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Mathematical Challenges in Biology: Identifying Core Learning Difficulties

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Abstract: Biology students often face difficulties in understanding basic mathematical concepts, which can impact their comprehension of advanced science courses. This study aims to identify the key mathematical topics that pose challenges for first-year biology students at a public university in Indonesia to facilitate instructional improvements before the final exam. A mixed-methods research design was employed, combining quantitative analysis of midterm exam results from 91 students enrolled in a Basic Mathematics course with qualitative insights from follow-up interviews. The quantitative data included completion time and accuracy rates across six key topics: equations and inequalities, matrices, absolute value, real numbers, probability, and sets. The results indicated that probability had the longest average completion time (4 minutes 36 seconds), while absolute value had the highest error rate, with only 13.19% correct responses. Further interviews revealed that students struggled with understanding the formal concept of absolute value and often misapplied probability rules for independent events. These findings highlight the need for improved teaching strategies, particularly for topics with high error rates, such as concept-based approaches and more structured problem-solving exercises. Enhancing students' mathematical proficiency through targeted interventions is expected to better prepare them for future academic challenges.

Keywords: Absolute value, Basic mathematics, Biology students, Learning improvement, Mathematical difficulties, Probability

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INTRODUCTION

Mathematics is an essential subject for students in various fields, including biology, where it plays a crucial role in areas such as statistical analysis, population modeling, and genetic probability (Etobro & Fabinu, 2017; Fleischner et al., 2017; Maass et al., 2019). However, many students, particularly those in non-mathematical disciplines, often face significant difficulties when engaging with mathematical concepts. These difficulties often stem from gaps in foundational mathematical knowledge, a lack of confidence in applying mathematical reasoning (Gunarti et al, 2022; Harini et al, 2018) or challenges in bridging the gap between abstract mathematical theories (Harini, 2019) and biological applications.

Previous studies have highlighted similar challenges in mathematics learning among biology students. For example, research by (England et al., 2019; Flanagan & Einarson, 2017; Hoffman et al., 2016) emphasized the growing need for quantitative skills in modern biology, yet many students enter higher education with insufficient mathematical preparation. (Cooper et al., 2018; England et al., 2019; Everingham et al., 2017) found that students often experience anxiety when dealing with mathematical problems in biology courses, leading to decreased engagement and performance. While these studies underscore the importance of integrating mathematics into biological contexts, they primarily focus on broad pedagogical recommendations rather than identifying the specific mathematical topics that pose the greatest difficulties for students. This study addresses this gap by analyzing student performance across key mathematical topics to pinpoint the most challenging areas, providing empirical evidence to guide targeted instructional interventions.

One of the key factors contributing to students' difficulties is their struggle with critical thinking in mathematical contexts (Ikhsan & Sa’adah, 2024; Sriwijayati et al., 2024; Zahro & Zuhri, 2024). Critical thinking in mathematics involves the ability to analyze problems, evaluate different solution strategies, and justify reasoning based on logical principles. Many students, however, tend to rely on rote memorization rather than developing deeper analytical skills. As a result, when faced with unfamiliar or complex mathematical problems, they experience difficulty in constructing coherent problem-solving approaches.

In the context of biology education, critical thinking plays an even more crucial role, as mathematical reasoning is often required to interpret data, analyze trends, and make predictions. For instance, when working with probability in genetics or statistical models in ecology, students must not only apply mathematical formulas but also critically assess the implications of their results. Without strong critical thinking skills, students may struggle to distinguish between correlation and causation, interpret statistical significance, or apply mathematical reasoning to real-world biological problems.

Furthermore, students’ difficulties in mathematics are often linked to their ability to make connections between concepts (Miswaro & Zuhri, 2023; Harini, 2024). Mathematics in biology is not learned in isolation but rather integrated into various biological topics, requiring students to transfer their mathematical knowledge across disciplines. Research has shown that students who struggle with critical thinking in mathematics often have trouble recognizing the relevance of mathematical principles in biological contexts. This disconnect can lead to misconceptions, such as misinterpreting exponential growth in population models or failing to grasp the probabilistic nature of genetic inheritance.

Another challenge related to critical thinking is students’ ability to evaluate the reasonableness of their solutions (Purba et al, 2019; Zuhri et al, 2022). When solving mathematical problems, students should be able to verify whether their answers align with logical expectations. However, many students exhibit a lack of self-monitoring skills, often accepting incorrect answers without question. This issue is particularly evident in areas such as probability and statistics, where intuitive reasoning sometimes conflicts with mathematical reality. For example, students may struggle with understanding why independent events should be multiplied in probability calculations or why a statistically significant result does not necessarily imply practical significance.

The role of instructional approaches in fostering critical thinking cannot be overlooked. Traditional teaching methods that emphasize procedural fluency without encouraging deeper exploration may contribute to students' struggles. Research suggests that active learning strategies, such as inquiry-based learning and problem-based learning, can help students develop stronger critical thinking skills in mathematics. By engaging students in discussions, encouraging them to justify their reasoning, and providing real-world applications, educators can create learning environments that promote deeper conceptual understanding and enhance students' ability to think critically about mathematical problems in biology.

Addressing these challenges requires not only adjustments in curriculum design but also targeted interventions that explicitly develop students' critical thinking skills. Providing structured opportunities for students to analyze mathematical problems, reflect on their reasoning processes, and engage in collaborative problem-solving can significantly improve their mathematical proficiency. Additionally, integrating formative assessments that emphasize reasoning and conceptual understanding over mere procedural correctness can help students build confidence in their mathematical abilities while reinforcing the importance of critical thinking.

This study aims to identify the core mathematical difficulties encountered by biology students. By analyzing students' performance across different mathematical topics, we seek to uncover specific areas where they face the most significant challenges. Understanding these difficulties is essential for developing more effective instructional strategies that enhance students' mathematical literacy and their ability to apply mathematical concepts in biological contexts. The findings of this study will provide insights into the most pressing mathematical challenges in biology education, offering valuable implications for curriculum development, instructional design, and student support initiatives. By addressing these issues, educators can better equip biology students with the mathematical skills necessary for success in their academic and professional careers.

METHODS

This study employs a descriptive qualitative approach to explore the mathematical difficulties encountered by biology students. The focus of the study is to identify key areas of difficulty in mathematics, specifically targeting the midterm topics, with the goal of addressing these challenges before the final exam. The participants in this study consist of 91 first-year biology students enrolled in a Basic Mathematics course, which covers fundamental mathematical concepts necessary for biological studies. The midterm topics analyzed include equations and inequalities, matrices, absolute value, real numbers, probability, and sets.

All participants in this study were graduates of the Ilmu Pengetahuan Alam (IPA) (Natural Sciences) track from Indonesian high schools and are currently enrolled at a public university in Indonesia. The students were between 18 and 20 years old. Additionally, the number of female students was higher than that of male students, consistent with enrollment trends in biology programs at Indonesian universities. Data were collected through a combination of written assessments and interviews. The written assessments were designed to evaluate students' understanding of the midterm topics and were analyzed to identify common errors and areas of difficulty. Additionally, semi-structured interviews were conducted with a subset of six students to gain deeper insights into their learning experiences and the specific challenges they faced in applying mathematical concepts to biology-related problems.

The analysis of the collected data involved qualitative methods. Written assessment results were examined to identify patterns in the types of errors students made, focusing on specific mathematical topics that presented challenges. Interview transcripts were analyzed using thematic analysis to identify recurring themes and student perceptions regarding their difficulties with mathematics. The findings from the assessments and interviews were then compared and cross-referenced to triangulate the results and provide a comprehensive understanding of the challenges faced by the students.

RESULTS AND DISCUSSION

Written Assessments

To better understand student performance across different mathematical topics, an analysis was conducted on their accuracy rates and completion times. The following table summarizes the percentage of correct answers and the average time taken to complete questions for each topic. This data provides insight into which topics were well understood and which posed significant challenges for students.

TABLE 1. *Data Analysis of Quizizz work*

Mathematical Topic	Average Time per Question	Correct answer
Equations and inequalities	00:03:41	91,21%
Matrices	00:02:53	81,32%
Absolute value	00:02:36	13,19%
Probability	00:04:36	61,54%
Sets	00:02:47	96,73%
Real numbers	00:03:11	54,95%

The analysis of student performance across six mathematical topics—equations and inequalities, matrices, absolute value, probability, sets, and real numbers—revealed variations in both completion time and accuracy. These differences highlight the areas where first-year biology students demonstrated proficiency and where they faced significant challenges. Among the six topics, probability had the longest average completion time at 4 minutes 36 seconds, suggesting that students required more time to process and solve problems related to this topic. However, the accuracy rate for probability was 61.54%, indicating a moderate level of understanding despite the extended problem-solving duration. In contrast, absolute value emerged as the most challenging topic, with a strikingly low accuracy rate of 13.19%, despite having one of the shortest completion times (2 minutes 36 seconds). This suggests that students may have struggled conceptually with absolute value, leading to frequent errors and a lack of confidence in their answers.

On the other hand, the sets topic had the highest accuracy rate (96.73%), indicating that students were highly proficient in this area. Similarly, equations and inequalities were well understood, with a 91.21% accuracy rate and an average completion time of 3 minutes 41 seconds. These results suggest that students were more comfortable with algebraic manipulation and fundamental set operations. Matrices, with an accuracy rate of 81.32%, also appeared to be well understood, though requiring slightly less time (2 minutes 53 seconds) than equations and inequalities. The real numbers topic showed a moderate level of difficulty, with an accuracy rate of 54.95% and an average completion time of 3 minutes 11 seconds. This indicates that students had some difficulties in handling real number concepts, but their performance was significantly better than in absolute value problems.

Interviews

From further interviews, it was found that students struggled to understand the formal definition of absolute value. The given question was: "TRUE or FALSE: The absolute value of x can be equal to x." This question tested whether students understood that $|x| = -x$ is a true statement only when x is negative. However, many students simply recalled the general concept that absolute value always yields a positive number without grasping the underlying definition.

For example, FT stated, "I thought absolute value always makes a number positive, so I immediately answered 'True' without considering negative numbers." Similarly, AM explained, "I never really learned why absolute value works that way; we usually just solve problems by taking the positive version." CN added, "I didn't consider negative numbers at all. I assumed the statement was true for all numbers." These responses indicate that students had limited experience in interpreting absolute value conceptually, as they were more accustomed to computational problems rather than logical analysis. Additionally, some students misunderstood the statement as a universal rule applying to all x, rather than recognizing its conditional nature, leading to incorrect answers. NA mentioned, *"I thought $|x|$ is always equal to x because that's what we usually do in calculations."* These findings align with previous research indicating that students often struggle with abstract mathematical definitions when they are not explicitly reinforced during instruction (Li & Schoenfeld, 2019; Louie, 2020; Spooner et al., 2017; Warshauer, 2015).

Further interviews also revealed that students' difficulties with the probability question were rooted in their understanding of compound probability. The given question was: "TRUE or FALSE: If the True-False section of this exam is graded at 50%, then your probability of getting a perfect score is 50%." This question required students to recognize that the probability of achieving a perfect score depends not only on the chance of answering a single question correctly but also on how probability applies across all questions. NA stated, *"I assumed that each question was graded separately, so I didn't consider that probabilities should be multiplied across all questions."*

This response suggests that although the concept of compound probability had been taught, some students still struggled to apply it correctly, particularly in distinguishing between the probability of a single event and the probability of multiple events occurring together. Many students incorrectly assumed that the overall probability remained 50%, failing to realize that the probability of answering all questions correctly should be calculated as the product of the probabilities for each individual question. These findings indicate a gap in students' ability to apply probability rules across multiple trials, a common challenge noted in prior studies on probabilistic reasoning among non-mathematics majors. Therefore, additional structured practice is needed to reinforce students' understanding and help them apply probability rules more effectively in various contexts (Canner & Clinkenbeard, 2023; Feliciano-Semidei et al., 2022; Luque et al., 2022).

The analysis offers valuable insights into student learning difficulties in basic mathematics. The prolonged completion time for probability suggests that students may struggle with interpreting and applying probability concepts, while the high error rate in absolute value indicates fundamental misunderstandings that require targeted intervention. In contrast, the strong performance in sets and equations and inequalities suggests that students have a solid foundation in certain algebraic and logical reasoning skills. These results highlight the need for instructional improvements, particularly in topics where students demonstrated significant difficulties, to enhance their mathematical proficiency in preparation for subsequent assessments. Previous studies have also emphasized the importance of reinforcing conceptual understanding in mathematical instruction to help students bridge the gap between procedural fluency and deeper comprehension (Hurrell, 2021).

CONCLUSION

In conclusion, the analysis revealed that first-year biology students struggled the most with absolute value and probability, indicating conceptual misunderstandings rather than mere computational errors. The low accuracy in absolute value questions suggests difficulties in interpreting its formal definition, while the extended time spent on probability questions highlights challenges in understanding compound probability. These findings emphasize the need for more targeted instructional support, including clearer explanations and additional practice, to strengthen students' mathematical reasoning and problem-solving skills.

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PROFILE

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