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# CRITICAL THINKING IN BIOLOGY TEACHER CANDIDATES: HOTS AND INFLUENCING FACTORS

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**Abstract:** This study aims to analyze the critical thinking skills of students in the Biology Education Study Program at Pattimura University in solving Higher Order Thinking Skills (HOTS) questions related to modern biotechnology. A descriptive research method was employed, utilizing a test instrument and unstructured interviews to identify factors influencing student performance. The measured critical thinking indicators include clarification, assessment, inference, and strategy. The analysis results indicate that the average student score was 72.5, categorized as "good." Students demonstrated strong abilities in clarification, assessment, and strategy but encountered difficulties in inference. The score variation, with a standard deviation of 11.95, reflects differences in students' proficiency levels. Factors affecting these results include academic background, experience in scientific argumentation, and access to learning resources. The findings highlight the need to strengthen inference skills through discussion-based learning, case studies, and problem-based learning strategies. Enhancing critical thinking skills is expected to better prepare students for challenges in the educational field and enable them to guide learners in developing analytical thinking abilities.

**Keywords:** critical thinking; HOTS; pre-service teachers.

## INTRODUCTION

Education extends beyond the mere transmission of knowledge; it also encompasses the cultivation of reflective and analytical thinking. Through critical thinking, teachers can design more effective and innovative learning strategies, ensuring that students do not merely receive information passively but actively construct their knowledge. Furthermore, critical thinking comprises various cognitive processes, including analysis, evaluation, and interpretation, all of which are essential for fostering independent understanding (Bellaera et al., 2021). In this context, teachers who possess critical thinking skills are better equipped to adapt their instructional methods to suit students' learning needs (Ramdani et al., 2021).

At Pattimura University, a significant challenge exists regarding how students manage and utilize information in the increasingly complex learning context. Particularly in biology education, students often memorize concepts without truly understanding or analyzing the relationships between them. This issue is exacerbated by limited

facilities and teaching methods that focus primarily on one-way information delivery. This highlights the need to create a learning environment that fosters the development of deeper analytical, evaluative, and decision-making skills. Therefore, this study aims to analyze the factors influencing students' thinking processes and information processing, with the expectation that it will enhance their ability to address more complex issues in biology education.

Indicators of critical thinking for prospective and current teachers encompass various cognitive aspects that reflect their ability to analyze, evaluate, and systematically solve problems. Prospective teachers with strong critical thinking skills can identify educational challenges, assess multiple alternative solutions, and select the most effective strategies based on empirical evidence and educational theories. Additionally, they must demonstrate flexibility in adjusting instructional strategies according to student characteristics and learning situations (Rasyid et al., 2023).

One of the primary indicators of critical thinking for teachers is the ability to analyze information objectively and systematically. Critical-thinking teachers do not accept concepts or theories unquestioningly but instead assess their validity and relevance within the educational context. In this regard, teachers do not merely deliver content but also encourage students to analyze concepts, make connections between pieces of information, and evaluate the validity of theories within the domain of science education (Lubis et al., 2021). This ability is crucial for filtering diverse sources of information and effectively integrating them into the teaching and learning process.

Furthermore, critical thinking encompasses the ability to evaluate arguments and evidence (Sari & Prasetyo, 2021). Teachers with strong critical thinking skills can distinguish between subjective opinions and facts supported by data or research (Santos, 2017). With this capability, they can guide students to critically assess unverified information while equipping them with the necessary skills to develop perspectives based on in-depth analysis (Rasyid et al., 2023).

Problem-solving ability is another key indicator of critical thinking, especially in science education, where students are expected not only to acquire information but also to understand causal relationships and develop logic-based solutions (Lubis et al., 2021). Teachers frequently encounter various challenges in education, such as student learning difficulties, resource limitations, and diverse classroom dynamics. By applying critical thinking, teachers can identify root causes, evaluate alternative solutions, and implement the most effective strategies to overcome these challenges (Rasyid et al., 2023).

Another critical thinking indicator is openness to multiple perspectives. Critical-thinking teachers recognize that no single approach is universally applicable, as each student has unique needs (Yuan & Liao, 2023). These teachers exhibit openness to new ideas, willingness to challenge their assumptions, and readiness to adjust their instructional approaches based on objective reflection and evaluation (Farcis et al., 2022).

In this study, the critical thinking abilities of prospective biology education teachers were analyzed through the use of Higher Order Thinking Skills (HOTS) assessments and interviews. The HOTS questions were designed to measure the extent to which students could think

analytically, evaluatively, and creatively in solving subject-related problems. Meanwhile, interviews were conducted to explore their reasoning, decision-making processes, and information evaluation skills within academic and professional contexts.

This research is of significant importance, as critical thinking is a crucial factor in shaping high-quality prospective teachers. By understanding the essential levels of thinking of biology education students, educational institutions can develop more effective teaching strategies to enhance these skills. Furthermore, the findings of this study can serve as a foundation for curriculum development and the implementation of more innovative teaching methodologies, ensuring that prospective teachers not only comprehend biological concepts theoretically but also apply them critically and systematically in problem-solving contexts.

Thus, critical thinking not only supports teachers' professionalism but also contributes to the creation of more effective and meaningful learning experiences. Teachers who think critically are better prepared to navigate the complexities of education and to guide students in developing analytical, evaluative, and problem-solving skills. Therefore, strengthening critical thinking skills among prospective and current teachers should be prioritized in the development of a high-quality education system.

## METHOD

This study employs a descriptive method by analyzing the results of Higher Order Thinking Skills (HOTS) tests administered to 13 students of the Biology Education Program at Pattimura University. The research subjects consisted of students enrolled in the Environmental Education course within the Biology Education Program at Pattimura University. Using purposive sampling, one of two available classes was selected based on its representativeness and student willingness to participate, ensuring diverse academic abilities for a comprehensive HOTS assessment. The test instruments were specifically designed to assess students' problem-solving and critical analysis abilities, adapted from the methodology developed (Fauzi & Abidin, 2019). The collected data were analyzed using descriptive statistics to identify score distributions and variations. Additionally, unstructured interviews were conducted to explore factors influencing students' performance in solving HOTS questions.

The critical thinking indicators measured in this test were adapted from (Abid & Rahaju, 2018), encompassing four main aspects: clarification, assessment, inference, and strategy. The test instruments in this study were designed to evaluate students' critical thinking abilities by incorporating these four key indicators. The questions in this instrument assess students' ability to identify core issues, recognize relevant information, and analyze the relationships between different parts of a problem (clarification). Furthermore, students were tested on their ability to assess the validity of information, justify their chosen strategies, and logically evaluate problem-solving steps (assessment). The ability to solve problems according to a predetermined plan, draw appropriate conclusions, and generalize findings was also included in

the measurement (inference). Additionally, the test instrument was structured to evaluate how students determine specific steps toward solutions and predict the outcomes of their applied strategies (strategy). Thus, this instrument comprehensively measures students' critical thinking abilities in systematically and logically solving problems. The collected data were subsequently analyzed and interpreted using the scoring interpretations provided by Hapsari et al. (2019).

Table 1. Score Interpretation Criteria

| Range | Interpretation |
|---|---|
| 84 – 100 | Very Good |
| 68 – 83 | Good |
| 52 – 67 | Fair |
| 36 – 51 | Poor |
| < 36 | Very Poor |

Using this approach, the study aims to gain a deeper understanding of students' thinking patterns in solving HOTS questions and the factors influencing their level of success.

## RESULT AND DISCUSSION

The data for this study were obtained through a test instrument designed with a focus on critical thinking indicators. This instrument was specifically constructed to assess students' critical thinking skills in solving problems related to modern biotechnology. The test includes questions that align with the key aspects of critical thinking, such as clarification, assessment, inference, and strategy, which were used to evaluate students' ability to analyze, evaluate, and formulate solutions. The analysis and discussion in this study provide insights into how students develop and apply critical thinking skills in understanding concepts, assessing information, and formulating solutions to challenges in modern biotechnology.

Before conducting a detailed analysis of critical thinking indicators, a descriptive table is presented, including the highest score, lowest score, mean, and standard deviation, to provide a general overview of the data distribution and trends (Table 2).

Table 2. Descriptive Statistics of Students' Competency Test

| Descriptive Data | Score |
|---|---|
| Highest Score | 93 |
| Lowest Score | 50 |
| Mean | 72,54 |
| Standard Deviation | 11,95 |

The table above presents the distribution of student scores, revealing a mean score of 72.54, which suggests a generally adequate level of comprehension, with a standard deviation of 11.95 indicating variability in performance across students. Scores range from below to above the mean, warranting further analysis of potential factors influencing these variations, which will be explored in the subsequent section. Additionally, the study extends to examining student performance across four critical thinking indicators (clarification, assessment, inference, and strategy) detailed in Table 3, which offers a nuanced perspective on areas of critical thinking proficiency and those requiring further development.

The table presents the analysis results for each critical thinking indicator. In general, pre-service biology teachers demonstrated a "good" category in clarification, assessment, and strategy,

while the inference aspect remains in the "fair" category.

Table 3. Critical Thinking Skills of Pre-Service Biology Teachers

| Indicator | Score | Interpretation |
|---|---|---|
| Clarification | 78 | Good |
| Assessment | 81 | Good |
| Inference | 61 | Fair |
| Strategy | 70 | Good |
| Mean | 72,5 | Good |

**Discussion**

Critical thinking skills constitute a fundamental competency in education, playing a significant role in the development of intellectual and professional capabilities. In an era characterized by rapid change and increasing complexity of information, individuals must be able to critically assess, analyze, and evaluate various sources of knowledge logically and systematically (Aktoprak & Hursen, 2022). For both prospective and current teachers, critical thinking is not only an essential skill to master but also a crucial ability to instill in students, enabling them to navigate academic and real-life challenges more effectively. This is because critical thinking facilitates the development of analytical, evaluative, and decision-making skills among students (Guo & Wang, 2021).

The findings of this study indicate that pre-service teachers exhibit a generally good level of critical thinking skills, with an average score of 72.5. However, there are variations in the achievement of each critical thinking aspect, where inference remains in the "sufficient" category (61), while clarification (78), assessment (81), and strategy (70) fall into the "good" category. These differences provide valuable insights into how students process information and construct solutions within the context of modern biotechnology.

Critical thinking is the ability to think clearly, logically, and independently in evaluating information, constructing arguments, and solving problems effectively. In this regard, critical thinking plays a crucial role in understanding and assessing arguments, enhancing awareness of biases and propaganda, facilitating comprehension of complex concepts, and fostering independent thinking, communication skills, and teamwork (Raj et al., 2022). Moreover, for pre-service teachers, critical thinking skills must be continuously developed to enhance problem-solving quality in both academic and professional domains (Uribe-Enciso et al., 2017).

Critical thinking is particularly essential in biological education, especially in understanding complex biotechnological concepts. The fact that clarification is categorized as "good" suggests that pre-service teachers can identify and comprehend fundamental biotechnological concepts relatively well. This reflects their ability to define problems and filter relevant information before formulating solutions. As future educators, honing clarification skills in critical thinking is crucial, as an optimal ability in this aspect helps prevent misconceptions that may lead to erroneous conclusions. In the educational context, teachers must ensure that each concept delivered to students is correctly understood to avoid misunderstandings that could impact the overall learning process (Lestari et al., 2021). Furthermore, clarification is a fundamental step in critical thinking that enables individuals to understand a

concept before proceeding to more complex stages such as analysis and evaluation (Rini & Aldila, 2023).

The assessment aspect, which obtained the highest score (81), indicates that students possess relatively strong skills in evaluating information, particularly regarding the validity and reliability of sources. Critical thinking assessment skills enhance proficiency in verifying the accuracy of information, justifying chosen strategies, and logically evaluating problem-solving steps. Moreover, problem-solving ability contributes to logical and analytical thinking skills, particularly in identifying problems, analyzing potential solutions, and assessing outcomes (Suradika et al., 2023). Additionally, problem-solving encourages students to connect previously learned concepts with new situations, thereby strengthening their analytical and reflective abilities (Rahmatika, 2022).

Meanwhile, the inference aspect received the lowest score (61), indicating that students still struggle with concluding or making predictions based on existing data. This suggests that although they can comprehend and evaluate information, the process of generalization and evidence-based reasoning still requires improvement. Inference is crucial in learning as it helps students connect acquired concepts with empirical data, enhances analytical skills, and supports evidence-based problem-solving (Saekawati & Nasrudin, 2021). Furthermore, inference is essential in science education, as it aids students in understanding the relationship between theoretical concepts and real-world applications. This skill also contributes to improving experimental data analysis (Herliandry et al., 2021). A low inference ability can lead to biased thinking and poor decision-making, as students may struggle to distinguish relevant information (Anggraeni et al., 2023).

The strategy aspect, which falls into the "good" category (70), reflects that students have a reasonable understanding of designing effective problem-solving steps. However, there is still room for improvement, particularly in applying more diverse and evidence-based strategies to achieve optimal solutions in biotechnology. Strategy in critical thinking refers to an individual's ability to select, implement, and evaluate steps to solve a problem or answer a question logically. Without strong strategic skills, students tend to rely on rote memorization of formulas or procedural steps without understanding the underlying logic (Pamungkas et al., 2019).

The variation in scores, reflected in a standard deviation of 11.95, indicates differences in critical thinking abilities among students. These disparities may be attributed to variations in academic backgrounds, experience in addressing biotechnological issues, and levels of engagement in vital discussions. Based on interviews with pre-service teachers who demonstrated high critical thinking skills, they revealed that their most frequently employed learning methods included digital research exploration and collaborative learning. This aligns with the findings of Indah et al. (2022), who stated that proficiency in research and digital literacy, combined with an academic environment that fosters discussion and reflection, are key factors in enhancing students' critical thinking skills.

In the context of teacher education, critical thinking skills are crucial as pre-service teachers are expected to transfer these competencies

to their future students. Therefore, instructional strategies should emphasize analytical and synthetic thinking exercises. According to Almulla & Al-Rahmi (2023), students who are accustomed to inquiry-based and reflective learning approaches exhibit higher critical thinking skills because they actively engage in the exploration and evaluation of information. Additionally, e-learning and technology-based learning systems can enhance critical thinking skills if designed with interactive methods that encourage reflective and analytical thinking.

The characteristics of education in Eastern Indonesia also present unique challenges in developing students' critical thinking skills. Limited access to learning resources, uneven educational facilities, and a lack of participation in broader academic forums are among the factors influencing the development of students' critical thinking abilities in this region. Limited access to technology and interactive learning materials can hinder the cultivation of critical thinking in educational environments (Mutohhari et al., 2021). Therefore, educational approaches that emphasize discussion, problem-solving, and technological integration in learning need to be further optimized to enhance students' critical thinking skills in Eastern Indonesia.

The findings of this study also indicate that while pre-service teachers' critical thinking skills are generally categorized as good, there are still areas for improvement, particularly in inference. Hence, educational interventions such as analytical thinking training, case-based learning, and problem-solving simulations in the context of biotechnology can be implemented to enhance this skill. Overall, these findings provide insights for educators and educational institutions to place greater emphasis on developing students' critical thinking skills, particularly in inference. By strengthening these abilities, it is expected that pre-service teachers will be better prepared to face challenges in the educational field and effectively guide their students in critical and analytical thinking.

This study provides novel insights into the critical thinking skills of pre-service biology teachers, particularly within the context of biotechnology education. It reveals variations in the achievement of key essential aspects of thinking clarification, assessment, inference, and strategy, highlighting differences in students' abilities to process information and construct solutions. The findings emphasize that, while overall critical thinking skills are categorized as good, areas such as inference require further improvement. The study also identifies factors influencing these skills, such as digital research exploration and collaborative learning, which are crucial for enhancing critical thinking. The impact of this research is significant, offering valuable implications for teacher education, particularly in strengthening the inference essential aspect of thinking. Educational interventions such as analytical thinking training, case-based learning, and problem-solving simulations are recommended to improve these skills. Ultimately, this study contributes to the understanding of how critical thinking can be developed in pre-service teachers, which is essential for their future role in fostering critical and analytical thinking in students.

## CONCLUSION

The research findings indicate that pre-service biology education students at Universitas Pattimura generally exhibit strong critical thinking skills, particularly in the areas of clarification, assessment, and strategy, while the inference aspect remains at a moderate level. These findings underscore the importance of more targeted educational interventions, such as problem-based learning and analytical reasoning training, to enhance students' logical reasoning abilities. Given the academic challenges in Eastern Indonesia, implementing discussion-based learning and integrating technology into the teaching process can serve as effective strategies to support the development of critical thinking skills. Strengthening these skills is expected to equip future educators better to guide students in analytical thinking and systematic problem-solving.

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