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Analysis of Pre-service Science Teachers Critical Thinking Abilities : A Valuable Insights for Designing Instructional Strategies

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Abstract: This study aims to analyze the critical thinking abilities of pre-service science teachers, specifically focusing on students majoring in physics. Recognizing the pivotal role of critical thinking in science education, this research investigates the key abilities of analysis, inference, evaluation, and decision-making within the context of routine science learning activities. The study employs a descriptive research design, utilizing quantitative observational methods. A critical thinking ability test, comprising eight items, was administered to 19 pre-service science teachers. The validity and reliability of the test instrument were rigorously assessed through empirical testing and Cronbach's alpha, confirming the instrument's suitability for measuring the intended abilities. Descriptive and inferential statistical analyses, including ANOVA, were conducted to evaluate the critical thinking abilities of the participants. The results indicate an overall low level of critical thinking across all indicators, with no significant differences identified among the abilities of analysis, inference, evaluation, and decision-making. The descriptive analysis revealed that the students generally fell into the "Not Critical" category, reflecting significant deficiencies in their ability to engage deeply with scientific content. The ANOVA results further supported these findings, showing a lack of significant variation in critical thinking abilities, which points to a systemic issue within the current educational practices. These findings have important implications for science education, underscoring the need for comprehensive instructional strategies that address all aspects of critical thinking.

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Introduction

Critical thinking is a cornerstone of science education, integral to enhancing students' academic performance, particularly in subjects that demand analytical reasoning and problem-solving skills (Bilad et al., 2022; Ekayanti et al., 2022). Developing these skills is crucial as it empowers students to excel in their studies while fostering creativity and innovation. Through critical thinking, students are encouraged to challenge assumptions, explore various solutions, and generate new ideas, which are essential for their academic growth and future success (Sari et al., 2019; Suhirman & Ghazali, 2022). Preparing students to question, analyze, and think critically is vital in cultivating the next generation of scientists, engineers, and informed citizens who can address complex societal challenges and contribute meaningfully to society.

The exploration of students' critical thinking abilities within science education has become a focal point of educational research due to its significance in navigating intricate scientific concepts and real-world issues. Numerous studies have been conducted to investigate the effectiveness of different teaching strategies in cultivating these skills among students. Research has demonstrated a positive correlation between critical thinking and academic achievement in science, suggesting that students who develop strong critical thinking abilities tend to perform better academically (Ali & Awan, 2021). This finding highlights the necessity of embedding critical thinking into the science curriculum to enhance overall student achievement.

In addition, the development of critical thinking skills is deeply intertwined with the application of scientific reasoning. Effective science education goes beyond the mere transmission of content knowledge, emphasizing the importance of understanding the epistemological foundations that support scientific inquiry (Dowd et al., 2018). This broader educational objective aims to nurture critical thinkers who can engage profoundly with scientific content. For instance, Güler (2023) noted that argumentation-based learning in science encourages students to participate in philosophical discussions and construct evidence-based arguments, thereby enhancing their critical thinking skills. Similarly, the use of instructional materials that present authentic problems has been associated with improvements in students' critical thinking abilities (Noor et al., 2023).

Moreover, research underscores the effectiveness of contextual learning approaches in strengthening students' critical thinking skills in science (Aliyu et al., 2023). By integrating real-world contexts into the learning process, students are more likely to apply critical thinking to solve problems and analyze concepts, leading to a deeper understanding of the material. Inquiry-based learning, particularly when combined with technology, has also proven to be instrumental in developing students' critical thinking abilities (Verawati et al., 2022). Engaging students in inquiry-based activities that demand critical analysis and problem-solving can significantly foster essential critical thinking skills (Prayogi et al., 2024). Furthermore, experiential learning methods, which emphasize practical, hands-on experiences, have been recognized as valuable for enhancing critical thinking, as they encourage students to apply their skills in real-world scenarios, preparing them for the challenges of the 21st century (Pamungkas et al., 2020).

Innovative instructional methods such as project-based learning, integrated with design thinking, have also been effective in cultivating students' critical thinking abilities (Maknuunah et al., 2021). By involving students in projects that require critical analysis, creativity, and problem-solving, educators can create an environment conducive to developing robust critical thinking skills (Maknuunah et al., 2021). Additionally, collaborative learning experiences have been shown to further enhance students' critical thinking through interactive and collective problem-solving activities (Suryani et al., 2021). Educational frameworks, including the Next Generation Science Standards (NGSS), emphasize the importance of critical thinking as a key component of scientific literacy (Lee et al., 2019; Zoller, 2012). According to the NGSS, students must engage in practices such as questioning, modeling, investigating, analyzing data, and constructing explanations, all of which require the application of critical thinking to understand and explore scientific phenomena (Hang & Srisawasdi, 2021).

Fostering critical thinking in students, despite its recognized significance, remains a formidable challenge for many educators due to several persistent obstacles. One major issue is the lack of adequate resources and insufficient professional development opportunities, which limits educators' ability to effectively incorporate critical thinking into their teaching practices (Prayogi & Asy'ari, 2023; Salvetti et al., 2023). Furthermore, the limited time allocated within the curriculum for higher-order thinking skills exacerbates this difficulty. Traditional teaching methods, which often emphasize rote memorization and passive learning, further hinder the development of critical thinking, as they do not provide the interactive and analytical environment necessary for nurturing these essential skills (Lee et al., 2016; Prayogi et al., 2024). Consequently, addressing these challenges is crucial for improving the integration of critical thinking in educational settings.

In response to these challenges, educational researchers have explored various strategies to promote critical thinking in the classroom. These include inquiry-based learning (Prayogi & Verawati, 2020), problem-based learning (Suhirman & Prayogi, 2023), and approaches that emphasize the importance of analyzing the cognitive processes involved in critical thinking and integrating these into instructional design (Holmes et al., 2015). For instance, inquiry-based learning encourages students to engage in scientific inquiry by asking questions, exploring phenomena, and drawing evidence-based conclusions. Problem-based learning presents students with real-world problems that require critical analysis and problem-solving.

Ennis (2018) supports the integration of critical thinking across all subject areas, culminating in projects that require students to investigate, argue, and defend positions, thus reinforcing their critical thinking skills and enhancing their subject knowledge. This approach aligns with the broader goal of embedding critical thinking into the curriculum to provide students with opportunities to apply their analytical skills in various contexts. Furthermore, providing resources for critical thinking education, including educator support and training, is crucial for overcoming challenges in teaching critical thinking (Mugisha et al., 2021). By equipping educators with the necessary tools and strategies, educational institutions can enhance the implementation of critical thinking initiatives in their curricula.

Given the crucial role of critical thinking in science education, it is essential to understand the specific abilities that contribute to effective critical thinking. Abilities such as analysis, inference, evaluation, and decision-making (Wahyudi et al., 2018) play a vital role in how students fully engage and shape their critical thinking. Identifying these abilities is crucial for developing instructional models that align with the demands of current and future science learning needs. The novelty of this research lies in its focused examination of critical thinking abilities among pre-service science teachers within the context of routine science learning activities. Unlike many studies that emphasize broader educational interventions, this research uniquely targets key critical thinking indicators—analysis, inference, evaluation, and decision-making—to assess their prevalence and effectiveness in everyday classroom settings. By utilizing a rigorously validated assessment tool, the study uncovers systemic challenges in fostering critical thinking, offering valuable insights for designing instructional strategies that integrate critical thinking development holistically into science education practices.

The primary objective of this study is to identify the critical thinking abilities of students within the routine science learning activities conducted by lecturers in regular classrooms. These abilities include analysis, inference, evaluation, and decision-making, which are crucial for students to engage deeply with scientific content and apply their knowledge effectively.

Research Method

This study employed a descriptive research design utilizing observational methods, specifically quantitative observation, to analyze the critical thinking abilities of students in science learning. The focus was on assessing four key abilities: analysis, inference, evaluation, and decision-making. To achieve this, a critical thinking ability test comprising eight items was administered to students engaged in science education courses. These test items were designed to evaluate the specific critical thinking indicators mentioned above. The participants consisted of 19 pre-service science teachers majoring in physics at the University of Mataram. The selection of participants was based on convenience sampling, targeting students currently enrolled in science education programs, specifically in physics. This sampling method was chosen to ensure ease of access and willingness to participate, which is critical in observational studies where participant involvement is key.

Ethical considerations were meticulously addressed throughout the research process. Before participating in the study, all students were provided with comprehensive information about the study's objectives, procedures, and their rights as participants. Informed consent was obtained from each participant, ensuring they fully understood the nature of the research and their voluntary participation. Participants were assured of the confidentiality and anonymity of their responses, with strict measures taken to protect their identities. Moreover, they were informed of their right to withdraw from the study at any time without any repercussions. The ethical approval for this research was granted by the institutional review board of the University of Mataram, ensuring that the study adhered to ethical standards in both data collection and analysis.

The primary instrument used in this research was the critical thinking ability test, consisting of eight items tailored to measure the specific abilities of analysis, inference, evaluation, and decision-making. The test items were carefully constructed and reviewed to ensure their validity and reliability. The validity of the test was assessed through empirical testing, where the items were administered directly to a group of students similar to the study participants. The responses from this group were analyzed to determine the extent to which the items accurately measured the intended critical thinking abilities. Reliability was determined through a pilot study conducted with this group of students prior to the main study. The results of the pilot study were analyzed using Cronbach's alpha to measure the internal consistency of the test items, ensuring that the instrument reliably measured the targeted critical thinking abilities.

Data collected from the critical thinking ability tests were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, including means and standard deviations, were calculated to summarize the overall critical thinking abilities of the students. This preliminary analysis provided an overview of the prevalence and distribution of different critical thinking tendencies within the sample. The mean scores for each critical thinking ability—analysis, inference, evaluation, and decision-making—were used to identify areas where students excelled or struggled. Standard deviations were calculated to understand the variability of responses, which could indicate the consistency of critical thinking skills across different students.

The average score for critical thinking ability is calculated and then converted into categories according to the criteria shown in Table 1 (Prayogi et al., 2018).

Table 1. The criteria of critical thinking ability

No	Score intervals	Criteria
1	$X > 8.8$	Very critical
2	$5.6 < X \leq 8.8$	Critical
3	$3.6 < X \leq 5.6$	Quite critical
4	$0.8 < X \leq 3.6$	Less critical
5	$X \leq 0.8$	Not critical

For the inferential analysis, ANOVA (Analysis of Variance) was employed to examine the relationships between the various critical thinking abilities. This statistical test was chosen to determine whether there were significant differences in the critical thinking abilities among the students, particularly in how they performed across different indicators such as analysis,

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inference, evaluation, and decision-making. The use of ANOVA allowed for the comparison of mean scores across the different critical thinking abilities, providing insights into potential disparities in students' critical thinking skills. This analysis was crucial in identifying whether certain abilities were more developed than others, which could inform targeted instructional strategies in science education.

Results and Discussion

Based on the research that has been done, the data description is obtained about: (a) the application of problem-based learning model in the learning process with Lesson Study pattern in human physiological anatomy course, and (b) the effectiveness of the application of Problem Based Learning model on students' critical thinking skills.

Validity and Reliability of the Test Instrument

Before delving into the analysis of students' critical thinking abilities, it is crucial to establish the reliability and validity of the test instrument used in this study. The test instrument, consisting of eight items, was designed to measure the critical thinking indicators of analysis, inference, evaluation, and decision-making. To ensure the instrument's appropriateness, empirical validity and reliability tests were conducted.

Table 2. The results of the test instrument validity using the Pearson correlation

Item		1	2	3	4	5	6	7	8
1	Pearson's r	—							
	p-value	—							
2	Pearson's r	0.262	—						
	p-value	0.134	—						
3	Pearson's r	0.412	0.642	—					
	p-value	0.015	< .001	—					
4	Pearson's r	0.393	0.262	0.289	—				
	p-value	0.022	0.134	0.097	—				
5	Pearson's r	0.817	0.090	0.245	0.326	—			
	p-value	< .001	0.614	0.162	0.060	—			
6	Pearson's r	0.289	0.838	0.742	0.408	0.107	—		
	p-value	0.098	< .001	< .001	0.016	0.547	—		
7	Pearson's r	0.214	0.340	0.326	-0.029	0.166	0.310	—	
	p-value	0.224	0.049	0.060	0.873	0.347	0.074	—	
8	Pearson's r	0.768	0.363	0.499	0.289	0.592	0.410	0.190	—
	p-value	< .001	0.035	0.003	0.098	< .001	0.016	0.281	—
Total	Pearson's r	0.769	0.705	0.770	0.544	0.617	0.762	0.466	0.762
	p-value	< .001	< .001	< .001	< .001	< .001	< .001	0.005	< .001
Annotation		Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

The validity of the test items was assessed using Pearson's correlation, with the results presented in Table 2. The Pearson correlation coefficients (r-values) for the individual items ranged from 0.214 to 0.817, with most items showing statistically significant correlations (p-values < 0.05), indicating that the test items are valid for measuring the intended critical thinking abilities. Specifically, items 3, 5, and 6 showed strong correlations (r > 0.6), suggesting a high level of validity. Items 1 and 7, while still valid, had lower correlations, which may indicate the need for further refinement in future iterations of the test.

Table 3. Frequentist scale reliability statistics

Estimate	Cronbach's α	Greatest Lower Bound
Point estimate	0.829	0.925
95% CI lower bound	0.714	0.915
95% CI upper bound	0.904	0.972

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Table 4. Frequentist individual item reliability statistics

Item	Cronbach's α	Item-rest correlation
1	0.793	0.674
2	0.804	0.590
3	0.793	0.677
4	0.830	0.394
5	0.818	0.484
6	0.794	0.664
7	0.841	0.303
8	0.794	0.664

The reliability of the test instrument was evaluated using Cronbach's alpha, a measure of internal consistency. The results, as shown in Table 3, indicate a high level of reliability, with a point estimate of Cronbach's alpha at 0.829 and a Greatest Lower Bound (GLB) estimate of 0.925. These values exceed the commonly accepted threshold of 0.7, confirming that the test instrument reliably measures the critical thinking abilities of the participants. Table 4 further breaks down the reliability of individual test items, with most items showing acceptable levels of internal consistency, as indicated by the item-rest correlation values. Items 4 and 7, however, exhibited lower correlations, suggesting that these items may require revision to improve their alignment with the overall test construct. The combined validity and reliability results demonstrate that the test instrument used in this study is both valid and reliable, providing a solid foundation for the subsequent analysis of students' critical thinking abilities.

Descriptive Analysis of Students' Critical Thinking Abilities

The descriptive analysis of the critical thinking abilities of the 19 pre-service science teachers is presented in Table 5. The analysis focused on four key indicators: analysis, inference, evaluation, and decision-making. The mean scores, standard errors (SE), and standard deviations (SD) for each indicator were calculated to provide an overview of the students' performance.

Table 5. The descriptive analysis results of the critical thinking abilities

Indicator	Valid	Mean	SE	SD	Criteria
Analysis	19	0.237	0.140	0.609	Not Critical
Inference	19	0.421	0.192	0.838	Not Critical
Evaluate	19	-0.263	0.129	0.562	Not Critical
Decision Making	19	0.053	0.209	0.911	Not Critical
Average		0.112	0.097	0.421	Not Critical

The overall average score for critical thinking ability was 0.112 (SE = 0.097, SD = 0.421), which falls within the "Not Critical" category according to the criteria outlined in Table 1. This finding is concerning, as it suggests that the students, on average, did not exhibit strong critical thinking skills. Given the importance of critical thinking in science education, this result indicates a significant area for improvement.

The mean score for the analysis indicator was 0.237 (SE = 0.140, SD = 0.609), placing it in the "Not Critical" category. This low score implies that the students struggled with breaking down complex concepts and systematically examining the underlying components of scientific problems. The ability to analyze is fundamental in science, as it involves identifying patterns, making connections, and understanding the relationships between different elements. The low performance in this area suggests a need for instructional interventions that focus on enhancing analytical skills.

The inference indicator had a mean score of 0.421 (SE = 0.192, SD = 0.838), which also falls into the "Not Critical" category. Inference involves drawing logical conclusions from available information and is a critical skill in scientific reasoning. The students' low scores in this area suggest that they may have difficulty in synthesizing information and making reasoned judgments based on evidence. This finding highlights the importance of teaching strategies that encourage students to practice drawing inferences, such as through hypothesis testing and predictive reasoning in science experiments.

The evaluation indicator showed a mean score of -0.263 (SE = 0.129, SD = 0.562), which not only falls into the "Not Critical" category but also reflects a negative average score. This result is particularly alarming, as it indicates a significant deficiency in the students' ability to assess the credibility and relevance of information, a skill that is essential for scientific inquiry. Evaluation requires students to critically assess evidence, compare arguments, and determine the validity of conclusions. The negative score suggests that the students may have provided incorrect or flawed evaluations in their responses, which could stem from a lack of practice or understanding of evaluation criteria in scientific contexts.

The decision-making indicator had a mean score of 0.053 (SE = 0.209, SD = 0.911), placing it in the "Not Critical" category. Decision-making in science involves selecting the best course of action based on analysis, inference, and evaluation. The low score in this area suggests that the students struggled with making informed decisions when presented with scientific scenarios, which could impede their ability to apply scientific knowledge in real-world situations. This finding underscores the need for educational approaches that integrate decision-making exercises into the science curriculum, allowing students to practice making choices based on critical evaluation of evidence.

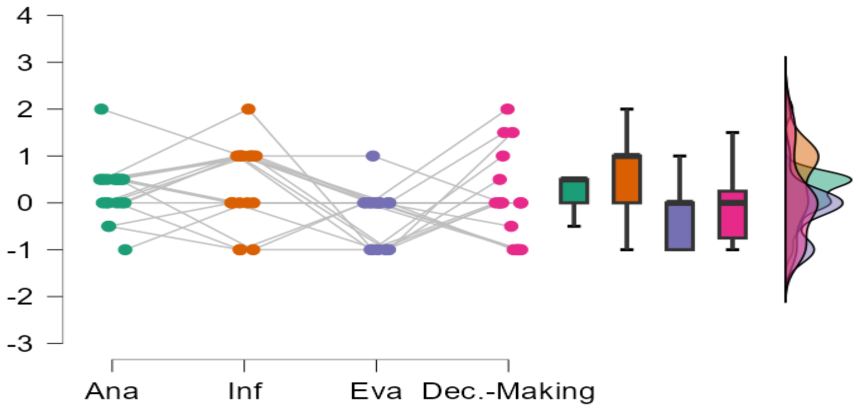

Figure 1. Descriptive plot of critical thinking indicators

The descriptive plot of the critical thinking indicators, as shown in Figure 1, visually represents the mean scores across the four indicators. The plot clearly illustrates the low levels of critical thinking across all indicators, with evaluation being the lowest and inference the highest, albeit still in the "Not Critical" range. This graphical representation reinforces the need for targeted interventions to improve critical thinking skills across all areas, with a particular emphasis on evaluation and analysis.

Inferential Analysis Using ANOVA

To further explore the differences in critical thinking abilities across the four indicators, an Analysis of Variance (ANOVA) was conducted. The ANOVA results, presented in Table 6, provide insights into whether there are statistically significant differences in the critical thinking abilities of the students across the indicators.

Table 6. The ANOVA result

Cases	Sum of Sqrs.	df	Mean Sqr.	F	p	VS-MPR*
RM Factor 1	3.154	3	1.051	2.182	0.101	1.585

RM Factor 1 ✻ Average	2.760	3	0.920	1.909	0.140	1.337
Residuals	24.576	51	0.482	-	-	-

The ANOVA analysis revealed that the differences in critical thinking abilities across the four indicators were not statistically significant, with an F-value of 2.182 and a p-value of 0.101 for the main effect (RM Factor 1). This suggests that there is no strong evidence to support that students' critical thinking abilities differ significantly across the indicators of analysis, inference, evaluation, and decision-making. The lack of significant differences may be attributed to the overall low levels of critical thinking observed in the descriptive analysis, where all indicators were categorized as "Not Critical."

The interaction between the critical thinking indicators and the average scores also did not reach statistical significance, with an F-value of 1.909 and a p-value of 0.140. This outcome further supports the conclusion that the critical thinking abilities of the students do not vary meaningfully across different indicators, indicating a uniformity in their performance. The absence of significant interaction effects suggests that the students' overall critical thinking ability is consistently low across all areas, reflecting a pervasive issue in their ability to engage deeply with scientific content. This consistency in low performance across all critical thinking indicators highlights the need for a comprehensive approach to developing these essential skills.

The ANOVA findings have important implications for science education, particularly in the design and implementation of instructional strategies. The lack of significant differences in critical thinking abilities across the indicators suggests that any interventions aimed at improving critical thinking should be holistic, addressing all aspects of critical thinking rather than focusing on specific areas. A comprehensive approach is necessary to ensure that students develop balanced and well-rounded critical thinking skills that can be applied effectively in scientific contexts. By fostering a more integrated development of analysis, inference, evaluation, and decision-making abilities, educators can better prepare students to navigate the complexities of scientific inquiry and real-world problem-solving, thereby enhancing their overall academic and professional readiness.

The findings from this study reveal significant insights into the state of critical thinking abilities among pre-service science teachers, highlighting an overall low level of critical thinking as indicated by the descriptive analysis and a lack of significant differences across the indicators, as shown by the ANOVA results. This suggests a pressing need for targeted interventions to enhance the development of these essential skills in science education. The uniformity in low performance across all critical thinking indicators points to a systemic issue within the current educational practices, where students are not sufficiently challenged or supported to develop their analytical reasoning, inference, evaluation, and decision-making abilities. Therefore, it is crucial to implement comprehensive educational strategies that address these deficiencies, ensuring that future science educators are equipped with the critical thinking skills necessary to navigate complex scientific concepts and effectively solve real-world problems.

One of the key challenges highlighted by this study is the difficulty in fostering critical thinking abilities among science students, a task that is crucial yet complex within the realm of science education. Despite the recognized importance of developing critical thinking, many students struggle to acquire these abilities, often due to the persistence of traditional teaching methods that emphasize rote memorization over analytical reasoning. This challenge is further exacerbated by the inadequacy of resources designed to support the teaching of critical thinking and the limited opportunities available for educators to engage in professional development that focuses on these skills (Prayogi & Asy'ari, 2023). This issue is not new, as prior research has consistently indicated that many educators lack the necessary training and experience to effectively teach critical thinking, which leads to a reliance on outdated instructional methods that fail to nurture students' analytical capabilities (Mugisha et al., 2021; Ssenyonga et al., 2022).

Moreover, the lack of resources specifically tailored for teaching critical thinking is a pervasive issue across various educational contexts, further complicating the efforts to enhance these abilities among students. Many educators report that they do not have access to adequate materials or support systems that would enable them to effectively teach critical thinking. A comprehensive review of educational practices revealed that, due to these limitations, educators often resort to using a narrow range of instructional strategies that do not adequately promote critical thinking abilities (Chesire et al., 2022). The absence of a structured approach to integrating critical thinking into the curriculum exacerbates the situation, as educators may struggle to know how to incorporate these essential skills into their existing teaching practices. This lack of resources is particularly evident in developing countries, where educational institutions may not have the necessary infrastructure or support to provide an environment conducive to teaching and learning critical thinking (Hamzah et al., 2018; Ssenyonga et al., 2022).

Professional development opportunities for educators are also crucial in the quest to foster critical thinking abilities among students. However, many educators express a need for more training in this area but face significant barriers, including time constraints and a lack of institutional support (Saito & Tangkiengsirisin, 2023). Research has shown that ongoing professional development can significantly enhance educators' ability to implement critical thinking strategies in their classrooms, making it an essential component of educational reform (Abrami et al., 2015; Saeed, 2017). Without adequate training and support, even well-intentioned efforts to promote critical thinking in the classroom may fall short, leaving students ill-equipped to engage in the analytical reasoning and problem-solving that are vital for success in science and beyond.

The lack of significant differences in critical thinking abilities across indicators highlights the importance of adopting comprehensive instructional models that address all aspects of critical thinking. Such models should integrate analysis, inference, evaluation, and decision-making into the science curriculum, ensuring that students develop a full range of critical thinking skills. Instructional approaches such as project-based learning, which requires students to engage in critical analysis and decision-making as part of the learning process, can be particularly effective in this regard abilities (Maknuunah et al., 2021).

Finally, the study underscores the need for professional development opportunities for educators to enhance their ability to teach critical thinking. Educators need to be equipped with the knowledge and tools to integrate critical thinking into their teaching practices effectively. This includes training in the use of inquiry-based, contextual, and collaborative learning approaches, as well as access to resources that support the development of critical thinking skills (Mugisha et al., 2021).

The results of this study have both conceptual and practical implications for science education. Conceptually, the findings highlight a systemic issue in the integration of critical thinking into routine science learning, emphasizing the need to shift educational paradigms toward approaches that prioritize higher-order cognitive skills over traditional rote learning. The lack of significant differences among critical thinking indicators such as analysis, inference, evaluation, and decision-making suggests a uniformly low emphasis on fostering these abilities across educational practices, pointing to a critical gap in curriculum design and pedagogical strategies. Practically, these insights underscore the necessity for comprehensive instructional reforms that embed critical thinking into all facets of science education. Strategies such as project-based and inquiry-based learning should be implemented to provide students with opportunities for active engagement, analytical reasoning, and decision-making. Additionally, professional development programs must be established to equip educators with the skills and resources needed to facilitate critical thinking effectively. By addressing these gaps, educational stakeholders can better prepare students to meet the demands of the 21st-century scientific and societal challenges.

Conclusion

This study provides significant insights into the critical thinking abilities of pre-service science teachers, revealing a concerning trend of low performance across key indicators such as analysis, inference, evaluation, and decision-making. The uniformity in these low scores suggests that the current educational practices are inadequate in fostering the critical thinking abilities essential for success in science education. The lack of significant differences across the indicators further underscores the systemic nature of this issue, highlighting the need for comprehensive and integrated instructional strategies that address all aspects of critical thinking. The findings emphasize the importance of adopting educational models that not only focus on content delivery but also actively engage students in analytical reasoning, problem-solving, and decision-making processes. Additionally, the study points to the critical need for enhanced professional development opportunities for educators, ensuring they are equipped with the necessary skills, resources, and support to effectively cultivate critical thinking in their students. This research underscores the urgency of reforming science education to better prepare future educators and students for the complex challenges of the scientific world.

Recommendation

Based on the findings of this study, several recommendations are proposed to improve the critical thinking abilities of pre-service science teachers. First, educational institutions should adopt comprehensive instructional models that integrate critical thinking skills across all areas of the science curriculum. Approaches such as project-based learning, inquiry-based learning, and contextual learning should be prioritized, as they have been shown to be effective in developing students' analytical reasoning and problem-solving abilities. Second, there is a need for enhanced professional development opportunities for educators, focusing specifically on the integration of critical thinking into teaching practices. Educators should be provided with the necessary training, resources, and support to effectively incorporate critical thinking into their instructional strategies. Finally, educational policymakers should address the lack of resources available for teaching critical thinking, particularly in developing countries, by investing in appropriate learning materials and infrastructure that support the development of these essential skills.

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References

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for Teaching Students to Think Critically: A Meta-Analysis. *Review of Educational Research*, *85*(2), 275–314. https://doi.org/10.3102/0034654314551063

Ali, G., & Awan, R.-N. (2021). Thinking based Instructional Practices and Academic Achievement of Undergraduate Science Students: Exploring the Role of Critical Thinking Skills and Dispositions. *Journal of Innovative Sciences*, *7*(1). https://doi.org/10.17582/journal.jis/2021/7.1.56.70

Aliyu, H., Ebikabowei, M., & Kola, A. J. (2023). Problem-Based Learning in Remote Learning Scenario Utilizing Climate Change Virtual Reality Video in Mobile Application to Train Critical Thinking. *International Journal of Essential Competencies in Education*, *2*(2), 144–159. https://doi.org/10.36312/ijece.v2i2.1612

Bilad, M. R., Anwar, K., & Hayati, S. (2022). Nurturing Prospective STEM Teachers' Critical Thinking Skill through Virtual Simulation-Assisted Remote Inquiry in Fourier Transform Courses. *International Journal of Essential Competencies in Education*, *1*(1), Article 1. https://doi.org/10.36312/ijece.v1i1.728

Chesire, F. C., Ochieng, M. A., Mugisha, M., Senyonga, R., Oxman, M., Nsangi, A., Semakula, D., Nyirazinyoye, L., Lewin, S., Sewankambo, N. K., Kaseje, M., Oxman, A. D., & Rosenbaum, S. (2022). *Contextualizing critical thinking about health using digital technology in secondary schools in Kenya: A qualitative analysis*. https://doi.org/10.21203/rs.3.rs-1345080/v1

Dowd, J. E., Thompson, R. J., Schiff, L. A., & Reynolds, J. A. (2018). Understanding the Complex Relationship between Critical Thinking and Science Reasoning among Undergraduate Thesis Writers. *CBE—Life Sciences Education*, *17*(1), ar4. https://doi.org/10.1187/cbe.17-03-0052

Ekayanti, B. H., Prayogi, S., & Gummah, S. (2022). Efforts to Drill the Critical Thinking Skills on Momentum and Impulse Phenomena Using Discovery Learning Model. *International Journal of Essential Competencies in Education*, *1*(2), Article 2. https://doi.org/10.36312/ijece.v1i2.1250

Ennis, R. (2018). Critical Thinking Across the Curriculum: A Vision. *Topoi*, *37*(1), Article 1.

Güler, O. (2023). Argumentation-Based Learning and P4C Approach: A Seventh-Grade Study on Socio-Scientific Issues. *Kaygı. Uludağ Üniversitesi Fen-Edebiyat Fakültesi Felsefe Dergisi*. https://doi.org/10.20981/kaygi.1334782

Hamzah, M. I., Zhaffar, N. M., & Razak, K. A. (2018). Barriers in Teaching Critical Thinking in Islamic Education. *Creative Education*, *09*(14), 2350–2356. https://doi.org/10.4236/ce.2018.914175

Hang, N. T. T., & Srisawasdi, N. (2021). Perception of the Next Generation Science Standard instructional practices among Vietnamese pre-service and in-service teachers. *Journal of Technology and Science Education*, *11*(2), 440. https://doi.org/10.3926/jotse.1154

Holmes, N. G., Wieman, C. E., & Bonn, D. A. (2015). Teaching critical thinking. *Proceedings of the National Academy of Sciences*, *112*(36), 11199–11204. https://doi.org/10.1073/pnas.1505329112

Lee, J., Lee, Y., Gong, S., Bae, J., & Choi, M. (2016). A meta-analysis of the effects of non-traditional teaching methods on the critical thinking abilities of nursing students. *BMC Medical Education*, *16*(1), 240. https://doi.org/10.1186/s12909-016-0761-7

Lee, O., Llosa, L., Grapin, S., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education*, *103*(2), 317–337. https://doi.org/10.1002/sce.21498

Maknuunah, L., Kuswandi, D., & Soepriyanto, Y. (2021). *Project-Based Learning Integrated with Design Thinking Approach to Improve Students' Critical Thinking Skill:* International Conference on Information Technology and Education (ICITE 2021), Malang, Indonesia. https://doi.org/10.2991/assehr.k.211210.025

Mugisha, M., Uwitonze, A. M., Chesire, F., Senyonga, R., Oxman, M., Nsangi, A., Semakula, D., Kaseje, M., Lewin, S., Sewankambo, N., Nyirazinyoye, L., Oxman, A. D., & Rosenbaum, S. (2021). Teaching critical thinking about health using digital technology in lower secondary schools in Rwanda: A qualitative context analysis. *PLOS ONE*, *16*(3), e0248773. https://doi.org/10.1371/journal.pone.0248773

Noor, A. F., Yunus, R., Suyidno, S., & Fahmi, F. (2023). Development of Predict-Observe-Explain (POE) Based Authentic Problems' Instructional Package to Improve Students' Critical Thinking Skills. *Jurnal Pendidikan Matematika Dan IPA*, *14*(1), 69. https://doi.org/10.26418/jpmipa.v14i1.53932

Pamungkas, S. F., Widiastuti, I., & Suharno, S. (2020). 21st Century Learning: Experiential Learning to Enhance Critical Thinking in Vocational Education. *Universal Journal of Educational Research*, *8*(4), 1345–1355. https://doi.org/10.13189/ujer.2020.080427

Prayogi, S., & Asy'ari, M. (2023). The Essential Competencies in Education: An Article Content Review. *Lensa: Jurnal Kependidikan Fisika*, *11*(2), 75. https://doi.org/10.33394/j-lkf.v11i2.10456

Prayogi, S., Bilad, M. R., Verawati, N. N. S. P., & Asy'ari, M. (2024). Inquiry vs. Inquiry-Creative: Emphasizing Critical Thinking Skills of Prospective STEM Teachers in the Context of STEM Learning in Indonesia. *Education Sciences*, *14*(6), 593. https://doi.org/10.3390/educsci14060593

Prayogi, S., & Verawati, N. N. S. P. (2020). The Effect of Conflict Cognitive Strategy in Inquiry-based Learning on Preservice Teachers' Critical Thinking Ability. *Journal of Educational, Cultural and Psychological Studies (ECPS Journal)*, *21*, Article 21. https://doi.org/10.7358/ecps-2020-021-pray

Prayogi, S., Yuanita, L., & Wasis. (2018). Critical Inquiry Based Learning: A Model of Learning to Promote Critical Thinking Among Prospective Teachers of Physic. *Journal of Turkish Science Education*, *15*(1), Article 1.

Saeed, S. (2017). Evidence-Based Education: Faculty Development Workshop to Promote Critical Thinking Skills in Dental Education. *MedEdPORTAL*, 10600. https://doi.org/10.15766/mep_2374-8265.10600

Saito, S., & Tangkiengsirisin, S. (2023). The Perceptions of Pre-Service EFL Teachers Toward A Training Program Integrating Online Coaching. *European Journal of Education Studies*, *10*(6). https://doi.org/10.46827/ejes.v10i6.4845

Salvetti, F., Rijal, K., Owusu-Darko, I., & Prayogi, S. (2023). Surmounting Obstacles in STEM Education: An In-depth Analysis of Literature Paving the Way for Proficient Pedagogy in STEM Learning. *International Journal of Essential Competencies in Education*, *2*(2), 177–196. https://doi.org/10.36312/ijece.v2i2.1614

Sari, R. M., Sumarmi, S., Astina, I. K., Utomo, D. H., & Ridhwan, R. (2019). Measuring Students Scientific Learning Perception and Critical Thinking Skill Using Paper-Based Testing: School and Gender Differences. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(19), 132. https://doi.org/10.3991/ijet.v14i19.10968

Ssenyonga, R., Sewankambo, N. K., Mugagga, S. K., Nakyejwe, E., Chesire, F., Mugisha, M., Nsangi, A., Semakula, D., Oxman, M., Nyirazinyoye, L., Lewin, S., Kaseje, M., Oxman, A. D., & Rosenbaum, S. (2022). Learning to think critically about health using digital technology in Ugandan lower secondary schools: A contextual analysis. *PLOS ONE*, *17*(2), e0260367. https://doi.org/10.1371/journal.pone.0260367

Suhirman, & Prayogi, S. (2023). Problem-based learning utilizing assistive virtual simulation in mobile application to improve students' critical thinking skills. *International Journal of Education and Practice*, *11*(3), 351–364. https://doi.org/10.18488/61.v11i3.3380

Suhirman, S., & Ghazali, I. (2022). Exploring Students' Critical Thinking and Curiosity: A Study on Problem-Based Learning with Character Development and Naturalist Intelligence. *International Journal of Essential Competencies in Education*, *1*(2), 95–107. https://doi.org/10.36312/ijece.v1i2.1317

Suryani, Y., Nurfadilah, E., Setiawan, I., & Suhartini, C. (2021). The Effect of Round Table Cooperative Learning Model and Learning Motivation On Students' Critical Thinking Skills. *Proceedings of the 1st Universitas Kuningan International Conference on Social Science, Environment and Technology, UNiSET 2020, 12 December 2020, Kuningan, West Java, Indonesia*. https://doi.org/10.4108/eai.12-12-2020.2304979

Verawati, N. N. S. P., Ernita, N., & Prayogi, S. (2022). Enhancing the Reasoning Performance of STEM Students in Modern Physics Courses Using Virtual Simulation in the LMS Platform. *International Journal of Emerging Technologies in Learning (iJET)*, *17*(13), Article 13. https://doi.org/10.3991/ijet.v17i13.31459

Wahyudi, P Verawati, N. N. S., Ayub, S., & Prayogi, S. (2018). Development of Inquiry-Creative-Process Learning Model to Promote Critical Thinking Ability of Physics Prospective Teachers. *Journal of Physics: Conference Series*, *1108*, 012005. https://doi.org/10.1088/1742-6596/1108/1/012005

Zoller, U. (2012). Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *Journal of Chemical Education*, *89*(3), 297–300. https://doi.org/10.1021/ed300047v