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The animal macroanatomy practicum's evaluation based on science process skills, science literacy, critical thinking, and conceptual understanding

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ABSTRACT

Systematic evaluation is essential to determine whether learning objectives are achieved and to assess the contribution of laboratory activities to the quality of biology education. However, empirical evidence regarding students' scientific process skills, science literacy, critical thinking abilities, and conceptual understanding in animal macroanatomy practicums at the University of Timor remains limited. This study aimed to analyze students' scientific process skills, science literacy, critical thinking abilities, and conceptual understanding as part of an evaluation of the implementation of an animal macroanatomy practicum in the Biology Education program at the University of Timor. This study employed a descriptive quantitative research design to examine these competencies through structured observation instruments and validated questionnaires. The research procedure consisted of five stages: data collection, data reduction, data presentation, triangulation, and conclusion drawing. The findings indicated that the animal macroanatomy practicum was generally effective in enhancing students' scientific competencies. Mean scores showed that students achieved skilled to high levels across all assessed domains, including science process skills (67,40%), science literacy (65,54%), critical thinking skills (64,67%), and conceptual understanding (61,86%). Students demonstrated strong performance in experimental planning, observation, questioning, and interpretation, as well as in science literacy related to investigation, reasoning, and the science–technology–society context. Critical thinking was most prominent in basic explanation and foundational skills, while conceptual understanding was strongest in interpretation, exemplification, and classification. These results suggest that animal macroanatomy practicum activities contribute substantially to the development of fundamental scientific competencies and support the integration of theoretical knowledge with empirical observation.

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Animal macroanatomy practicum, Critical thinking skills, Conceptual understanding evaluation, Science process skills.

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INTRODUCTION

Biology education has a fundamental role in promoting students' science process skills, conceptual understanding, science literacy, and critical thinking skills (Ridzal & Hazwan, 2023; Abas et al., 2024). The instructional approach in biology extends beyond the transmission of theoretical knowledge to include the development of deeper comprehension and scientific problem-solving competencies (Hsu et al., 2024). Laboratory activities constitute an essential component of biology instruction, as they provide learners with opportunities to directly observe biological objects and connect theoretical principles with empirical phenomena (Ruqia et al., 2025). In particular, laboratory work on animal anatomical structures requires students not only to identify organismal components but also to develop a comprehensive understanding of the relationships between structure and function (Choudhary & Sarkar, 2025).

Nevertheless, the effectiveness of laboratory activities is influenced not solely by their implementation but also by the evaluation processes that accompany them. Systematic evaluation is therefore required to determine the extent to which learning objectives have been achieved and to examine how laboratory experiences contribute to the overall improvement in the quality of biology learning (Pangsuma et al., 2025). In the context of the Biology Education program at the University of Timor, empirical data regarding students' scientific process skills, science literacy, critical thinking abilities, and conceptual understanding in animal macroanatomy practicums remain limited (Kusumawardani et al., 2025). Consequently, this study aims to analyze these competencies as part of an evaluation of the implementation of an animal macroanatomy practicum, providing evidence-based insights to improve the quality of practical instruction.

Evaluation of biology laboratory activities, especially those focusing on animal anatomical structures, plays a pivotal role in enhancing students' science process skills by enabling educators to assess, in a structured manner, students' abilities to observe, classify, measure, analyze, and interpret data, as well as to formulate conclusions based on empirical evidence (Kusumawardani et al., 2025). Through continuous and well-designed evaluation, educators can identify the level of mastery of science process skills acquired during laboratory sessions while simultaneously detecting deficiencies or procedural inaccuracies that may impede the attainment of instructional objectives (Tommy et al., 2024; Syahirah et al., 2024). Beyond serving as an instrument for measuring learning outcomes, evaluation also serves as a reflective mechanism for improving the design and implementation of laboratory activities to promote greater student engagement in scientific inquiry. Consequently, animal anatomy practicums are directed not only toward the identification of organismal structures but also toward reinforcing science process skills as the foundation of scientific reasoning in biology education (Sulistyawati et al., 2025).

Within the framework of science literacy, practicum evaluation assumes a strategic function in assessing students' capacity to interpret observational data, apply scientific terminology accurately, and relate experimental findings to relevant biological concepts. In the absence of structured evaluation, laboratory activities risk being reduced to procedural routines with limited influence on the development of scientific understanding. Accordingly, evaluation functions not only as a means of assessing learning outcomes but also as a tool for reflecting on the effectiveness of practicum approaches in fostering students' science literacy (Marwidayanti et al., 2025; Husamah et al., 2024).

Beyond science literacy, animal anatomy laboratory activities also have substantial potential to foster students' critical thinking skills (Zulfadli et al., 2025). Through processes of observation, identification, and analysis of anatomical structures, learners are stimulated to formulate questions, construct inferences, and derive conclusions based on empirical evidence (Sa'idah et al., 2025). Carefully designed evaluation instruments can determine the extent to which these critical thinking skills have developed, for instance, by assessing reasoning patterns, scientific argumentation, and problem-solving processes that emerge during laboratory activities (Abidin & Fatimatuzzaro, 2025; Abidin & Soewondo, 2025). Consequently, evaluation functions as a vital mechanism to ensure that laboratory learning is oriented not only toward outcomes but also toward the development of students' scientific reasoning processes (Marwidayanti et al, 2025).

Furthermore, conceptual understanding represents a central objective of biology education that cannot be optimally attained without continuous and systematic evaluation. Animal anatomy laboratory activities frequently involve complex concepts, including organ systems, structural adaptations, and the interrelationships among body components. Through evaluation, educators can identify potential misconceptions and assess students' depth of understanding of these concepts. The resulting evaluative data provide a foundation for refining instructional strategies, both in the design of subsequent laboratory sessions and in integrating theoretical content with practical activities (Mura et al., 2025).

Accordingly, assessing students' science process skills, science literacy, critical thinking abilities, and conceptual understanding is essential as an evaluative basis for improving the quality of future practical learning (Kusumawardani et al., 2025). Comprehensive and sustained evaluation serves not only as an indicator of learning achievement but also as a mechanism for improving the overall quality of practicum implementation. Therefore, the development and application of an appropriate evaluation system for animal anatomy laboratory activities constitute an essential requirement for achieving meaningful, contextually relevant biology learning that strengthens students' scientific competence.

METHOD

This study employed a descriptive quantitative research design. The research framework was intended to examine students' science process skills (SPS), science literacy, critical thinking skills, and conceptual understanding. The investigation was conducted from April to June 2025 in the Biology Education Laboratory of Timor University. The study population comprised 124 undergraduate students enrolled in the Biology Education program at the Faculty of Teacher Training and Education, Timor University, from the 2023 cohort (fourth semester) in the 2024/2025 academic year. The research sample was determined using a minimum proportion of 30% of the total population ($n > 37$).

The research procedure included five phases: (1) data collection using observation instruments to measure science process skills, science literacy, critical thinking skills, and conceptual understanding; (2) data reduction through classification, grouping, and simplification to obtain meaningful and relevant information; (3) data presentation using descriptive statistical techniques in tabular form to facilitate the identification of patterns and relationships among variables; (4) triangulation as a data validation process, performed by comparing findings from direct observations of practicum activities with students' practicum reports and interviews with lecturers; and (5) conclusion drawing based on the results of data reduction and triangulation (Tommy et al., 2024).

Data were collected using test & non-test instruments. The instrument indicators applied in this study were designed to measure science process skills (SPS), science literacy, critical thinking skills, and conceptual understanding. Table 1 shows the instruments used to measure the indicators. Data collection was supported by two observers who monitored the implementation of the animal macroanatomy practicum, assessed students' practicum reports, and evaluated students' practicum presentations.

Table 1. Instrument of science process skill, science literacy, critical thinking skills, & conceptual understanding.

No	Parameter	Indicator	Instrument Type	Reference
1	Science Process Skills	Planning the experiment, Asking question, Using tools and materials, Observation, Interpretation, Classification, Prediction, Hypothesis, Applying concepts or principles, & Communication.	Observation rubric + SPS test	Tommy et al., 2024; Syahirah et al., 2025
2	Science Literacy	Understanding, Interpreting, Showing, Sorting, Concluding, Classifying, Comparing, Analyzing, Reasoning, Linking, Evaluating, Recommending, & Responding.	Context-based test + questionnaire	Rokhmah et al., 2017; Mukti et al., 2023; Bhakti et al., 2023
3	Critical Thinking Skills	Providing simple explanation, Building basic skills, Drawing conclusions, Providing further explanation, Providing further explanation, Strategizing, & Tactic.	Essay test + scoring rubric	Syam et al., 2024; Rizki et al., 2024; Marwan et al., 2025;
4	Conceptual Uncerstanding	Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing, & Explaining.	Concept test (MC + reasoning)	(Fauziyah & El Hakim, 2025; Edelia & Kuswanti, 2025)

The science process skills data obtained were then analyzed descriptively using a formula adapted from Jannah (2024) as follows in equation (1):

$$Percentage\ (\%) = \frac{observation\ result\ score}{maximum\ score}\ x\ 100\% \qquad (1)$$

The Likert-scale categories for the science process skills resulting from equation 1 are shown in Table 2.

Table 2. Science process skills likert scale categories

Value Scale	Score	Percentage (%)	Category
4	45,5 – 56	81,25 – 100	Highly Skilled
3	35,25 – 44,4	62,5 – 81,24	Skilled
2	24,5 – 35,24	43,75 – 62,4	Less Skilled
1	14 – 24,4	25 – 43,74	Very Less Skilled

The science literacy, critical thinking skills, and conceptual understanding data obtained were then analyzed descriptively using a formula adapted by OECD (2024) as follows in equations (2) and (3):

$$Percentage\ Correct\ Answer\ (\%) = \frac{Frequency\ of\ Correct\ Answers}{Total\ Number\ of\ Student\ Participants}\ x\ 100\% \qquad (2)$$

$$Percentage\ Incorrect\ Answer\ (\%) = \frac{Frequency\ of\ Incorrect\ Answers}{Total\ Number\ of\ Student\ Participants}\ x\ 100\% \qquad (3)$$

The likert scale categories are shown in table 3.

Table 3. Science literacy, critical thinking skills, and conceptual understanding likert scale categories

No	Percentage (%)	Category
1	Correct Answer ≥ 80	Very High
2	60 ≤ Correct Answer ≤ 79	High
3	40 ≤ Correct Answer ≤ 59	Low
4	Correct Answer ≤ 39	Very Low

RESULTS AND DISCUSSION

This study aimed to analyze students' scientific process skills, science literacy, critical thinking abilities, and conceptual understanding as part of an evaluation of the implementation of an animal macroanatomy practicum in the Biology Education program at the University of Timor. The study was conducted during the Animal Anatomical Structure practicum from April to May at the Biology Education Laboratory at Timor University. The research sample comprised 40 students, representing more than 30% of the total population (n > 30%). The practicum was implemented across six sessions: five dedicated to dissection procedures and the observation of animal anatomical structures, and one final session devoted to response activities as a form of practicum evaluation (Figure 1). Data collection for the assessment of science process skills was performed concurrently with the practicum sessions. In contrast, data on science literacy, critical thinking skills, and conceptual understanding were collected after the response activities conducted during the final session.

Figure 1. Animal anatomy practicum activities

Figure 2. Group photograph

The results of data analysis on students' science process skills, science literacy, critical thinking skills, and conceptual understanding in the animal anatomical structure practicum are presented in Table 4.

Table 4. Student's science process skills indicator result

No	SPS Indicator	Score	Average Percentage (%)	Category
1	Planning the experiment	44,8	80	Skilled
2	Asking question	40,32	72	Skilled
3	Using tools and materials	43,68	78	Skilled
4	Observation	45,92	82	Highly Skilled
5	Interpretation	38,08	68	Skilled
6	Classification	39,20	70	Skilled
7	Prediction	32,48	58	Less Skilled
8	Hypothesis	33,60	60	Less Skilled
9	Apply concepts or principles	31,36	56	Less Skilled
10	Communication	28,00	50	Less Skilled
	Average	**37,74**	**67,4**	**Skilled**

The findings indicate that students' science process skills (SPS) in the animal macroanatomy practicum were generally categorized as skilled (average = 67.4%), with the highest achievement observed in observation (82%), followed by planning experiments (80%), and using tools and materials (78%) (Table 4). This result is consistent with the view that laboratory-based learning strongly promotes basic and integrated science process skills, particularly those related to direct observation and manipulation of specimens. According to OECD (2023), observation and measurement are foundational SPS that develop more readily through repeated hands-on laboratory experiences. The high performance in observation suggests that dissection-based activities provide concrete learning experiences that enhance students' ability to identify anatomical structures accurately and systematically. Similarly, the strong performance in experimental planning reflects students' growing procedural understanding, which aligns with constructivist learning theory's emphasis on active engagement in scientific inquiry (Chen et al., 2025).

However, several higher-order SPS indicators—namely, prediction (58%), hypothesis formulation (60%), application of concepts (56%), and communication (50%)—were classified as less skilled (Table 4). These findings indicate that although students perform well in procedural and observational tasks, they experience difficulties in abstract reasoning and scientific communication. This pattern is consistent with previous research showing that higher-level SPS, such as hypothesizing and predicting, require explicit instructional scaffolding and are less likely to develop automatically through routine laboratory activities (Tommy et al., 2024). Furthermore, weak communication performance suggests limited opportunities for structured scientific discussion and argumentation during practicum sessions, despite their importance in reinforcing conceptual understanding and critical thinking.

The imbalance between basic and higher-order SPS highlights the need for instructional redesign in practicum implementation. Inquiry-based and problem-based laboratory models have been shown to significantly improve students' abilities in prediction, hypothesis testing, and application of scientific concepts (Kassaye et al., 2025). In addition, incorporating reflective reports and oral presentations may strengthen students' communication skills and scientific reasoning. These results also align with the science literacy framework promoted by OECD (2023), which emphasizes not only procedural competence but also reasoning, explanation, and communication as essential components of scientific competence. Therefore, while the animal macroanatomy practicum effectively develops foundational SPS, targeted pedagogical strategies are needed to enhance higher-level cognitive and communicative skills to achieve more comprehensive scientific learning outcomes (Andini et al., 2022). Table 5 shows the students' science literacy indicator results.

The results of the science literacy (SL) indicators, as shown in Table 5, indicate that students achieved a high overall level of science literacy, with an average of 65.54%. Strong performance was observed in the domains of understanding (82%), interpreting (70%), and showing (75%) (Table 5), indicating that students were able to comprehend biological information and represent scientific concepts accurately based on practicum experiences. These findings support the argument that laboratory-based learning enhances students' ability to construct meaning from empirical observations and connect theoretical knowledge with real phenomena. According to Fitriana & Permatasari (2024), science literacy involves not only knowledge acquisition but also the capacity to explain phenomena scientifically and interpret data, as reflected in the high achievement on these indicators.

Table 5. Student's science literacy indicator result

No	Main Indicator	SL Indicator	Average Percentage (%) Correct	Incorrect	Category
1	Science Literacy	Understanding	82	18	Very High
2		Interpreting	70	30	High
3		Showing	75	25	High
4	Investigating	Sorting	78	22	High
5		Concluding	72	28	High
6		Classifying	68	32	High
7		Comparing	65	35	High
8	Thinking	Analyze	56	44	Low
9		Reasoning	45	55	Low
10		Linking	40	60	Low
11	Interaction of science, technology, and society	Evaluate	67	33	High
12		Recommend	72	28	High
13		Respond	62	38	High
Average			**65,54**	**34,46**	**High**

From table 5, students similarly, demonstrated high performance in the investigating dimension, particularly in sorting (78%), concluding (72%), classifying (68%), and comparing (65%). This suggests that the practicum effectively supported inquiry-based learning processes that require students to organize data, identify patterns, and draw conclusions from observations. These results align with Erkacmaz (2023), who emphasized that inquiry-oriented laboratory activities foster essential scientific competencies such as data interpretation and evidence-based reasoning. The high achievement in these indicators indicates that students were actively engaged in scientific investigation rather than merely following procedural steps (Maroco et al., 2024).

However, lower performance was identified in the thinking dimension, specifically in analyzing (56%), reasoning (45%), and linking (40%), which were categorized as low (Table 5). These findings suggest that while students can understand and organize scientific information, they experience difficulties with higher-order cognitive processes, such as analyzing relationships, constructing logical arguments, and connecting scientific concepts to broader contexts. This pattern is consistent with previous studies indicating that higher-level science literacy skills require explicit instructional support and reflective learning strategies (Reith & Nehring et al., 2026). Without structured opportunities for discussion, argumentation, and problem-solving, students tend to focus more on factual understanding than on analytical reasoning.

In the dimension of interaction between science, technology, and society (STS), students showed high achievement in evaluating (67%), recommending (72%), and responding (62%). This result indicates that students were relatively capable of relating biological concepts to real-world issues and making judgments based on scientific information. This finding aligns with the OECD's (2023) science literacy framework, which emphasizes the importance of applying scientific knowledge in societal and technological contexts. Overall, these results suggest that the animal macroanatomy practicum effectively supports fundamental science literacy skills, particularly in understanding and investigation, but requires further pedagogical refinement to strengthen higher-order thinking skills, such as analysis, reasoning, and conceptual linkage, to achieve more comprehensive scientific competence. Table 6 shows the results for the student critical thinking skill indicator.

Table 6. Student's critical thinking skills indicator result

No	CTS Indicator	Average Percentage (%)		Category
		Correct	Incorrect	
1	Providing a simple explanation	82	18	Very High
2	Building basic skills	75	25	High
3	Drawing conclusions	68	32	High
4	Providing further explanation	50	50	Low
5	Strategizing	58	42	Low
6	Tactic	55	45	Low
	Average	**64,67**	**35,33**	**High**

The results of the critical thinking skills (CTS) indicators indicate that students demonstrated strong performance in providing simple explanations (82%), building basic skills (75%), and drawing conclusions (68%), all of which were classified as high to very high. These findings suggest that students were able to identify problems, interpret information, and formulate basic conclusions based on practicum observations. This pattern is consistent with the framework proposed by Erkacmaz (2023), which states that core critical thinking skills include interpretation, inference, and explanation as fundamental components that can be effectively developed through experiential learning such as laboratory activities. The high achievement in these indicators reflects the effectiveness of practicum-based instruction in supporting foundational reasoning and evidence-based conclusions.

However, lower performance was observed in the indicators of providing further explanation (50%), strategizing (58%), and tactics (55%), which were categorized as low. These indicators represent higher-order critical thinking processes that require students to evaluate alternative solutions, plan systematic approaches, and apply strategies to complex problems (Rasyid et al., 2020). The relatively weak performance in these aspects indicates that students may still rely on surface-level reasoning and have limited opportunities to engage in metacognitive reflection and advanced problem-solving during practicum sessions. Previous studies have shown that higher-level critical thinking skills do not develop automatically through routine laboratory activities but require structured instructional support such as inquiry-based learning, argumentation, and reflective discussion (Haoxin Xu et al., 2024).

This imbalance between basic and advanced CTS aligns with the science literacy framework of Zivan & Tsabari (2025), which emphasizes that effective science education should promote not only understanding and explanation but also evaluation, decision-making, and strategic reasoning in real-world contexts. Without explicit emphasis on these components, students tend to perform well on descriptive and interpretative tasks but struggle with strategic and evaluative reasoning. Therefore, the findings suggest that although the animal macroanatomy practicum successfully develops basic critical thinking competencies, it requires pedagogical enhancement to foster deeper analytical and strategic thinking skills (Fajriah et al., 2021).

To address these limitations, the integration of inquiry-based practicum models, problem-based learning, and guided scientific argumentation is recommended. Such approaches have been shown to significantly improve students' abilities in explanation, strategy formulation, and decision-making (Samadun et al., 2023; Carmona, 2023). Overall, the results indicate that the practicum contributes positively to foundational critical thinking skills but should be redesigned to include more reflective, analytical, and strategy-oriented tasks to achieve comprehensive development of students' critical thinking competence. The student conceptual understanding Indicator result shown in Table 7.

Table 7. Student's Conceptual Understanding Indicator Result

No	CU Indicator	Average Percentage (%)		Category
		Correct	Incorrect	
1	Interpreting	70	30	High
2	Exemplifying	72	28	High
3	Classifying	66	34	High
4	Summarizing	48	52	Low
5	Inferring	65	35	High
6	Comparing	58	42	Low
7	Explaining	54	46	Low
	Average	**61,86**	**38,14**	**High**

The results of students' conceptual understanding (CU) indicators demonstrate an overall high level of achievement (61.86%), with strong performance in interpreting (70%), exemplifying (72%), classifying (66%), and inferring (65%). These findings suggest that students were generally able to comprehend biological concepts related to animal macroanatomy and apply them to identify examples, recognize patterns, and draw logical inferences from practicum observations. This outcome supports constructivist learning theory, which posits that conceptual understanding develops through active engagement with learning materials and direct interaction with real objects or phenomena (Munandar et al., 2024). Laboratory-based learning provides meaningful contexts for students to link abstract biological concepts with concrete anatomical structures, thereby strengthening conceptual frameworks.

However, lower achievement was observed in the indicators of summarizing (48%), comparing (58%), and explaining (54%), which were categorized as low. These indicators reflect higher-order cognitive processes that require students to synthesize information and articulate conceptual relationships coherently. The relatively weak performance in these aspects indicates that students may still struggle to integrate multiple concepts into concise representations and to communicate scientific explanations effectively. According to Anderson and Krathwohl's revision of Bloom's taxonomy, summarizing and explaining involve deeper cognitive processing at the levels of analysis and evaluation, which are more challenging to develop without explicit instructional scaffolding. Similar findings have been reported in previous studies, showing that students often perform better on recognition and classification tasks than on synthesis and explanation tasks during laboratory learning (Zahro et al., 2023).

The high performance in interpreting and exemplifying suggests that the practicum successfully facilitated students' understanding of the relationship between anatomical structures and their functions. This result aligns with the OECD's (2023) science literacy framework, which emphasizes that students should be able to interpret scientific information and apply it to explain phenomena in meaningful contexts. Nevertheless, lower scores in summarizing and explaining highlight the need for more reflective, discussion-oriented learning strategies, such as concept mapping, guided questioning, and scientific argumentation, to promote deeper conceptual integration (Novak & Treagust, 2022).

Overall, these findings indicate that the animal macroanatomy practicum effectively supports fundamental conceptual understanding, particularly in interpretation, classification, and inference.

However, pedagogical improvements are needed to strengthen students' ability to synthesize and explain concepts. Integrating inquiry-based learning and structured reflection into practicum activities may enhance higher-order conceptual processing and lead to a more comprehensive and enduring understanding of biological concepts.

CONCLUSION

Based on the evaluation results, the implementation of the animal macroanatomy practicum demonstrated an overall high level of effectiveness in fostering students' science process skills, science literacy, critical thinking skills, and conceptual understanding. The mean scores indicated that students achieved skilled to high categories across all major domains, with science process skills (67,40%), science literacy (65,54%), critical thinking (64,67%), and conceptual understanding (61,86%). Analysis of individual indicators revealed strong performance in experimental planning, observation, questioning, and interpretation, as well as in science literacy dimensions related to investigation, reasoning, and the interaction between science, technology, and society. Critical thinking skills were particularly evident in providing simple explanations and building basic skills, while conceptual understanding was strongest in interpreting, exemplifying, and classifying concepts. These results suggest that animal macroanatomy practicum activities contribute substantially to the development of fundamental scientific competencies and support the integration of theoretical knowledge with empirical observation.

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