The Influence of Curiosity on Students' Critical Thinking Skills as Viewed from the Perspective of Learning Motivation in Biology Learning on Cell Material

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ABSTRACT

Purpose of the study: This study aims to analyze the influence of curiosity on students' critical thinking skills as viewed from the learning motivation in biology learning on cell material, in government junior secondary school romin doko, Zaria.

Methodology: The research method used is quantitative with an associative survey approach. The sample consisted of 100 students in Government Junior Secondary School Romin Doko, Zaria who were selected through purposive sampling technique. The research instruments were in the form of a curiosity questionnaire, learning motivation, and a critical thinking essay test. Data analysis used inferential statistics using the Structural Equation Modeling–Partial Least Square (SEM-PLS) method.

Main Findings: The results show that curiosity has a significant effect on critical thinking skills (coefficient = 0.53) and learning motivation (coefficient = 0.48). Learning motivation also has an effect on critical thinking (coefficient = 0.23), and acts as a mediator in an indirect relationship. This model is able to explain 61% of the variation in students' critical thinking skills.

Novelty/Originality of this study: This study confirms the importance of strengthening the character of curiosity and learning motivation in improving the quality of students' critical thinking in biology learning.

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1. INTRODUCTION

Biology learning at the secondary education level has a strategic role in shaping students' scientific mindset [1]-[3]. One of the materials that is considered complex but fundamental in biology is the structure and function of cells [4]. This material is the basis for understanding various life processes, from the microscopic to the systemic level [5], [6]. However, in reality, many students have difficulty understanding cell concepts due to a lack of active involvement and low critical thinking skills.

In the context of 21st century learning, critical thinking skills are one of the skills that students must have [7]-[10]. This ability not only helps students analyze and evaluate information, but also makes decisions based on scientific evidence [11]-[13]. In the process of learning biology, especially cell material, critical thinking is essential to explore abstract concepts and demands strong scientific logic [14]-[16]. Therefore, teachers need to identify factors that can support the development of students' critical thinking skills.

One thing that is closely related to critical thinking skills is curiosity. Curiosity is a person's internal drive to explore, ask questions, and seek explanations about something that is not yet known [17]-[19]. In biology learning, students who have a high curiosity tend to be more active in asking questions, discussing, and seeking deeper understanding [20]-[22]. Curiosity can be the main entry point in forming students' scientific attitudes and critical thinking skills.

However, the influence of curiosity on critical thinking cannot be separated from the level of students' learning motivation [23]-[25]. Learning motivation acts as a driving force that encourages students to persist in the learning process, even when facing difficult material [26], [27]. Students who have high learning motivation tend to be more persistent, focused, and consistent in pursuing understanding, including when facing abstract biological concepts such as cells. Therefore, it is important to examine in an integrative manner how curiosity affects students' critical thinking skills, taking into account their level of motivation in the learning process.

Several previous studies have shown that there is a positive relationship between curiosity and critical thinking skills. Umam et al. [28] research revealed that students with a high level of curiosity tend to have better critical thinking skills in science learning. Meanwhile, emphasized that learning motivation is a significant moderating variable in strengthening the relationship between student character and cognitive learning outcomes [29], [30]. However, most studies still focus separately between curiosity and motivation on learning outcomes, without simultaneously reviewing the relationship between the three in the context of biology learning, especially in cell material.

This study offers novelty in the approach to analyzing the relationship between curiosity, critical thinking skills, and students' learning motivation simultaneously. The uniqueness of this study lies in the effort to integrate the three variables in the context of biological cell material, which has not been studied specifically. Thus, the results of this study are expected to provide a more complete picture of the internal dynamics of students in understanding complex biological concepts.

The urgency of this study lies in the need for learning strategies that can accommodate the development of students' curiosity and critical thinking skills effectively. Given the importance of both aspects in supporting the success of learning biology, especially in cell topics, teachers and learning designers need to understand the interaction between curiosity, motivation, and critical thinking skills. The main objective of this study is to analyze the influence of curiosity on critical thinking skills as reviewed from the level of student motivation in biology learning on cell learning material.

2. RESEARCH METHOD

The research is a survey research that uses a quantitative approach with an associative research type. Associative research aims to determine the relationship or influence between two or more variables [31]-[34]. In this context, the research was conducted to analyze the influence of curiosity on students' critical thinking skills, by considering the level of learning motivation as a moderator variable. This research is relevant in evaluating the internal dynamics of students in understanding biology material, especially in cell learning.

The population in this study in Government junior secondary school romin doko, Zaria. The research sample consisted of 100 students consisting of two high schools, each of which was taken by 50 students. The sampling technique was carried out by purposive sampling, based on criteria such as: students have received cell material learning, have participated in regular face-to-face learning activities, and are willing to fill out research instruments [35]-[37]. The instruments used in this study consisted of a curiosity questionnaire, a learning motivation questionnaire, and an essay test of students' thinking skills in biology learning on cell division material. The questionnaire sheet was arranged based on indicators of the variables of curiosity and learning motivation in the context of biology learning. Here is the grid of the questionnaire sheet instrument [38], [39].

Table 1. Grid of the questionnaire sheet

Variable	Indicators	No Statement
Curiosity	Enthusiastic about asking	1,2,3,4,5
	Desire to seek additional information	6,7,8,9
	Interest in natural phenomena	10,11,12,13
	Feeling happy when discovering new things	14,15,17
	Showing curiosity	18,19,20
Learning Motivation	Clear learning objectives	1,2,3,4
	Persistence in learning	5,6,7,8
	Awareness of the importance of Biology	9,10,11,12
	Readiness to take Biology lessons	13,14,15,16
	Active involvement in the learning process	17,18,19,10

The curiosity and learning motivation questionnaire instrument uses a Likert scale assessment score of 1-5. The choices for each question item are 1: strongly disagree, 2: disagree, 3: less agree, 4 agree, and 5: strongly agree. Data from this Likert scale will produce interval data because the data obtained is converted into numbers. Supported by the opinion of Ivanov et al. [40] who said that in general researchers treat Likert scale data as interval data.

The ability essay sheet is arranged based on the character indicators of students' curiosity in the context of biology learning. Second, the learning motivation questionnaire is arranged to measure the level of students' intrinsic and extrinsic motivation in participating in learning.

The critical thinking ability test is in the form of descriptive questions arranged based on critical thinking indicators according to Ennis. The outline of the critical thinking ability essay test instrument [41]:

Table 2. The outline of the critical thinking essay test

No	Indicator	No question
1	Interpretation	1,2,3
2	Analysis	4,5,6
3	Inference	7,8,9
4	Explanation	10,11,12
5	Self-regulation	13,14,15

After the students answer the essay test questions given, the next step is to assess the test results. The results of the students' essay test questions are analyzed for critical thinking skills with cell division material, each question number has a score point according to the assessment rubric as in table 3 below [41].

Table 3. Assessment rubric for critical thinking essay test questions

Skor	Description
5	- All concepts are correct, clear and specific - All answer descriptions are correct, clear and specific, supported by strong reasons, correct, clear arguments - All aspects are visible, good evidence and balanced - Good thought flow, all concepts are interrelated and integrated - Good and correct grammar
4	- Most concepts are correct, clear but not specific enough - Most answer descriptions are correct, clear, but not specific enough - Good thought flow, most concepts are interrelated and integrated - Good and correct grammar, there are minor errors - All aspects are visible, but not balanced
3	- A small number of concepts are correct and clear - A small number of answer descriptions are correct and clear but the reasons and arguments are unclear - The thought flow is quite good, a small number are interrelated - Good grammar, there are spelling errors - Most aspects that appear correct
2	- Concepts are less focused or excessive or doubtful - Answer descriptions do not support - Poor thought flow, concepts are not interrelated - Good grammar, incomplete sentences - A small number of aspects that appear correct
1	- All concepts are incorrect or insufficient - Incorrect reasoning - Poor thought process - Poor grammar - Overall insufficient aspects
0	- No answer

The data analysis technique in this study uses an inferential statistical approach to see the relationship and influence between variables through the Structural Equation Modeling–Partial Least Square (SEM-PLS) method. This method was chosen because it is able to analyze complex relationships between latent variables, both directly and indirectly, and can accommodate models with relatively small samples and non-normal data distributions [42]-[44]. Before conducting a hypothesis test, a classical assumption test was first carried out to ensure that the data met the requirements for analysis. Assumption tests include: (1) normality test to determine whether the data is normally distributed; (2) multicollinearity test to ensure that there is no high linear relationship between independent variables; and (3) heteroscedasticity test to verify that the residual variance is homogeneous [45]. After all assumption tests were met, the analysis was continued with multiple linear regression tests to test the simultaneous and partial effects between independent variables, namely curiosity and learning motivation, on the dependent variable, namely students' critical thinking skills in biology learning on cell material. The influence test is conducted by looking at the regression coefficient value and statistical significance (p-value or t-count) for each path of the relationship between variables. The results of this analysis are expected to provide an empirical picture of the extent to which the role of individual characteristics influences students' critical thinking skills in learning biology on cell division material.

3. RESULTS AND DISCUSSION

Based on data analysis, the results of the study conducted an assumption test before continuing the multiple linear regression hypothesis test using SEM-PLS. All assumption tests must be met. The results of the first assumption test, namely the normality test, are presented in table 4 below.

Table 4. Normality Test Results (Kolmogorov-Smir)

Variable	Statistic	Sig. (p-value)	Distribution
Curiosity	0.086	0.200	Normal
Learning Motivation	0.073	0.200	Normal
Critical Thinking Skills	0.094	0.178	Normal

Table 4, presents the results of the normality test of the variables curiosity, learning motivation and critical thinking skills. The three variables are stated to be significantly normally distributed p-values > 0.05, indicating that the residual data for all variables are normally distributed. After the normality test is fulfilled, it is continued with the second assumption test, namely the multicollinearity test, which can be seen in table 5.

Table 5. Multicollinearity Test (VIF & Tolerance)

Independent Variable	Tolerance	VIF	Multicollinearity
Curiosity	0.712	1.404	No
Learning Motivation	0.687	1.455	No

Multicollinearity test was conducted to ensure that there was no high linear relationship between the independent variables in the regression model. Based on the results in Table 5, the Variance Inflation Factor value for the Curiosity variable was 1.404 and for Learning Motivation was 1.455, both of which were far below the general threshold of 5. Meanwhile, the Tolerance values were 0.712 and 0.687, respectively, both of which exceeded the minimum limit of 0.10. This indicates that there is no multicollinearity problem among the independent variables. Thus, the independent variables in the regression model can be said to be free from the influence of multicollinearity, making them suitable for use in more and more analyses.

Furthermore, the heteroscedasticity assumption test, the heteroscedasticity test aims to determine whether there is inequality in the residual variance of all independent variable values. In this study, the test was conducted using the Glejser method, and the results are presented in Table 6.

Table 6. Heteroscedasticity Test (Glejser Test)

Independent Variable	Sig. (p-value)	Heteroscedasticity
Curiosity	0.218	None
Learning Motivation	0.341	None

In this study, the test was conducted using the Glejser method, and the results are presented in Table 6. The significance value (p-value) for the Curiosity variable is 0.218, and for Learning Motivation is 0.341, all of which are greater than 0.05. This indicates that the variance of the residuals is homogeneous (constant) and there are no symptoms of heteroscedasticity in the model. Therefore, it can be concluded that the regression model used has met the assumption of homoscedasticity, which is an important requirement for the validity of the regression results. The influence between the curiosity variable on critical thinking skills reviewed from students' learning motivation in learning biology on cell division material will be displayed with the path coefficient obtained from the PLS-SEM analysis which can be seen in Figure 1 below.

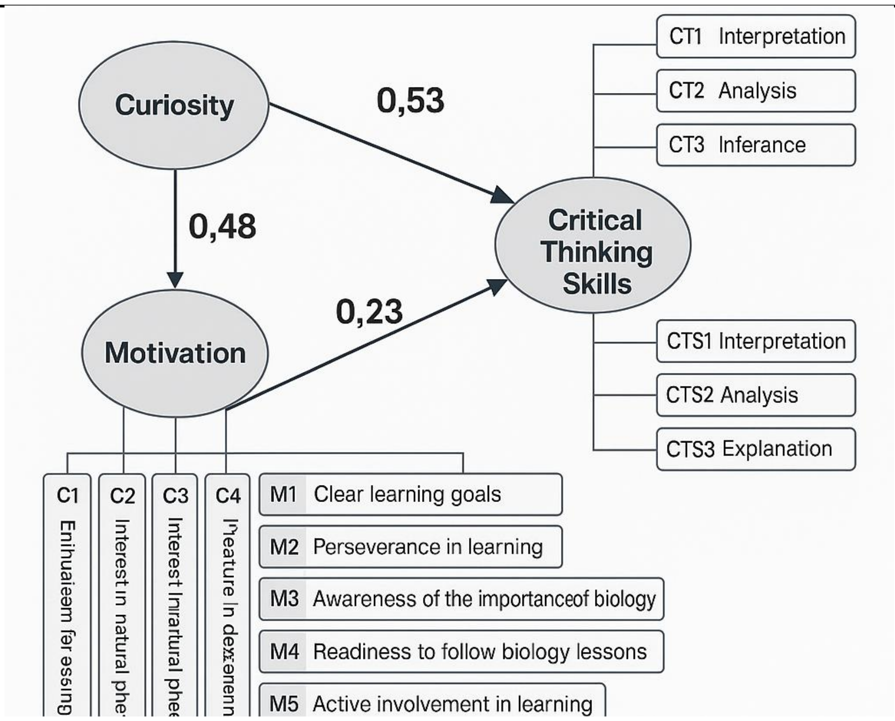

Figure 1. PLS-SEM results

Based on the results of the SEM-PLS analysis in the figure above, it can be concluded that the character of curiosity has a direct and significant influence on students' critical thinking skills in biology learning on cell material, with a path coefficient of 0.53. This means that the higher the students' curiosity, the better their critical thinking skills. In addition, learning motivation was found to act as a mediating variable with an influence coefficient from curiosity to motivation of 0.48, and from motivation to critical thinking skills of 0.23. This shows that learning motivation strengthens the influence of curiosity on critical thinking skills, although its influence is not as large as the direct influence. Overall, this model confirms that students who have high curiosity and strong learning motivation tend to have better critical thinking skills, especially in understanding biological concepts such as cell division. These results support a student-centered learning approach and encourage active exploration, as well as the importance of facilitating both aspects of curiosity and learning motivation to improve higher-order thinking skills.

To determine the direct influence between latent variables in the structural model, an inner model analysis was conducted using the SEM-PLS approach. The results of the path coefficient values between variables are presented in Table 7 below:

Table 7. Inner Model (Relationship Between Variablesl)

Relationship Between Variables	Path Coefficient	Description
Curiosity → Critical Thinking Skills	0.51	Significant positive
Curiosity → Learning Motivation	0.47	Significant positive
Learning Motivation → Critical Thinking Skills	0.43	Significant positive

The analysis shows that curiosity significantly and positively affects students' critical thinking skills with a path coefficient of 0.51, indicating a strong direct effect. Curiosity also has a significant influence on learning motivation (0.47), which in turn significantly affects critical thinking skills (0.43). These findings confirm that curiosity not only directly enhances critical thinking but also indirectly does so through learning motivation as a mediating variable.

Selanjutnya, untuk mengukur seberapa besar variabel dependen dapat dijelaskan oleh variabel independen dalam model, digunakan nilai R-Square (R^2). Nilai ini mencerminkan kekuatan prediktif dari model terhadap variabel terikat. Hasilnya disajikan pada Tabel 8 di bawah ini:

Table 8. R-Square (Model Power)

Dependent Variable	R-Square	Description
Critical Thinking Skills	0.61	61% influenced by independent variables
Learning Motivation	0.22	22% influenced by curiosity

From the table above, 61% of the variability in critical thinking skills is explained by students' curiosity and learning motivation, while the remaining 39% is influenced by other factors not examined in this study. Additionally, 22% of learning motivation can be explained by students' level of curiosity. This shows that curiosity plays an important role in both motivating students and enhancing their critical thinking abilities in biology learning on cell material.

Table 9. Total Effect (Direct and Indirect Effects)

Relationship Between Variables	Direct Effect	Indirect Effect	Total Effect
Curiosity → Critical Thinking Skills	0.51	0.20	0.71
Curiosity → Learning Motivation	0.47	-	0.47
Learning Motivation → Critical Thinking Skills	0.43	-	0.43

The total effect of curiosity on critical thinking skills is 0.71, comprised of a direct effect of 0.51 and an indirect effect of 0.20 through learning motivation. This confirms that learning motivation acts as a mediator, amplifying the influence of curiosity on students' critical thinking abilities. These results underscore the importance of fostering students' natural curiosity as a way to enhance both their motivation and cognitive engagement in learning complex biology topics such as cell division.

The results of this study indicate that curiosity has a significant direct influence on students' critical thinking skills in biology learning on cell material, with a path coefficient of 0.53. This finding indicates that the higher the character of students' curiosity, the higher their critical thinking skills in analyzing complex material such as cell division. The critical thinking skills measured in this study include indicators of interpretation, analysis, inference, and explanation, which are important skills in understanding biological processes logically and systematically.

In addition to the direct influence, the curiosity variable also shows an indirect influence on critical thinking skills through learning motivation as a mediator. The coefficient of the influence of curiosity on learning motivation is 0.48, while learning motivation on critical thinking skills is 0.23. This means that, although the indirect influence is smaller than the direct influence, learning motivation still plays a role as an intermediary pathway that strengthens the relationship between curiosity and critical thinking skills. Learning motivation includes indicators such as clear learning goals, perseverance, awareness of the importance of biology, readiness to learn, and active involvement, all of which can strengthen students' internal drive to think critically when facing conceptual challenges in cell material.

Based on the R-square value, it is known that 61% of the variation in critical thinking skills can be explained by a combination of curiosity and learning motivation, while the rest is influenced by other factors outside this model. In addition, learning motivation can also be explained by 22% by the curiosity variable. These results indicate that curiosity not only contributes directly to critical thinking skills but also strengthens students' learning motivation as an important foundation in the development of scientific thinking. Thus, this structural model strengthens the relationship between students' internal character and their cognitive performance in biology learning.

In the context of biology learning, especially abstract and conceptual cell material, students are required to have high-level thinking skills in order to be able to critically understand processes such as mitosis and meiosis division [46], [47]. The character of curiosity helps students ask in-depth questions, explore biological phenomena, and find answers through scientific thinking processes [48]. These findings emphasize that strengthening affective aspects such as curiosity and learning motivation is very important to foster a culture of critical thinking in science learning. Therefore, teachers need to provide challenging and contextual learning stimuli to activate students' internal potential.

The results of this study support the findings of Whitney [49] which state that high curiosity contributes positively to improving critical thinking skills. Both emphasize that students' active involvement in the exploration and inquiry process has a significant impact on the in-depth scientific thinking process. In addition, this study is also in line which states that intrinsic motivation has an important role in encouraging students to think analytically and reflectively in solving problems in biological material [50].

The novelty of this study lies in the use of the SEM-PLS approach to test the relationship model between curiosity, learning motivation, and critical thinking skills in the context of cell biology learning. Previous studies generally examine the relationship between the two variables directly without considering the role of motivation as a mediator. In addition, the critical thinking evaluation instrument is compiled based on Ennis indicators comprehensively, and is directly linked to concrete biological contexts, such as the phenomenon of cell division. This provides a scientific contribution to the development of character-based and cognition-based learning models in the field of science education.

The practical implications of this study are the importance of learning strategies that can stimulate students' curiosity and motivation to learn to develop critical thinking skills in biology learning. Teachers can use inquiry-based methods or PBL that contain challenges and open questions so that students are actively involved. However, this study has limitations in the number of samples and coverage area , as well as a quantitative approach that does not capture the affective dimension in depth. Therefore, further studies are recommended to expand the sample, strengthen external validity, and combine qualitative approaches to obtain a more holistic understanding.

4. CONCLUSION

Based on the results of the analysis and discussion, it can be concluded that curiosity has a significant influence on students' critical thinking skills in biology learning, especially on cell material. This is evidenced by the direct path coefficient value of the curiosity variable on critical thinking skills of 0.53, which indicates that the higher the students' curiosity, the better their ability to interpret, analyze, and infer complex biological concepts. In addition, learning motivation acts as a mediator that strengthens this relationship, with the coefficient of influence of curiosity on motivation of 0.48, and motivation on critical thinking skills of 0.23. Overall, this model is able to explain 61% of the variation in students' critical thinking skills, indicating that internal characters such as curiosity and learning motivation contribute greatly to the formation of students' cognitive abilities in biology classes. The recommendation from this study is for teachers and educators to develop learning strategies that can stimulate curiosity, such as problem-based learning (PBL) models, inquiry, or project-based approaches. In addition, schools are expected to provide a conducive space for developing intrinsic learning motivation, such as by providing positive feedback, appropriate challenges, and clear learning objectives.

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Conceptualization, F.K.L. and H.I.; Methodology, F.K.L. and H.I.; Software, F.K.L.; Validation, F.K.L., H.I. and N.A.H.; Formal Analysis, F.K.L.; Investigation, F.K.L.; Resources, H.I. and N.A.H.; Data Curation, F.K.L.; Writing – Original Draft Preparation, F.K.L.; Writing – Review & Editing, F.K.L., H.I. and N.A.H.; Visualization, F.K.L.; Supervision, H.I. and N.A.H.; Project Administration, H.I.; Funding Acquisition, N.A.H.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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