Efficacy of Learners. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 82–90. https://doi.org/10.29303/jppipa.v11i7.9386

Zha, S., Bragdon, M. M., Gong, N., Wang, J., Leavesley, S., Eaton, R., & Bosarge, E. (2025). A Case Study of Integrating AI Literacy Education in a Biology Class. *International Journal of Artificial Intelligence in Education*. https://doi.org/10.1007/s40593-025-00476-8

Zhao, L., Zhao, B., & Li, C. (2023). Alignment analysis of teaching–learning-assessment within the classroom: how teachers implement project-based learning under the curriculum standards. *Disciplinary and Interdisciplinary Science Education Research*, *5*(1), 1–23. https://doi.org/10.1186/s43031-023-00078-1

Zheng, Q. M., Li, Y. Y., Yin, Q., Zhang, N., Wang, Y. P., Li, G. X., & Sun, Z. G. (2023). The effectiveness of problem-based learning compared with lecture-based learning in surgical education: a systematic review and meta-analysis. *BMC Medical Education*, *23*(1), 1–11. https://doi.org/10.1186/s12909-023-04531-7