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Original Research

Correlational Study Between Conceptual Understanding and Critical Thinking Skills of Students on Biology Materials

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ABSTRACT

This study aims to identify the relationship between students' understanding of biological concepts and their critical thinking skills. This research uses a quantitative approach with a correlational study design. The research was carried out in Tanjung Jabung Barat Regency, which involved a sample of 328 class XI students, who were selected using simple random sampling from a population of four selected high schools. The data was collected using two validated research instruments, namely the biology concept understanding test and the critical thinking skills test. Descriptive statistics and Pearson Product-Moment correlation were used to test the strength and direction of correlation between the two quantities. The average score for students' understanding of biology concepts was 59.32 (SD = 15.28), while the average score for critical thinking skills was 53.15 (SD = 9.20). This indicates that, on average, students still face difficulties in both aspects. The analysis results showed a significant positive correlation between students' understanding of biological concepts and their critical thinking skills ($r = 0.797$, $p < 0.01$). These findings indicate that a good understanding of biological concepts can improve students' critical thinking skills, which are essential for the development of higher-order thinking skills. The critical thinking scores are significantly explained by the students' conceptual understanding since $R^2 = 0.635$, which shows that the biological concepts comprehension could account for 63.5% of the critical thinking variance, while the other 36.5% will be due to other factors. These findings highlight the importance of understanding concepts for developing critical thinking skills. The study suggests that teaching strategies focusing on understanding the biological concepts that the students are being taught should come first for students to develop their higher-order thinking skills. Moreover, it is advisable to broaden the scope of contributing factors to encompass such issues as teaching approaches and students' active participation in future studies. The findings offer useful information for the development of curricula, the goal of which is to integrate the conceptual understanding and critical thinking skills of those being taught biology.

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1. INTRODUCTION

Education occupies one of the central positions in the development of an individual and society, and the quality of education determines the growth level of the nation's development (Hartatiana et al., 2022; Muhardi, 2004; Safitri et al., 2022). As a discipline that comprises the processes of acquiring set knowledge, skills, and character, education not only prepares people to cope with the challenges in the workplace but also molds a well-rounded and insightful character. In the era of globalization, education is the factor that helps in raising innovative, creative, and nation-building offspring. On a personal scale, education serves as windows and doors to better opportunities, such as better employment, better standards of living, and decision-making. Whereas on a societal scale, education brings about developed, tolerant, and competitive societies. Thus, education is a fundamental issue that needs to be improved in all aspects, even in biology.

Biology is a branch of science that studies life and all processes related to living things (Barbieri, 2012). This science is vital to human life because it provides an in-depth understanding of ecosystems, health, agriculture, and biology-based technology. For example, understanding genetics helps develop effective medical therapies, while knowledge of ecology helps maintain the balance of nature and mitigate climate change. In addition, biology also underlies various technological innovations, such as biotechnology, that produce solutions for food and energy needs. In education, biology is one of the subjects that enriches students' insights about themselves and the surrounding environment (Jeronen et al., 2017). Therefore, mastery of biology is important for individuals who want to pursue a career in science and is relevant for every individual in everyday life. The importance of biology is increasingly evident in the face of global challenges such as pandemics, environmental crises, and food safety.

Conceptual understanding of biology and critical thinking skills are two interrelated aspects of the learning process. Conceptual understanding is the ability to master, organize, and apply scientific knowledge in specific contexts. On the other hand, critical thinking skills include analyzing information, evaluating arguments, and making decisions based on evidence. Critical thinking skills are essential for facing challenges and making wise decisions in this complex information age (Amelia, 2024; Moustahfir & Brigui, 2024). Academics and those in active environments tend to use these skills for purposes such as analyzing health issues or evaluating environmental policies. Therefore, instilling biological understanding will likely enable students to achieve critical abstraction and hone their reasoning skills. Investigating the relationship between biological concept understanding and critical thinking skills is important because the ability to understand deep biological concepts can improve students' ability to think analytically and critically, which is essential for evidence-based decision-making in science and everyday life. By understanding basic concepts in biology, students not only learn facts, but also develop the ability to analyze, evaluate, and apply their knowledge in complex real-life situations.

Research on the relationship between understanding biological concepts and critical thinking skills is crucial in education (Fitriani et al., 2020). Good concept understanding can be the basis for training students to think critically (Malagola et al., 2023), while critical thinking can help students deepen concept understanding. Both are essential learning objectives that students should continue to be trained in. Correlational studies between the two provide insights into how biology learning can be designed to achieve more holistic educational goals. By knowing the pattern of this relationship, educators can develop more effective and relevant teaching methods. For example, inquiry-based or problem-based learning methods can be explored to see how much they support the simultaneous development of these two abilities. Furthermore, the results of this study can also provide input for education policymakers in designing a curriculum oriented toward developing 21st-century skills. Therefore, this research is relevant to the academic community and the wider community, which is interested in the quality of education.

2. METHOD

This study used a quantitative approach with a correlational study design to analyze the relationship between students' understanding of biology concepts and critical thinking skills. A correlational study is a type of research that aims to determine whether there is a relationship between two or more variables (Umstead & Mayton, 2018), as well as the strength and direction of the relationship. In this study, no manipulation of the variables under study was conducted; the relationships that occurred naturally were measured and analyzed. The study was conducted in four high schools in Tanjung Jabung Barat Regency, with the research subjects consisting of 11th grade students. The research population consisted of 328 students, and the sample was taken using simple random sampling. The four senior high schools were selected randomly from four schools that met certain criteria, such as representative location and diversity of student population. This approach was chosen to ensure that every student had an equal chance of being

selected as a research participant, while also increasing the representativeness of the sample. Thus, the results of the study can describe the relationship between variables with a high degree of accuracy.

The research tools used consisted of two types of tests. The first test was a biology concept comprehension test consisting of 14 multiple-choice questions designed to measure the extent to which students understood the biology concepts taught. The second test was a critical thinking skills test consisting of five descriptive questions. These questions measure students' ability to analyze, evaluate, and solve problems critically related to biology material. All instruments have undergone validation to ensure that the questions meet the validity and reliability criteria required in quantitative research. Construct validation was carried out by two senior university lecturers and two senior teachers. Meanwhile, a pilot study was conducted on 68 students.

Data was collected directly at school by giving test instruments to students selected as samples. The test was carried out in one session for each student with close supervision from researchers and subject teachers to ensure the honesty and accuracy of the results. After the data was collected, the analysis was carried out using the Pearson Product-Moment correlation statistical test. This analysis aims to determine the strength and direction of the relationship between the concept understanding variable as the independent variable (X) and critical thinking skills as the dependent variable (Y). The analysis process includes calculating each variable's mean value and standard deviation, testing the assumptions of normality and linearity of data, calculating the correlation coefficient, and coefficient of determination. The analysis results are then interpreted to answer the research questions and provide insight into the importance of developing learning that integrates concept understanding and students' critical thinking skills.

3. RESULTS AND DISCUSSION

3.1. Bolology conceptual understanding and critical thinking skills

This study first discusses descriptive analysis of data on concept understanding scores and students' critical thinking skills. The results of the analysis as shown in Table 1. The data obtained were analysed descriptively to provide an overview of the distribution of scores on both variables. The descriptive statistics we calculated included the minimum, maximum, mean, standard deviation, and skewness for each variable.

Based on the analysis, the conceptual understanding score showed a minimum value of 14.29 and a maximum of 100.00. The mean value was 59.32, with a standard deviation of 15.28, indicating a moderate variation in the scores obtained by students. The data distribution had a skewness of 0.325 with a standard error of 0.135, indicating that scores were slightly skewed to the right but still close to a normal distribution. This finding indicates that many grade XI students still have difficulties understanding important biological concepts. As found in previous research, many students experience difficulties when faced with biological concepts (Putri et al., 2024; Tanner & Allen, 2005; Tekkaya et al., 2001). Biological material has a broad scope, even many abstract concepts, which is one of the reasons students find it difficult to understand the material. On the other hand, students also tend to only focus on memorizing without understanding (Wardyaningrum & Suyanto, 2019).

The critical thinking ability variable's minimum value was 20.00, while the maximum value reached 84.00. The mean score of critical thinking ability was recorded at 53.15, with a standard deviation of 9.20, indicating that the score variation was smaller than that of conceptual understanding. The data distribution for critical thinking skills had a skewness of -0.011, indicating that scores were almost symmetrical. The mean score of students' critical thinking skills, which only reached 53.15 with a relatively small standard deviation (9.20), showed that most students were below the expected standard. The results of this study are in line with the findings of previous researchers, such as Mahanal et al. (2019), Anwar et al. (2020), Alsarayreh (2021), and several other researchers who showed that students' critical thinking skills in biological disciplines tend to be low.

Table 1. The statistic descriptive of conceptual understanding and critical thinking skill score

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Conceptual_understanding	14.29	100.00	59.3200	15.27526	.325	.135	14.29
Critical_thinking	20.00	84.00	53.1463	9.19795	-.011	.135	20.00
Valid N (listwise)	14.29	100.00	59.3200	15.27526	.325	.135	14.29

Some critical thinking indicators, such as the ability to construct evidence-based arguments, evaluate the validity of information, and make logical conclusions, are often not optimally mastered by students. Also, the ability to use various information to make final decisions is difficult for students to master (Nur et al., 2024). These skills are essential in learning biology, especially in understanding complex concepts such as ecology, genetics, and evolution that require in-depth analysis and scientific reasoning. Several factors can cause a low level of critical thinking skills. First, the learning approach is still dominant in memorizing concepts rather than applying concepts in a real context. Learning that only emphasizes students‘ ability to remember has no significant impact on student's critical thinking skills (Ironside, 2005; Snyder & Snyder, 2008; Willingham, 2008). Second, the lack of use of learning methods that stimulate students to think critically, such as problem-based learning or scientific experiments (Fitriyah & Ghofur, 2021; Ratnawati et al., 2020; Taqwa & Rivaldo, 2019; Yulianti & Gunawan, 2019). Thirdly, there is a lack of emphasis on discussions and collaborative activities that encourage students to ask critical questions and defend their arguments (Styers et al., 2018). This condition has profound implications for students' readiness to face the challenges of the modern world that require critical thinking skills to solve complex problems. This is considering the importance of critical thinking skills to be trained in students as one of the 21st-century skills. Therefore, strategic efforts are needed to improve students' critical thinking skills. Teachers need to adopt innovative learning approaches that focus on mastering the material and involve students actively in the critical thinking process. In addition, learning evaluations should be designed to measure higher-order thinking skills so that students are trained to analyze and solve problems, not just remember facts.

3.2. Correlation of conceptual understanding and critical thinking skills

Analysis of the relationship between understanding biological concepts and critical thinking skills showed that both variables fulfilled the assumption of linearity (Figure 1). This linearity test is important for parametric statistics, as is the normality test (Hansen, 1999). This linearity indicates a proportional relationship between students' understanding of biological concepts and their critical thinking skills. In other words, an increased understanding of biological concepts accompanies increased critical thinking ability.

The statistical analysis conducted in this study supports this relationship, with the data pattern showing a positive linear relationship. These results illustrate that understanding biological concepts is essential as a learning objective and a prerequisite for developing critical thinking skills. In the context of learning, this confirms that deep concept-based learning should be prioritized before training students in more complex tasks, such as evaluation or synthesis of information. As teachers, we need to realize that in teaching, we cannot train students in complex skills, such as critical thinking skills, before students understand the fundamental concepts of biology. The existence of this linear relationship also opens up opportunities to design learning strategies that integrate concept understanding with critical thinking activities. For example, problem-based or project-based learning can strengthen the relationship between these two abilities. Thus, students not only theoretically understand biological concepts but can also apply them to solve real-world problems.

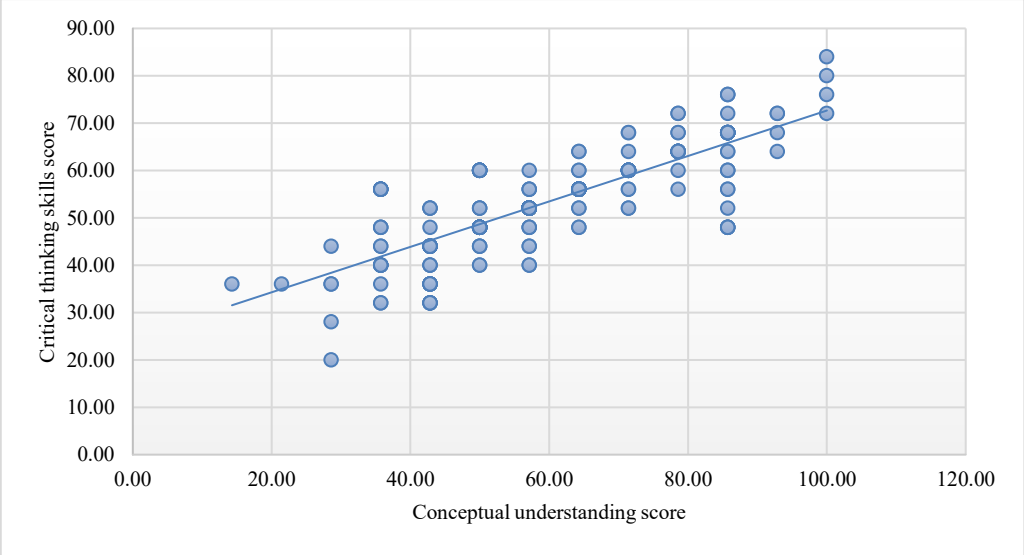

Figure 1. Linearity Plot of The Relationship Between Understanding of Biological Concepts and Critical Thinking Skills

Table 2. The result of Pearson Product Moment analysis

		Conceptual understanding	Critical thinking
Conceptual understanding	Pearson Correlation	1	.797**
	Sig. (2-tailed)		.000
	N	328	328
Critical thinking	Pearson Correlation	.797**	1
	Sig. (2-tailed)	.000	
	N	328	328

**. Correlation is significant at the 0.01 level (2-tailed).

Furthermore, the correlation test results between the two variables are shown in Table 2. The Pearson Product-Moment correlation analysis results showed a strong and statistically significant relationship between the understanding of biological concepts and students' critical thinking skills. Based on the correlation table, the correlation coefficient (r) value is 0.797 with a significance level (Sig. 2-tailed) of 0.000. This value is below the threshold of 0.01, so it can be concluded that the relationship between the two variables is significant at the 99% confidence level. The correlation coefficient of 0.797 indicates that the relationship between understanding of biological concepts and critical thinking skills is positive and very strong. In other words, the better the students' conceptual understanding of biological concepts, the higher their critical thinking skills, and vice versa. The results of this study reinforce the data that conceptual understanding is an important aspect that students must possess before practicing other thinking skills, such as critical thinking skills. Wulandari (2018), Dessie et al. (2024), Wahyuningtyas & Wuryadi (2021), and Çoban & Erol (2020) have also found similar research results; there is a relationship between concept understanding and critical thinking skills. To interpret the strength of this relationship, the coefficient of determination (R^2) is calculated by squaring the correlation coefficient value. The R^2 value obtained is 0.635, or equivalent to 63.5%. This means that the understanding of biological concepts can explain 63.5% of the variation in students' critical thinking skills. The remaining 36.5% can be caused by other factors outside the concept understanding variable.

This result confirms the importance of mastery of biological concepts as a major factor in supporting the development of students' critical thinking skills. Therefore, learning strategies that emphasize an in-depth understanding of biological concepts need to be implemented to support better critical thinking skills. In designing learning, teachers also need to consider important aspects that support the improvement of students' conceptual understanding and critical thinking skills (Taqwa et al., 2019). In addition, it is also necessary to explore other factors that may affect critical thinking skills, such as learning methods, learning motivation, and students' practical experience. Further research should also explore other skills that factor into developing critical thinking skills. The results of this correlation provide a strong foundation for curriculum development that not only targets mastery of material but also trains students in higher-order thinking skills.

4. CONCLUSION

This study highlights a significant relationship between students' understanding of biological concepts and their critical thinking skills. The findings reveal that many students struggle to grasp fundamental biological concepts, hindering critical thinking development. Challenges such as the abstract nature of biological topics, reliance on rote memorization, and insufficient use of learning strategies that foster critical analysis contribute to these difficulties. The analysis shows that a deeper comprehension of biological concepts is a primary learning objective and a prerequisite for enhancing critical thinking. This relationship underscores the need for innovative teaching approaches integrating conceptual learning with activities encouraging higher-order thinking. Problem-based and project-based learning can help students apply theoretical knowledge to practical problem-solving, bridging the gap between understanding and critical thinking. Furthermore, the study emphasizes the importance of re-evaluating teaching methods and assessments to focus on higher-order cognitive skills rather than memorization. Future research should explore additional factors influencing critical thinking, such as motivation, experiential learning, and collaborative strategies. This work provides a foundation for curriculum development aimed at nurturing conceptual understanding and critical thinking as essential competencies for 21st-century learners.

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