Analysis of Students' Critical Thinking Disposition in Science Learning

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Abstract - *The study aimed to analyze the specific dispositions that contribute to effective critical thinking among prospective science students. Utilizing a descriptive survey method, the study involved 52 participants from different universities, aiming to gather comprehensive data on their critical thinking dispositions. The research instrument, a structured questionnaire comprising 36 items derived from Ennis's critical thinking indicators, was validated and tested for reliability, ensuring its efficacy in measuring the intended constructs. The findings revealed that the overall critical thinking disposition of the students was predominantly below the critical threshold, with significant variability across different indicators. For instance, indicators such as seeking and offering clear statements and reasons scored relatively high, while others like taking into account the total situation scored lower. This disparity highlights the need for targeted interventions to enhance specific critical thinking dispositions. The study recommends integrating contextual and inquiry-based learning approaches, which have been shown to effectively foster critical thinking by engaging students in real-world problem-solving scenarios. Moreover, incorporating collaborative and experiential learning experiences can further nurture critical thinking skills, promoting deeper understanding and innovation. The research emphasizes the importance of developing specific disposition like open-mindedness to improve the critical thinking capabilities of prospective science teachers, ultimately enhancing their academic performance and preparedness to tackle complex scientific issues.*

Keywords: *Analysis; Critical Thinking Disposition; Science Learning; Survey Method.*

INTRODUCTION

Critical thinking is a foundational skill in education, particularly within the context of science learning. It involves the ability to analyze information critically, evaluate evidence, and synthesize new ideas. In science education, critical thinking enables students to understand complex concepts, engage in scientific inquiry, and solve problems effectively. These skills are essential not only for academic success but also for preparing students to become informed citizens capable of making reasoned decisions based on scientific evidence (Prayogi et al., 2018).

Critical thinking plays a crucial role in science education, supported by various studies emphasizing its importance in improving students' academic performance, especially in subjects requiring analytical reasoning and problem-solving (Bilad et al., 2022; Ekayanti et al., 2022). Developing strong critical thinking skills enables students to excel academically and fosters creativity and innovation by challenging assumptions, exploring diverse solutions, and generating novel ideas (Sari et al., 2019; Suhirman & Ghazali, 2022). This ability to question, analyze, and think critically is essential for preparing the future generation of scientists, engineers, and well-informed citizens who can navigate complex challenges and contribute meaningfully to society.

Research indicates that implementing contextual learning approaches effectively enhances students' critical thinking skills in subjects like science (Aliyu et al., 2023). By incorporating real-world contexts into the learning process, students are motivated to apply critical thinking to solve problems and analyze concepts, leading to a deeper understanding of the subject matter. Similarly, strategies such as inquiry learning combined with technology have been found to be instrumental in improving students' critical thinking abilities (Verawati et al., 2022). Engaging students in inquiry activities that necessitate critical analysis and problem-solving effectively nurtures the development of essential critical thinking skills (Prayogi et al., 2024). Moreover, the use of experiential learning methods has been recognized as a valuable approach to enhancing critical thinking in education, emphasizing the importance of practical, hands-on experiences in fostering critical thinking abilities (Pamungkas et al., 2020). By immersing students in real-world scenarios and challenges, educators can promote the application of critical thinking skills in authentic contexts, preparing students for the demands of the 21st century. Additionally, integrating STEM (Science, Technology, Engineering, and Mathematics) approaches has been identified as a promising strategy to cultivate critical thinking skills among students, highlighting the interdisciplinary nature of critical thinking in education (Yaki, 2022).

Furthermore, innovative teaching methods, such as project-based learning integrated with design thinking approaches, have been found to be effective in improving students' critical thinking skills (Maknuunah et al., 2021). By involving students in hands-on projects that require critical analysis, creativity, and problem-solving, educators can create an environment conducive to developing robust critical thinking abilities (Maknuunah et al., 2021). Additionally, engaging students in collaborative learning experiences enhances their critical thinking abilities through interaction and shared problem-solving (Suryani et al., 2021). Several educational frameworks emphasize the role of critical thinking in science learning. For example, the Next Generation Science Standards (NGSS) highlight critical thinking as a key component of scientific literacy (O. Lee et al., 2019; Zoller, 2012). According to the NGSS, students should be able to engage in practices such as asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, and constructing explanations. These practices require students to apply critical thinking skills to understand and investigate scientific phenomena (Hang & Srisawasdi, 2021).

Despite its importance, developing critical thinking skills in students presents several challenges. Many educators struggle to incorporate critical thinking into their teaching practices effectively. This difficulty is often due to a lack of resources, inadequate professional development, and insufficient time within the curriculum to focus on higher-order thinking skills (Prayogi & Asy'ari, 2023; Salvetti et al., 2023). Additionally, traditional teaching methods, which often emphasize rote memorization and passive learning, do not adequately support the development of critical thinking (J. Lee et al., 2016; Prayogi et al., 2024).

To address these challenges, educational researchers and practitioners have explored various instructional strategies aimed at promoting critical thinking. These strategies include inquiry-based learning (Prayogi & Verawati, 2020), problem-based learning (Suhirman & Prayogi, 2023), and emphasize the importance of analyzing cognitive processes involved in critical thinking and developing instructional designs that incorporate these processes (Holmes et al., 2015). Inquiry-based learning, for instance, encourages students to engage in scientific inquiry by posing questions, investigating phenomena, and drawing evidence-based conclusions. Problem-based learning involves presenting students with real-world problems that require critical analysis and problem-solving.

Previous study (R. Ennis, 2018) advocates for integrating critical thinking across subject-matter courses, culminating in projects that require students to investigate, take, and defend positions, thereby reinforcing critical thinking abilities and increasing subject-matter knowledge. This approach aligns with embedding critical thinking within the curriculum to provide students with opportunities to apply their analytical skills in various contexts. In addition, the importance of providing critical thinking learning resources that include support and training for teachers to effectively address the challenges in teaching critical thinking (Mugisha et al., 2021). By equipping educators with the necessary tools and strategies, institutions can enhance the implementation of critical thinking initiatives in educational settings.

Given the significant role of critical thinking in science education, it is imperative to understand the specific dispositions that contribute to effective critical thinking (R. H. Ennis, 2015). Dispositions such as open-mindedness, inquisitiveness, cognitive maturity, and perseverance are believed to play a crucial role in how students approach and engage with scientific problems. Identifying and fostering these dispositions can enhance students' ability to think critically and achieve better learning outcomes in science education. This study aims to analyze these dispositions in the context of science learning, providing insights into how educators can better support the development of critical thinking skills in their students.

Despite the recognized importance of critical thinking in science education, there is a significant gap in the research regarding the specific dispositions that contribute to effective critical thinking among students. Most existing studies focus broadly on critical thinking skills without delving into the particular attitudes, habits of mind, and personality traits that facilitate these skills in the context of science learning. As a result, educators lack detailed guidance on how to cultivate these dispositions in their students, potentially limiting the effectiveness of their teaching strategies (Fitriani et al., 2019). Furthermore, the challenge of integrating critical thinking into science curricula is compounded by a lack of empirical evidence on the impact of specific critical thinking dispositions on students' academic performance and engagement in science. This gap in understanding hinders the development of targeted interventions and instructional strategies aimed at enhancing critical thinking in science education. Therefore, there is an urgent need for research that identifies and examines the dispositions that underpin critical thinking in science learning, providing a foundation for more effective educational practices.

This study addresses a critical gap in the literature by focusing on the specific dispositions that support critical thinking in science education. Unlike previous research that broadly addresses critical thinking skills, this study investigates the unique dispositions that influence students' ability to engage in scientific inquiry and problem-solving. By identifying these dispositions, the research provides targeted insights for educators seeking to enhance critical thinking among students, thereby contributing to more effective science education practices. The study's findings will offer valuable guidance for educators on how to develop these dispositions through specific teaching strategies and curricular interventions, ultimately leading to improved critical thinking skills and academic performance in science education.

Research Objectives

The primary objective of this study is to identify and analyze the dispositions that contribute to critical thinking in science learning. By examining the relationships between specific dispositions, such as open-mindedness, inquisitiveness, and cognitive maturity, and students' academic performance and engagement in science, the research aims to provide a detailed understanding of how these dispositions influence critical thinking. The study seeks to inform the development of targeted instructional strategies and interventions that can effectively foster these dispositions, enhancing critical thinking skills and educational outcomes in science education

RESEARCH METHODS

This research is descriptive in nature, utilizing a survey method to measure students' critical thinking dispositions in the context of science learning. The survey method is particularly suitable for this study as it allows for the collection of data from a relatively large number of participants, facilitating the analysis of trends and patterns in critical thinking dispositions among prospective physics science students. The research design involves administering a structured questionnaire to gather quantitative data on various critical thinking disposition indicators. The survey method ensures that data can be collected efficiently and systematically, providing a comprehensive overview of the critical thinking dispositions present among the respondents. The data collected will be analyzed to identify the prevalence and strength of different critical thinking dispositions and their potential impact on science learning.

The sample for this study comprises 52 prospective physics science students from a range of universities. This sample size is deemed adequate for achieving the study's objectives and allows for meaningful statistical analysis. The selection of participants was based on convenience sampling, targeting students who are currently enrolled in physics-related programs and are likely to engage with critical thinking in their studies. Demographic information such as age, gender, and academic background was collected to ensure a diverse representation within the sample.

Ethical considerations were taken into account, with informed consent obtained from all participants prior to their involvement in the study. Participants were assured of the confidentiality and anonymity of their responses, and they were informed of their right to withdraw from the study at any time without any consequences. The ethical approval for this study was obtained from the relevant institutional review board, ensuring that the research adheres to ethical standards in data collection and analysis.

The primary instrument used in this study is a questionnaire developed to measure critical thinking dispositions. The questionnaire consists of 36 statement items derived from 12 critical thinking disposition indicators as outlined by thinking Ennis (2015). Each indicator was expanded into three specific statement items to capture a comprehensive view of the students' dispositions. The validity of the questionnaire was reviewed by experts in the field to ensure that the items accurately measure the intended dispositions. A pilot test was conducted to refine the questionnaire (on aspects of validity and reliability). Participants responded to each statement on a Likert scale, ranging from "strongly disagree" to "strongly agree." The data collection process involved distributing the questionnaires electronically to the participants, with instructions provided to ensure consistent and accurate completion.

The collected data were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, including means, and standard deviations, were used to summarize the respondents' critical thinking dispositions. This initial analysis provided an overview of the prevalence and distribution of various critical thinking dispositions among the sample. Inferential statistic, such as ANOVA, was then employed to examine the relationships between different critical thinking dispositions variables.

RESULTS AND DISCUSSION

The results of the instrument testing for students' critical thinking disposition include both validity and reliability, as presented in Table 1 and Table 2, respectively. Validity testing is crucial because it determines whether the instrument accurately measures what it is intended to measure.

Table 1. The results of the test instrument validity using the Pearson correlation

Variable		1	2	3	4	5	6	7	8	9	10	11	12
Indicator-1	Pearson's r	—											
	p-value	—											
Indicator-2	Pearson's r	0.773	—										
	p-value	< .001	—										
Indicator-3	Pearson's r	0.830	0.762	—									
	p-value	< .001	< .001	—									
Indicator-4	Pearson's r	0.662	0.741	0.775	—								
	p-value	< .001	< .001	< .001	—								
Indicator-5	Pearson's r	0.438	0.426	0.548	0.426	—							
	p-value	0.001	0.002	< .001	0.002	—							
Indicator-6	Pearson's r	0.435	0.361	0.500	0.610	0.341	—						
	p-value	0.001	0.008	< .001	< .001	0.013	—						
Indicator-7	Pearson's r	0.218	0.220	0.515	0.445	0.502	0.383	—					
	p-value	0.120	0.116	< .001	< .001	< .001	0.005	—					
Indicator-8	Pearson's r	0.280	0.280	0.418	0.495	0.482	0.488	0.564	—				
	p-value	0.045	0.045	0.002	< .001	< .001	< .001	< .001	—				
Indicator-9	Pearson's r	0.571	0.615	0.613	0.599	0.419	0.362	0.305	0.301	—			
	p-value	< .001	< .001	< .001	< .001	0.002	0.008	0.028	0.030	—			
Indicator-10	Pearson's r	0.521	0.616	0.588	0.623	0.459	0.428	0.312	0.421	0.495	—		
	p-value	< .001	< .001	< .001	< .001	< .001	0.002	0.024	0.002	< .001	—		
Indicator-11	Pearson's r	0.433	0.493	0.480	0.359	0.371	0.060	0.385	0.244	0.427	0.379	—	
	p-value	0.001	< .001	< .001	0.009	0.007	0.674	0.005	0.081	0.002	0.006	—	
Indicator-12	Pearson's r	0.607	0.659	0.638	0.726	0.429	0.605	0.484	0.429	0.557	0.569	0.546	—
	p-value	< .001	< .001	< .001	< .001	0.002	< .001	< .001	0.001	< .001	< .001	< .001	—
Avrerage	Pearson's r	0.799	0.816	0.894	0.866	0.649	0.633	0.588	0.604	0.720	0.735	0.585	0.823
	p-value	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .001
Annotation		Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

In the context of this study, validity testing ensures that the questions in the instrument genuinely assess the critical thinking disposition of students. A valid instrument provides confidence that the conclusions drawn from the data are well-founded and meaningful. Reliability testing, on the other hand, assesses the consistency of the instrument. It evaluates whether the instrument yields stable and consistent results over repeated applications. High reliability indicates that the instrument produces dependable results, reducing the likelihood of measurement errors. This is important for ensuring that the instrument can be trusted to provide accurate assessments of students' critical thinking disposition over time and across different groups.

The results of the test instrument validity for the critical thinking disposition indicators, as presented in Table 1, demonstrate the effectiveness of the questionnaire in measuring the intended constructs. The Pearson correlation coefficients for the twelve indicators range from 0.218 to 0.830, with the majority of the correlations being statistically significant ($p < .001$). This high level of statistical significance indicates that the items within each indicator are highly correlated with one another, suggesting strong internal consistency and validity. Specifically, indicators such as Indicator-3 ($r = 0.830$) and Indicator-2 ($r = 0.773$) exhibit exceptionally high correlations, reinforcing their robustness as measures of critical thinking dispositions. Even the lowest significant correlation (Indicator-7, $r = 0.218$, $p = 0.120$) shows some degree of internal validity, although it is less robust compared to the others. The average Pearson's r values for each indicator further affirm the instrument's validity, with all indicators except Indicator-7 showing strong correlations (r values above 0.361). The comprehensive validity of the instrument is underscored by the annotation that all indicators, except for Indicator-7, are valid. This thorough validation process confirms that the questionnaire reliably measures the critical thinking dispositions of the students, making it a credible tool for assessing these essential educational outcomes.

Table 2. The reliability test results

Estimate	Cronbach's α
Point estimate	0.932
95% CI lower bound	0.901
95% CI upper bound	0.955

The results of the reliability test for the critical thinking disposition questionnaire, as shown in Table 2, indicate a high level of internal consistency, with a Cronbach's alpha point estimate of 0.932. This value falls well within the acceptable range for educational research, typically considered excellent for scales measuring psychological constructs. The 95% confidence interval for Cronbach's alpha, ranging from 0.901 to 0.955, further supports the robustness and reliability of the instrument. These high reliability scores suggest that the questionnaire items consistently measure the intended dispositions, providing reliable data across different administrations. The narrow confidence interval indicates precision in the reliability estimate, confirming that the instrument is dependable for assessing students' critical thinking dispositions. Such a high level of reliability is crucial for ensuring that the results obtained from the questionnaire are stable and reproducible, thus providing a solid foundation for any conclusions drawn from the research data.

Furthermore, the results of the descriptive analysis of students' critical thinking dispositions are presented in Table 3. This analysis measures 12 indicators of critical thinking based on Ennis's (2015) theory.

Table 3. Results of descriptive analysis of students' critical thinking dispositions

Indicator of critical thinking disposition	N	Mean	SE	SD	Coef. of Var.
1. Seek and offer clear statements of the thesis or question	52	3.795	0.096	0.690	0.182
2. Seek and offer clear reasons.	52	3.667	0.095	0.683	0.186
3. Try to be well informed.	52	3.814	0.099	0.712	0.187
4. Use credible sources and observations.	52	3.596	0.091	0.655	0.182
5. Take into account the total situation.	52	3.263	0.060	0.435	0.133
6. Keep in mind the basic concern in the context.	52	3.231	0.075	0.538	0.167
7. Be alert for alternatives.	52	3.417	0.070	0.506	0.148
8. Be open-minded.	52	3.391	0.079	0.571	0.168
9. Take a position and change a position when the evidence and reasons are sufficient.	52	3.276	0.075	0.539	0.165
10. Seek as much precision as the situation requires.	52	2.994	0.077	0.554	0.185
11. Try to “get it right” to the extent possible or feasible.	52	3.372	0.074	0.531	0.157
12. Employ their critical thinking abilities.	52	3.160	0.064	0.460	0.145
Average		3.400	0.058	0.422	0.124

The descriptive analysis of students' critical thinking dispositions, as illustrated in Table 3, reveals a range of engagement levels across the different indicators among the 52 prospective physics science students. The mean scores for these indicators vary from 2.994 to 3.814, with an overall average score of 3.400, which falls under the "sufficient" category. Indicators such as "Try to be well informed" (Mean = 3.814), "Seek and offer clear statements of the thesis or question" (Mean = 3.795), and "Seek and offer clear reasons" (Mean = 3.667) are categorized as "critical," indicating that students are particularly strong in staying informed, formulating clear research questions, and providing logical reasoning. Additionally, "Use credible sources and observations" (Mean = 3.596) and "Be alert for alternatives" (Mean = 3.417) also meet the "critical" criteria, showing students' proficiency in identifying credible sources and considering alternative viewpoints.

However, several indicators fall under the "sufficient" category, suggesting areas for improvement. Indicators such as "Seek as much precision as the situation requires" (Mean = 2.994), "Employ their critical thinking abilities" (Mean = 3.160), and "Keep in mind the basic concern in the context" (Mean = 3.231) indicate that students have a moderate focus on precision, application of critical thinking skills, and contextual understanding. The overall average score of 3.400 highlights that while students demonstrate some critical thinking dispositions, these are not yet at a level deemed "critical." This finding underscores the need for targeted educational interventions to enhance these dispositions and elevate students' critical thinking skills to a higher level of proficiency.

The differences in the average scores of students' critical thinking dispositions across 12 indicators were analyzed using ANOVA. The results are detailed in Table 4.

Table 4. The ANOVA result

Cases	Sum of Squares	df	Mean Square	F	p
RM Factor 1	37.501	11	3.409	19.793	< .001
Residuals	96.628	561	0.172		

The results of the ANOVA analysis, as detailed in Table 4, indicate significant differences in the average scores of students' critical thinking dispositions across the 12 indicators. The sum of squares for RM Factor 1 is 37.501, with 11 degrees of freedom, resulting in a mean square of 3.409. The residual sum of squares is 96.628

with 561 degrees of freedom, leading to a mean square of 0.172. The F-value is 19.793, and the p-value is less than 0.001, indicating that the differences in critical thinking dispositions among the indicators are statistically significant.

This significant F-value suggests that the variation observed in the critical thinking dispositions is not due to random chance, but rather to genuine differences among the indicators. These findings highlight that certain critical thinking dispositions are more developed among students than others, which aligns with the descriptive analysis results. Indicators such as "Try to be well informed," "Seek and offer clear statements of the thesis or question," and "Seek and offer clear reasons" show higher average scores, indicating stronger engagement in these areas.

The significant differences identified by the ANOVA analysis emphasize the need for targeted educational interventions to address the less developed critical thinking dispositions. For instance, the lower scores in "Seek as much precision as the situation requires" and "Employ their critical thinking abilities" indicate areas where students may benefit from more focused training and practice. Enhancing these dispositions can lead to a more balanced and comprehensive development of critical thinking skills. Moreover, the significant p-value (<0.001) underscores the reliability of these findings, providing a strong basis for recommending educational strategies that focus on the weaker indicators. By systematically addressing these areas, educators can help students develop a more rounded critical thinking skill set, essential for effective scientific inquiry and problem-solving.

The ANOVA results confirm that there are significant differences in students' critical thinking dispositions across the 12 indicators. These findings provide valuable insights into which areas need more attention and support, guiding educators in designing effective interventions to enhance critical thinking skills comprehensively. The overall goal is to elevate all critical thinking dispositions to a "critical" level, ensuring that students are well-prepared for the challenges of scientific and academic endeavors.

Critical thinking disposition among students is a crucial aspect that influences their academic performance and future success. As a comparison, previous research has shown that critical thinking disposition is distinct from critical thinking skills, with less known about the factors contributing to it (Stupnisky et al., 2008). Studies have indicated that younger students tend to exhibit higher levels of critical thinking disposition, being more inquisitive and self-confident compared to older students (Zhang & Lambert, 2008). Furthermore, there are gender differences in critical thinking disposition, with female students showing significantly different levels of critical thinking disposition compared to male students (Syahfitri & Firman, 2022).

CONCLUSION

The analysis of students' critical thinking dispositions in science learning reveals that the dispositions fall within the sufficient category, meaning they are below the critical criteria. This finding is significant as it highlights a gap between the current state of students' critical thinking skills and the level required for effectively engaging in scientific inquiry and problem-solving. The average scores for various critical thinking disposition indicators, such as seeking clear reasons and using credible sources, indicate that while students demonstrate some level of critical thinking, it is not at the level needed for advanced scientific analysis. The reliability and validity of the instrument used in this study confirm the robustness of these findings, underscoring the need for a planned, strategic effort to enhance students' critical thinking abilities. To address this deficiency, educators and institutions must implement targeted instructional strategies and curricular interventions that foster critical thinking dispositions. This could involve integrating inquiry-based learning, problem-based learning, and experiential learning methods that actively engage students in critical analysis and problem-solving. Additionally, providing professional development and resources for educators to effectively teach and assess critical thinking can help bridge the gap.

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