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Profiling students' critical thinking skills in the human digestive system

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ABSTRACT

Critical thinking is an important component in 21st-century Biology education, which demands the ability to critically analyze scientific concepts and information. However, students' critical thinking skills are still relatively low. This study aims to describe the profile of critical thinking skills of eleventh-grade students at a high school in North Sulawesi on the human digestive system. The method used is a quantitative approach with a descriptive design. The sample consisted of 19 randomly selected students. The research instrument was a test developed based on five critical thinking indicators according to Ennis, providing simple explanations, building basic skills, concluding, providing advanced explanations, and developing strategies and tactics. Data were analyzed descriptively quantitatively by looking at the percentage of achievement in each indicator. The results showed that most students' critical thinking skills were in the low category. As many as 74% of students were very low in providing simple explanations, and 89% were in the very low category in the advanced explanation indicator. The highest achievement only reached the sufficient category. These findings indicate that conventional Biology learning practices have not been able to encourage the development of critical thinking skills optimally. Therefore, this study emphasizes the importance of implementing profile-based diagnostic assessments and integrating active, contextual learning strategies that are oriented towards higher-order thinking skills in Biology learning.

INTRODUCTION

Critical thinking has emerged as one of the most essential competencies for students to thrive in the rapidly evolving landscape of the 21st century. In science education, critical thinking is widely recognized as a foundational skill that enables learners to analyze data, evaluate arguments, and make reasoned decisions grounded in empirical evidence (Facione, 2015); (Wandari et al., 2024). It represents a high-level cognitive ability involving reflective judgment and the capacity to interpret and evaluate information from multiple perspectives to arrive at logical conclusions. Within biology education, critical thinking is indispensable because it nurtures scientific literacy, encourages inquiry, and promotes lifelong learning. As the challenges faced by modern societies become increasingly complex—spanning from environmental issues to public health crises—developing critical thinkers capable of evidence-based reasoning becomes a fundamental educational goal (Saduakas et al., 2025); (Diartika, 2024).

In Indonesia, educational reform through the implementation of the Independent Curriculum (*Kurikulum Merdeka*) has emphasized the integration of higher-order thinking skills (HOTS) such as analysis, evaluation, and synthesis across all levels of education (Kemendikbudristek, 2022); (Pasaribu, 2023). The curriculum promotes student-centered learning that values autonomy, creativity, and contextual engagement in real-world problem-solving. This paradigm shift encourages science educators to employ learning strategies that foster analytical reasoning, argumentation, and reflection (Sebastian et al., 2023); (Ayuningrum et al., 2024). Within this framework, biology learning serves as an ideal domain for cultivating critical thinking skills, as it engages students in exploring natural phenomena, interpreting biological systems, and constructing explanations based on evidence (Bangun & Naphiah, 2021). However, despite these curricular advancements, substantial challenges persist in translating pedagogical ideals into effective classroom practice.

A growing body of research indicates that students' critical thinking skills in biology remain underdeveloped, particularly in topics requiring conceptual reasoning and abstraction (Nuryanti et al., 2018); (Santi et al., 2018). The persistence of conventional, teacher-centered instructional models—which emphasize rote memorization and factual recall—has limited students' opportunities to practice analytical thinking and scientific reasoning (Hamdani M. et al., 2019); (Putri et al., 2021). Such practices hinder learners from engaging deeply with content, connecting biological concepts to authentic contexts, and articulating logical arguments (Misfalla, 2020); (Jamil et al., 2024). Consequently, despite national reforms emphasizing competency-based learning, many students continue to demonstrate a superficial understanding of biological material and struggle to apply knowledge critically (Johnson & Czerniak, 2023); (Pasutri & Yeni, 2022). Addressing this gap requires systematic efforts to assess and develop students' critical thinking abilities through structured diagnostic and instructional interventions.

Research suggests that effective development of critical thinking skills demands intentional learning environments that promote inquiry, reflection, and collaborative exploration (Manishimwe et al., 2022Harahap et al., 2023). However, in Indonesian classrooms, teachers often face multiple constraints such as limited access to technological resources, insufficient training in inquiry-oriented pedagogy, and rigid assessment systems emphasizing standardized testing (Jamil et al., 2024;Supit & Winardi, 2024). These systemic barriers restrict the adoption of innovative teaching models like Inquiry-Based Learning (IBL), Problem-Based Learning (PBL), and Socio-Scientific Issues (SSI)-based approaches that are known to strengthen students' higher-order cognitive processes (Chavda et al., 2023;Liline et al., 2024). Therefore, to improve the quality of science education, it is crucial to explore strategies that not only enhance students' cognitive outcomes but also provide a comprehensive understanding of their existing critical thinking profiles.

Several pedagogical approaches have demonstrated effectiveness in fostering critical thinking skills in biology education. Inquiry-Based Learning encourages students to formulate questions, design investigations, and draw conclusions through empirical reasoning (Yaki, 2022). This approach promotes active participation and curiosity-driven exploration, allowing students to construct meaning through direct interaction with phenomena. Similarly, PBL engages learners in authentic, real-world problems that require reasoning, data interpretation, and collaborative solution-seeking, thereby nurturing analytical and evaluative thinking (Fakhrizal & Hasanah, 2021; Harahap et al., 2023). Furthermore, SSI-based instruction integrates scientific content with ethical and social dimensions, challenging students to deliberate, justify positions, and evaluate consequences of scientific decisions

(Smith & Paradise, 2022). Each of these models underscores the necessity of moving beyond traditional content transmission toward pedagogies that foster reasoning and reflective judgment.

Within this pedagogical landscape, the human digestive system serves as a particularly relevant and effective context for developing critical thinking skills. As one of the core topics in biology, it encompasses interconnected physiological processes that lend themselves to analytical exploration and contextual understanding (Andini et al., 2022; Ristanto et al., 2020). Students are encouraged to investigate questions related to nutrition, health, and body function, which provide opportunities to apply reasoning to phenomena that directly affect daily life. Engaging learners in activities that examine digestive processes, identify disorders, or evaluate dietary habits can stimulate higher-order thinking by linking scientific concepts to real-world implications (Zhu, 2023; Tuaputty et al., 2023). Moreover, such contextual learning aligns with the goals of the Independent Curriculum, which emphasizes problem-solving and inquiry as vehicles for meaningful science learning.

Despite the recognized importance of critical thinking in biology education, few studies have systematically mapped students' critical thinking profiles across specific topics such as the human digestive system. Previous investigations have largely focused on general academic achievement or content mastery, overlooking detailed cognitive indicators that reveal how students reason, analyze, and evaluate scientific problems (Riwayati & Cintamulya, 2017). As a result, the existing literature lacks fine-grained diagnostic data that could inform tailored interventions or curriculum design. Mapping the profile of students' critical thinking skills provides valuable insights into which cognitive domains—such as inference, explanation, and evaluation—require targeted instructional attention. Such information is essential for teachers seeking to design adaptive and contextually relevant learning strategies that address specific weaknesses rather than applying uniform, one-size-fits-all approaches.

The current study seeks to fill this gap by investigating the profile of eleventh-grade students' critical thinking skills in the topic of the human digestive system. Specifically, it aims to analyze students' achievements across Ennis's five critical thinking indicators—simple explanations, basic skills, conclusion drawing, further explanations, and strategy and tactics—to provide an in-depth understanding of their reasoning patterns. This profile-based diagnostic approach offers a more nuanced representation of students' cognitive performance and serves as an empirical basis for refining biology instruction under the Independent Curriculum framework. The novelty of this study lies in its integration of topic-specific analysis with a validated theoretical model of critical thinking, providing evidence that can guide teachers and curriculum developers in constructing more effective, inquiry-driven, and contextually responsive science learning environments.

METHODS

Research Design

This study adopted a quantitative descriptive design to analyze the profile of students' critical thinking skills in the topic of the human digestive system. Quantitative descriptive research is used to describe and interpret phenomena as they are, based on measurable and observable data, enabling the identification of patterns and tendencies within the studied population (Nurhabiba & Misdalina, 2023). According to Jariyah and Husamah (2024), descriptive research in education provides a foundational understanding of learning phenomena that can inform the development of pedagogical interventions. Through this method, the study aims to offer empirical insight into students' achievement across five indicators of critical thinking, as defined by Ennis (1993). The choice of this design aligns with previous critical thinking research that utilizes structured test instruments to capture detailed profiles of students' reasoning abilities in specific learning contexts (Weidman & Salisbury, 2020).

Population and Samples

The study was conducted in February 2025. The population consisted of all eleventh-grade science students enrolled in the school. From this population, a sample of 19 students was selected using a random sampling technique. Random sampling provides equal opportunities for each student to participate, thereby minimizing sampling bias and enhancing the representativeness of the findings (Prasetyo et al., 2022). This technique is particularly suitable for quantitative research involving small populations, as it maintains statistical validity while controlling for potential selection bias. The selected students represented a balanced gender composition and academic performance levels, ensuring that the findings reflected diverse cognitive profiles across the class population, with student demographics consisting of 12 female students and 7 male students, with an age range between 17-18 years. The sample size, although limited, aligns with the nature of diagnostic studies that aim to obtain detailed and context-specific data rather than broad generalizations (Purwanto et al., 2023). The selected students represented a balanced composition of gender and academic performance levels, ensuring that the findings reflect diverse cognitive profiles across the class population.

Instrument

The research instrument used was an essay test consisting of five questions covering critical thinking indicators, developed according to the framework established by (Ennis, 1993). The test comprised context-based descriptive questions aligned with the topic of the human digestive system in biology. The instrument measured five indicators of critical thinking 1) providing simple explanations, 2) building basic skills, 3) concluding, 4) providing further explanations, and 5) organizing strategies and tactics. Each indicator reflects a core dimension of critical reasoning, encompassing students' abilities to identify arguments, evaluate evidence, and propose solutions based on logical reasoning (Weidman & Salisbury, 2020). The use of open-ended, contextually grounded questions was intended to assess not only factual knowledge but also analytical depth and reasoning coherence. This instrument has gone through a content validation process by material experts and learning evaluation experts to ensure the suitability of the content with the indicators being measured.

Procedure

The data collection technique in this study involved administering a test to students. This test was designed to measure the critical thinking skills of the students being studied. This test allowed for systematic and measurable data collection and provided a clear picture of the students' level of understanding and skills in a context relevant to the research objectives. The research procedure consisted of several systematic stages designed to maintain consistency and transparency throughout the study. The first stage involved compiling test items based on Ennis's five indicators and the human digestive system. The second stage involved expert validation and pilot testing. Feedback obtained during the pilot test was used to revise ambiguous or overly difficult questions, ensuring readability and fairness across student ability levels. The third stage was the administration of the validated critical thinking test to the selected sample of Grade XI students. The test was conducted under standardized classroom conditions to prevent external factors from influencing performance. Each student was allotted 60 minutes to complete the test. Responses were collected immediately after completion to maintain data integrity. In the fourth stage, all responses were reviewed and scored using a rubric developed based on Lestari and Ilhami (2022), as shown in Table 1**.**

Table 1.
Assessment Rubric for Critical Thinking Test

No	Score	Information
1.	4	Very good
2.	3	Good
3.	2	Enough
4.	1	Less

Source: (Lestari & Ilhami, 2022)

The final stage of the procedure involved summarizing test results from all respondents and processing them using quantitative techniques. Scores were tabulated to represent the level of achievement for each indicator of critical thinking**. T**his procedure aligns with methods employed in previous quantitative studies on students' critical thinking (Amin et al., 2020); (Pertiwi, 2022)**.** In addition to categorical classification, data were visualized through bar graphs for each indicator to illustrate the distribution of student performance.

RESULTS AND DISCUSSION

The results of the study revealed that the overall profile of students' critical thinking skills on the topic of the human digestive system was in the low category. The analysis of the critical thinking test refers to Ennis, (1993) five indicators, which showed that students struggled to demonstrate higher-order reasoning across all components. Overall, most students' scores fell into the "very low" or "low" categories, indicating limited development of analytical and evaluative thinking skills. These findings confirm earlier research suggesting that Indonesian high school students generally exhibit low levels of critical thinking in biology learning contexts (Sugiharti & Gayatri, 2021); (Hamdani M. et al., 2019). Overall, the results of the analysis of students' critical thinking skills are presented in Figure 1.

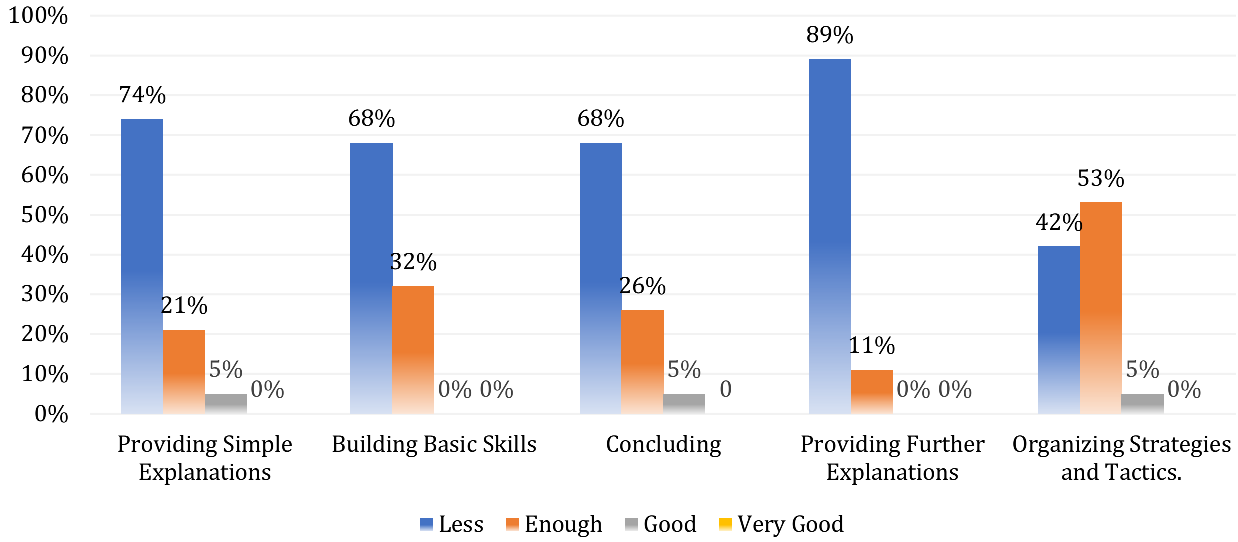

Figure 1. Percentage Comparison of Each Indicator of Students' Critical Thinking Ability Results

Based on Figure 1 known that the first indicator, students' ability to provide simple explanations, demonstrated notably weak performance. The descriptive analysis showed that 74% of students were classified as "less," 21% as "enough," and only 5% as "good." This trend suggests that most students were unable to identify relevant information or articulate coherent scientific explanations for biological phenomena. Such difficulties align with previous findings that students often oversimplify complex biological concepts and rely on memorized facts rather than constructing meaningful explanations (Ilham et al., 2023; Arifah et al., 2023). Furthermore, Umami et al., (2023) and Yuliastrin et al., (2023) found that misconceptions and fragmented conceptual understanding are prevalent when students attempt to explain biological systems, especially those involving abstract mechanisms such as digestion. These results highlight the need for inquiry-based and guided inquiry learning approaches, which have been shown to strengthen students' ability to construct clear and concise explanations (Amizera et al., 2023; Hidayatullah et al., 2021). Instructional strategies emphasizing scientific discourse, experimentation, and reflection foster more accurate conceptualization and improve students' confidence in articulating scientific ideas (Marnita et al., 2021; Sebastian et al., 2023).

Students' performance in the "building basic skills" indicator also fell within the low category. A total of 68% of participants scored in the "less" range and 32% in the "enough" range. This indicator assesses students' competence in identifying assumptions, definitions, and information sources relevant to biological reasoning. The results suggest weak foundational reasoning skills, particularly in linking observations with appropriate scientific concepts. This pattern mirrors previous studies reporting that students often face difficulties in recognizing underlying assumptions in biology tasks, indicating a gap between conceptual knowledge and scientific reasoning (Purnamasari et al., 2025; Rochim et al., 2025). Mastery of basic critical thinking skills correlates positively with higher-order reasoning such as synthesis and evaluation (Gavgani et al., 2021; Napitupulu et al., 2024). The current findings, therefore, imply that deficiencies at the basic level may hinder the development of advanced reasoning competencies. According to Rohman et al., (2024), assessment designs integrating open-ended or scenario-based questions can encourage students to apply reasoning in meaningful contexts. In contrast, the dominance of traditional testing formats focused on recall may contribute to the observed limitations in students' critical reasoning performance.

The results of the third indicator revealed that 68% of students were categorized as "less," 26% as "enough," and 5% as "good." This indicates a consistent pattern of low ability in making logical inferences and formulating evidence-based conclusions. The inability to synthesize information or distinguish between correlation and causation likely contributes to this outcome. Many students rely heavily on rote learning, which limits their ability to analyze data critically or generate valid generalizations (Sulistiowati, 2022). Instructional interventions such as argumentation-based and guided inquiry learning have demonstrated success in improving students' capacity to conclude empirical data (Ladachart et al., 2022; Amanda et al., 2022). By fostering active engagement with scientific evidence, these models promote deeper conceptual understanding and enable students to connect theory with practice (Harahap et al., 2023).

Analysis of the fourth indicator showed that 89% of students were classified as "less," while 11% were "enough." This reflects students' limited capacity to elaborate on arguments, provide justifications, or integrate multiple sources of information when explaining biological concepts. These results found that low conceptual understanding often impairs students' ability to develop coherent arguments and extended explanations. (Misfalla, 2020) similarly noted that monotonous, teacher-centered learning environments restrict opportunities for discussion and exploration, hindering students' advanced reasoning development. A lack of elaborative reasoning can also stem from limited exposure to problem-based learning (PBL) environments that encourage students to explore complex scenarios (Laksmi et al., 2021). PBL, coupled with argumentation-based learning, enables learners to construct explanations grounded in evidence while engaging in collaborative reasoning (Huang et al., 2020).

The final indicator, "organizing strategies and tactics," also demonstrated weak outcomes. The results showed that 42% of students were in the "less" category, 53% were "enough," and only 5% were "good." This suggests that most students lacked the ability to design systematic approaches to problem-solving or formulate structured reasoning strategies. Such limitations are consistent with prior studies showing that students often depend on surface-level reasoning rather than employing systematic, evidence-based analytical methods (Suryono et al., 2023); (Juhji & Nuangchalerm, 2020). Previous research indicates that students who engage in structured inquiry, project-based, or cooperative learning environments tend to exhibit stronger strategic reasoning abilities (Triani et al., 2023; Tika & Agustiana, 2021).

The findings of this study reveal that the critical thinking skills of eleventh-grade students on the topic of the human digestive system remain predominantly in the low category across all five indicators of Ennis, (1993) the framework. This overall low performance highlights the persistent challenges faced by students in transitioning from rote-based learning to analytical reasoning within biology education. Previous studies have consistently reported similar trends, showing that students exhibit limited ability to analyze data, make inferences, and justify conclusions, particularly when learning abstract or process-oriented biological topics (Rini et al., 2020; Nuryanti et al., 2018). These results underscore the urgent need to strengthen critical thinking instruction in science education through pedagogical innovations that promote active engagement and metacognitive reflection.

The implications of these findings are particularly significant for implementing inquiry-based and independent learning models, as emphasized in Indonesia's Kurikulum Merdeka. Inquiry-based approaches rely on students' ability to formulate questions, analyze data, and synthesize findings—skills that are contingent upon foundational critical thinking competencies (Lestari et al., 2024). When these foundational skills are weak, as shown in this study, students are likely to struggle in open-ended or problem-based tasks, leading to frustration and decreased motivation (Susilowati et al., 2023). Therefore, teachers must ensure that critical thinking instruction is systematically embedded into lessons, beginning with structured guidance and gradually transitioning toward student independence (Kusmaryono, 2023). Without explicit scaffolding, students may fail to benefit from inquiry-based models intended to foster higher-order thinking.

The results of this study also have implications for teacher professional development and curriculum design. Diagnostic data obtained from critical thinking assessments offer valuable insights for tailoring teacher training programs to address specific weaknesses in teaching practices (Özdemir, 2021). For example, if data indicate widespread deficiencies in drawing conclusions or providing further explanations, teachers could undergo targeted training in argumentative pedagogy or inquiry facilitation techniques. This alignment between diagnostic evidence and professional development ensures that teaching strategies are responsive to students' actual needs (Supartin, 2023). At the curriculum level, integrating critical thinking objectives into learning outcomes fosters a coherent focus on reasoning and analysis, rather than rote memorization. This targeted approach improves instructional quality and student engagement, ultimately enhancing academic achievement.

Furthermore, integrating assessment with pedagogy offers a promising direction for future educational practice. Continuous assessment systems aligned with inquiry-based and problem-based learning can help monitor students' critical thinking progress in real time, allowing for adaptive teaching strategies (Chytrý et al., 2020). Formative assessments emphasizing reasoning and evidence evaluation can complement summative assessments that measure conceptual mastery. (Nuryami, 2023) and (Susanti, 2020) emphasize that linking assessment data with pedagogical interventions creates a feedback loop that enhances both teaching and learning processes. Such integration supports sustainable improvement in students' analytical reasoning, ensuring that assessment serves not merely as measurement but as a tool for fostering intellectual growth.

CONCLUSION

This study concluded that twelfth-grade students' critical thinking skills on the topic of the human digestive system were generally low across all five indicators of Ennis's (1993) framework: providing simple explanations, building on basic skills, drawing conclusions, providing further explanations, and developing strategies and tactics. Quantitative analysis revealed that the majority of students scored in the "very low" to "low" categories, with percentages ranging from 68% to 89% across all indicators. The most critical weaknesses were found in the ability to provide further explanations and draw valid conclusions, reflecting a lack of analytical depth and coherence in reasoning. These findings suggest that conventional teacher-centered learning limits students' engagement in reflective and analytical thinking. This study underscores the importance of adopting inquiry-based, argumentation-based, and problem-based learning approaches to enhance students' reasoning and elaboration skills. From a theoretical perspective, integrating constructivist, metacognitive, and cognitive load frameworks can provide valuable insights into how students process and apply scientific concepts. This study contributes to the development of science by offering an in-depth diagnostic profile of students' critical thinking skills in biology

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