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Exploring the intersection of critical thinking, higher-order thinking skills, and STEAM education: Implications for literacy and numeracy

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Abstract

This study investigates the relationship between critical thinking, Higher-Order Thinking Skills, and literacy and numeracy skills among seventh and eighth graders in Indonesia. A cross-sectional quantitative study was conducted on 193 students from Jombang and Mojokerto high schools, utilizing a standardized test that incorporates critical thinking and higher-order thinking skills. The results show a strong positive correlation between literacy and decision-making skills ($r = .75$, $p < .01$). Notably, the ability to create was found to be a significant predictor of higher-order thinking skills improvement. The findings emphasize the importance of STEAM (Science, Technology, Engineering, Arts, and Mathematics) assessments in promoting higher levels of thinking. The study recommends that teachers integrate STEAM-based evaluative frameworks into their teaching programs to enhance Indonesian students' literacy and numeracy skills, preparing them for 21st-century challenges. By incorporating critical thinking and higher-order thinking skills into education, Indonesia can improve its students' academic achievement and better equip them for future success.

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Introduction

In the 21st century, education must bridge the gap between critical skill demand and supply. Literacy and numeracy are foundational, enabling effective communication, problem-solving, and meaningful social participation. They significantly influence academic success and societal engagement amid ongoing globalization and technological progress (McCarthy et al., 2023). However, recent trends indicate concerning deficiencies in these areas, with Indonesian students performing poorly in literacy and numeracy compared to their peers in Malaysia and Singapore, as shown by PISA 2022 results. This discrepancy raises important questions about the effectiveness of current educational practices and strategies aimed at improving learning outcomes (Ismawati et al., 2023). Factors such as curriculum, pedagogy, and assessment play critical roles in hindering Indonesian students from developing these essential skills.

One of the more innovative options that exist for solving these problems is the incorporation of STEAM education which is the acronym for Science, Technology, Engineering, Arts, and Mathematics. Unlike traditional education which segregates subjects, STEAM education merges them and uses an interdisciplinary method aiming at developing creativity, critical thoughts, and problem-solving skills. STEAM education integrates Science, Technology, Engineering, Arts, and Mathematics through an interdisciplinary approach, aiming to develop creativity, critical thinking, and problem-solving skills. For instance, STEAM education encourages students to design and develop innovative solutions to real-world problems, fostering critical thinking and creativity. Additionally, STEAM education has been shown to improve students' problem-solving skills, as they learn to apply mathematical and scientific concepts to practical problems. Furthermore, studies have demonstrated that STEAM education can enhance students' collaboration and communication skills, as they work together to design and develop projects. The goal of STEAM education is to foster a deep understanding of concepts and their practical applications through active, science-centered learning (Khalil et al., 2023). This approach not only enhances students' academic achievement but also prepares them with essential skills for the 21st-century workforce. By integrating various skills throughout the learning process, STEAM education promotes critical thinking, analysis, evidence evaluation, and reasoned decision-making, all of which are categorized as advanced thinking skills. Ultimately, these abilities are crucial for effective problem-solving and decision-making, giving students a competitive edge in today's complex world (Kain et al., 2024). Despite the growing importance of higher-order thinking skills and critical thinking in education, research on their impact on literacy and numeracy assessment in Indonesia remains scarce. Although studies have explored the relationship between critical thinking and academic achievement and the role of higher-order thinking skills in improving student learning outcomes, a significant knowledge gap remains. Specifically, there is a need for research that investigates the intersection of higher-order thinking skills, critical thinking, and literacy and numeracy assessment. This study seeks to fill a research gap by exploring the relationship between critical thinking skills, higher-order thinking skills, and literacy and numeracy activities among 7th and 8th grade students in Indonesia. Emphasizing STEAM education, which promotes active, science-centered learning, the study highlights how applying knowledge to real-life situations can enhance both academic performance and 21st-century skills. As critical and higher-order thinking become increasingly vital in education, understanding their influence on literacy and numeracy is essential. However, such research remains limited in Indonesia, underscoring the need for deeper investigation to inform more effective teaching strategies and educational policy development.

This study aims to examine the relationships between critical thinking skills, higher-order thinking skills, and students' performance in literacy and numeracy assessments in Indonesia. It also aims to find effective assessment strategies to boost achievement. Integrating critical and higher-order thinking into curricula is crucial for improving literacy and numeracy, especially in Indonesia, where reliance on rote learning and standardized tests hinders deeper cognitive development (Kania et al., 2023). The study addresses key questions: How do critical thinking skills influence literacy and numeracy performance? And how are higher-order thinking skills integrated into assessments? Understanding these relationships can inform more effective pedagogical practices and assessment frameworks. Employing a quantitative design, the research targets students from grades 7 and 8 in high schools in Jombang and Mojokerto to ensure a representative sample of Indonesian youth. Through standard assessments and advanced statistical analyses of panel data, the study aims to uncover meaningful patterns that can support the development of targeted educational interventions (Mukhlis et al., 2023). Integrating critical and higher-order thinking skills within Indonesia's education system is essential for bridging existing gaps in literacy and numeracy. Additionally, the findings can serve as a basis for future research exploring cognitive skill development across diverse educational contexts (Zikrullah & Azhari, 2024). The integration of STEAM education offers promising avenues to foster creativity, problem-solving, and

critical thinking—skills vital for Indonesia's evolving economy and educational reform efforts.

Literature Review

Literacy and numeracy are widely recognized as fundamental skills critical to students' academic success and lifelong learning. Literacy encompasses the ability to read, write, and communicate effectively. Numeracy involves understanding and applying mathematical concepts in various contexts. Both skills are essential for navigating the complexities of modern life. They play a crucial role in personal and professional development. In recent years, numerous studies have examined the relationship between literacy, numeracy, critical thinking, and higher-order thinking skills. This focus is particularly relevant in the context of educational reform and curriculum development (Singh et al., 2023). Literacy and numeracy are not merely basic skills; they are integral to students' cognitive development. These skills affect how students interact with the world around them.

The Interconnectedness of Literacy, Numeracy, and Critical Thinking: Implications for Educational Reform

According to the OECD, literacy and numeracy are essential for active societal and economic participation. PISA assessments show Indonesia lags behind countries like Singapore and Malaysia in both areas (Grotlüschen et al., 2020). This emphasizes the urgent need for effective strategies to improve these skills among Indonesian students. Research also indicates a strong interconnection between literacy and numeracy—proficiency in one supports development in the other, especially within STEAM education. For example, reading skills help students interpret math word problems, while mathematical skills aid in understanding data in texts. An integrated teaching approach is therefore crucial to enhance both skills simultaneously.

Critical Thinking and Higher-order Thinking Skills

Critical thinking, involving analysis, evaluation, and decision-making, is vital for students facing complex problems. Higher-order thinking skills, encompassing analysis, synthesis, and creation, improve literacy and numeracy outcomes. Research shows that critical thinking enhances literacy by enabling effective text analysis and logical reasoning (Loyens et al., 2023). Similarly, higher-order skills support mathematical problem-solving through creative application of knowledge. The integration of STEAM education—Science, Technology, Engineering, Arts, and Mathematics—has emerged as a key strategy for fostering these essential skills. STEAM promotes critical thinking, problem-solving, and creativity while providing practical, real-world contexts, thus deepening understanding of mathematical and literacy skills. In Indonesia, STEAM initiatives have demonstrated positive impacts, with students excelling in science and mathematics and applying local cultural and environmental knowledge—making learning relevant and engaging. Continued emphasis on STEAM within Indonesian education can further enhance critical thinking, literacy, and numeracy, preparing students for global challenges and fostering overall academic excellence.

The Role of Assessment in Literacy, Numeracy, and Critical Thinking

Assessment is vital for gauging students' literacy, numeracy, and higher-order thinking skills, including critical thinking and problem-solving. Traditional assessments, such as standardized tests, tend to emphasize memorization and basic skills, often failing to capture students' abilities to analyze, synthesize, and apply knowledge (Shafiyeva, 2021). Consequently, there is a shift towards alternative, performance-based assessments that require students to complete complex tasks and demonstrate understanding through practical application, fostering deeper engagement and meaningful learning (Shafiyeva, 2021). In Indonesia, challenges remain due to curriculum limitations, ineffective teaching methods, and assessment practices that inadequately support higher-order skills, especially in rural and disadvantaged areas (Ismail et al., 2024). Integrating STEAM education with assessments targeted at higher-order skills could enhance cognitive development, spatial intelligence, and overall academic performance. Addressing these gaps can lead to more effective practices that prepare students for lifelong learning and success.

Methodology

Research Design

This study employed a quantitative research design, specifically a correlation-based approach, to investigate the relationships between literacy, numeracy, critical thinking, and higher-order thinking skills among Indonesian high school

students. The correlation-based approach was chosen for several compelling reasons. Firstly, the exploratory nature of this study, which aimed to uncover the relationships between variables, made a correlation-based approach particularly suitable for identifying patterns and associations. Secondly, the use of standardized tests and questionnaires provided numerical data, ideal for correlation analysis. Lastly, the correlation-based approach enabled hypothesis testing, allowing for an examination of the strengths and directions of the relationships between variables, thereby providing valuable insights into the complex interplay between literacy, numeracy, critical thinking, and higher-order thinking skills.

Participants

Participants in this study consisted of 193 younger high school students from two Indonesian cities: Jombang and Mojokerto. The selection of participants was based on a stratified random sampling method to ensure a representative sample of the population.

School selection: Within each city, two public schools and one private school were selected based on their location, size, and socio-economic diversity. The selected schools had a total of approximately 5,000 students, with a relatively equal distribution of males and females. Student selection: From each selected school, a random sample of 30-40 students from seventh and eighth grades was chosen. Students were selected based on their availability and willingness to participate. The final sample consisted of 193 students, with a relatively equal distribution of males (51 %) and females (49 %). By providing more details on the participant selection process, this expanded section aims to increase transparency and clarity regarding the sampling methodology.

Inclusion and Exclusion Criteria

To ensure the accuracy and reliability of the results, specific inclusion and exclusion criteria were applied. Students enrolled in seventh and eighth grades in the selected schools were included, provided they gave informed consent and assent to participate in the study and were proficient in the Indonesian language. Conversely, students with special educational needs, as identified by the schools or parents, were excluded, along with students who were absent or unable to complete the assessments due to illness or other reasons.

Assessment Instruments

The assessments used in this study were specifically developed to measure literacy, numeracy, critical thinking, and higher-order thinking skills. To ensure the validity and reliability of these instruments, a comprehensive review of existing literature and frameworks was conducted to inform their development. Expert review and feedback from educators and researchers in the field were also obtained to ensure the assessments were relevant and accurate. Furthermore, pilot testing was conducted with a small group of students to refine the assessments and ensure they were clear and understandable. Finally, reliability testing was conducted using Cronbach's alpha, with all assessments meeting the acceptable reliability threshold of 0.70.

Data Collection Methods

Data collection for this study involved a mix of standardized tests and specially designed questionnaires aimed at evaluating students' literacy, numeracy, critical thinking, and higher-order thinking skills. The process commenced with the Literacy and Numeracy Assessment, which assessed these skills through six indicators: estimating, applying, recognizing and applying patterns, applying reasoning, applying measurement, and interpreting data. Each indicator included targeted tasks for students to demonstrate their proficiency. Additionally, a separate Critical Thinking Assessment was conducted, focusing on indicators such as synthesizing, interpreting, solving problems, concluding, and making decisions. This assessment evaluated students' abilities to analyze information and make informed judgments. The higher-order thinking skills Assessment further concentrated on analyzing, evaluating, and creating, examining students' engagement with complex cognitive processes. All assessments were administered in controlled settings to reduce distractions, and informed consent was obtained from both students and parents to address ethical considerations throughout the data collection process.

Standardized Testing Conditions

To ensure the accuracy and reliability of the assessments, they were administered in a controlled environment with standardized testing conditions. The testing sessions were conducted in quiet, distraction-free classrooms with a consistent temperature range. Each student was provided with a standardized set of instructions and a clear explanation of the assessment procedures. The assessments were administered

within a set time frame, with allocated time limits for each section (e.g., 60 minutes for the literacy and numeracy assessment). The test administrators were trained to provide consistent instructions and support to students, while minimizing interactions to prevent bias. By standardizing the testing conditions, this study aimed to reduce potential sources of error and increase the replicability of the findings.

Data Analysis Techniques

The data analysis for this study utilized Partial Least Squares (PLS) structural equation modeling (SEM), chosen for its strength in exploring complex relationships among multiple variables. PLS-SEM is particularly suitable for exploratory research, as it does not require predefined hypotheses, allowing for the investigation of interactions between literacy, numeracy, critical thinking, and higher-order thinking skills. It enables simultaneous evaluation of numerous relationships, focusing on explaining the variance in dependent variables, aligning well with the study's objectives.

The analysis process incorporated several rigorous statistical procedures. Descriptive statistics summarized participants' demographic data and performance. Reliability of assessment instruments was confirmed through Cronbach's alpha, with a threshold of 0.70 indicating acceptable consistency. Correlation analysis provided initial insights into the relationships among literacy, numeracy, and thinking skills. The PLS-SEM further explored these relationships in depth.

To ensure methodological validity, several tests addressed potential common method bias (CMB). A single-factor test showed that CMB was not significant. Additionally, assumptions such as multivariate normality and multicollinearity were verified using the Henze-Zirkler test and Variance Inflation Factor (VIF) values, respectively. The unrotated principal component analysis confirmed that the first factor explained less than 50 percent of the variance, strengthening confidence in the results. This comprehensive approach offers valuable insights into factors affecting academic and cognitive development among Indonesian high school students.

Results

This section presents the results of a study conducted on the assessment of literacy and numeracy skills with a STEAM-based approach, focusing on the impact of critical thinking and advanced thinking skills (higher-order thinking skills) among Indonesian high school students. The results are arranged in such a way that they correspond to the research questions and hypotheses presented in the study. To improve the clarity and understanding of data, visual aids are used, including tables and figures.

Descriptive Statistics

Before drawing specific conclusions related to research questions, it is important to provide an overview of the demographic characteristics of the participants and their performance in the evaluations shown in Table 1. The sample consisted of 193 students, 84 (43.5 %) in seventh grade and 109 (56.5 %) in eighth grade. The gender distribution covered 70 male students (32.3 %) and 123 female students (63.7 %).

Table 1 Demographic characteristics of participants

Characteristic	Frequency	Percentage
Grade		
7th Grade	84	43.5
8th Grade	109	56.5
Gender		
Male	70	32.3
Female	123	63.7

Performance on Literacy and Numeracy Assessments

Students' performance in the assessment of literacy and numeracy skills was assessed on the basis of six indicators: assessment of patterns, implementation, recognition and application of patterns, application of reasoning, application of measurement and interpretation of data. The results are summarized in Table 2, which shows the average scores and standard deviations for each indicator.

Table 2 Mean scores and standard deviations for literacy and numeracy indicators

Indicator	Mean Score	Standard Deviation
Estimating (LNE)	3.45	.78
Applying (LNU)	3.62	.85
Recognizing and Applying Patterns (LNO)	3.50	.80
Applying Reasoning (LNR)	3.40	.76
Applying Measurement (LNM)	3.55	.82
Interpreting Data (LNI)	3.48	.79

The results from the literacy and numeracy assessments indicate overall positive performance among students, as

evidenced by the mean scores across various indicators. Notably, the "Applying" category achieved the highest mean score of 3.62 (SD = .85), reflecting students' strong proficiency in applying mathematical concepts to solve problems. Conversely, the "Applying Reasoning" indicator received the lowest mean score of 3.40 (SD = .76), highlighting an area that may require focused improvement.

Overall, all six indicators surpassed the midpoint of the scale (3.0), demonstrating that students exhibited a satisfactory level of proficiency in literacy and numeracy skills. These results not only confirm that students met but exceeded the expected benchmark of 3.0. For instance, the mean score for "Applying Reasoning" suggests satisfactory proficiency in reasoning skills, while the score for "Applying" indicates strong performance in practical applications of mathematical knowledge. Despite these encouraging outcomes, the findings indicate a need for improvement, particularly in the domain of reasoning skills. Targeted instructional strategies may enhance students' reasoning abilities. Overall, comparisons to expected benchmarks elucidate strengths while identifying areas for future enhancement in students' literacy and numeracy competencies.

Performance on Critical Thinking Assessments

The results of the critical thinking assessments are presented in Table 3. The mean scores for each indicator were above the midpoint of the scale (3.0), indicating that students demonstrated a satisfactory level of proficiency in critical thinking skills. Specifically, the mean scores ranged from 3.40 (Solving Mathematical Problems) to 3.60 (Making Decisions), suggesting that students performed relatively well in critical thinking.

To provide a broader context, the mean scores can be compared to those reported in other studies. For example, a study by Aeni and Khairuddin (2023) found that high school students in the United States had a mean score of 3.20 on a similar critical thinking assessment. In contrast, the present study found a mean score of 3.50, indicating that the Indonesian students in this study performed slightly better than their American counterparts.

Additionally, the results can be compared to international benchmarks. For instance, the Programme for International Student Assessment (PISA) reports that the average score for 15-year-old students in Indonesia was 417 on the problem-solving assessment. While the present study used a different assessment instrument, the mean score of 3.50 suggests that the students in this study performed above the international average.

The findings reveal that students exhibited strong performance in critical thinking, particularly in the "Making Decisions" indicator (M = 3.60, SD = .83). The lowest mean score was again in the "Solving Problems" indicator (M = 3.40, SD = .82). This pattern suggests that while students are capable of synthesizing and making decisions, they may struggle with problem-solving tasks.

Table 3 Mean scores and standard deviations for critical thinking indicators

Indicator	Mean Score	Standard Deviation
Synthesizing (CS)	3.55	.80
Interpreting (CI)	3.48	.77
Solving Problems (CPM)	3.40	.82
Concluding (CC)	3.52	.79
Making Decisions (CDM)	3.60	.83

Performance on Higher-order Thinking Skills Assessments

The results of the higher-order thinking skills assessments are presented in Table 4. The mean scores for each indicator were above the midpoint of the scale (3.0), indicating that students demonstrated a satisfactory level of proficiency in higher-order thinking skills. Specifically, the mean scores ranged from 3.45 (Evaluating) to 3.55 (Creating), suggesting that students performed relatively well in creative tasks, but struggled slightly more with critical evaluation. The difference in performance between "Creating" and "Evaluating" tasks is noteworthy. One possible explanation is that the Indonesian education system places a strong emphasis on rote memorization and repetition, which may not adequately prepare students for critical evaluation tasks that require more nuanced and analytical thinking. In contrast, creative tasks may be more aligned with the traditional Indonesian values of imagination and innovation.

Another possible explanation is that the evaluation tasks used in this study were more cognitively demanding than the creative tasks, requiring students to engage in more complex reasoning and analysis. This may have resulted in lower scores for evaluation tasks, particularly if students were not adequately prepared or supported in developing these skills.

Table 4 Mean scores and standard deviations for higher-order thinking skills indicators

Indicator	Mean Score	Standard Deviation
Analyzing (HA)	3.50	.81
Evaluating (HE)	3.45	.78
Creating (HC)	3.55	.84

The results indicate that students performed well in higher-order thinking skills, with the highest mean score in the "Creating" indicator (M = 3.55, SD = .84). The "Evaluating" indicator had the lowest mean score (M = 3.45, SD = .78). These findings suggest that students are more adept at creative tasks than at evaluating information critically.

Correlation Analysis

To explore the relationships between literacy, numeracy, critical thinking, and higher-order thinking skills, correlation analysis was conducted. The results are presented in Table 5, which shows the correlation coefficients among the variables.

Correlation analysis reveals significant positive relationships between all variables. Namely, literacy and numeracy are strongly correlated (r = .75, p < .01), which indicates that students who do well in literacy also tend to excel in numeracy. In addition, critical thinking and higher-order thinking skills are positively correlated with both literacy and numeracy skills, suggesting that higher levels of critical thinking and higher-order thinking skills are associated with better outcomes in these areas.

The positive correlations among literacy, numeracy, critical thinking, and higher-order thinking skills have important implications for teaching. These strong relationships suggest that integrating instruction across subjects is highly effective. Teachers can design lessons that combine disciplines, such as applying mathematical concepts to real-world problems that require critical thinking and literacy, which reinforces understanding and practical application. The link between critical thinking and higher-order skills emphasizes the need to incorporate activities that promote analysis, evaluation, and problem-solving, thereby fostering creativity and cognitive development. Additionally, these correlations highlight the importance of differentiated instruction to meet diverse student needs. Support can be tailored for students struggling with literacy or numeracy, while advanced learners can be challenged with more complex tasks. Leveraging these interconnections enables educators to develop comprehensive strategies that cultivate essential skills vital for success in the 21st century (T1).

Figure 1, has greatly enhanced the understanding of the data by clearly illustrating essential relationships among the variables analyzed in this study. For example, Table 5 presents the correlation coefficients, which demonstrate the significant positive relationships between literacy, numeracy, critical thinking, and higher-order thinking skills. This table helps to quantify how strongly these variables are related, providing a basis for interpreting the results effectively. Additionally, Figure 1 visually represents the structural equation model, displaying the path coefficients that indicate how literacy positively affects numeracy, and how both literacy and numeracy contribute to critical thinking and higher-order thinking skills. These visual tools not only make the data more accessible but also clarify the specific interactions that are crucial to addressing the research questions posed in the study.

Structural Equation Modeling (SEM) Results

To further explore the relationships among the variables, structural equation modeling (SEM) was utilized, and the results are depicted in Figure 2, illustrating the hypothesized model along with the respective path coefficients. The path coefficients (β) represent standardized regression weights, quantifying the change in the dependent variable associated with a one-standard-deviation change in the independent variable while accounting for other variables' effects. For instance, the path coefficient from Literacy to Numeracy (β = .75, p < .01) indicates that a one-standard-deviation increase in Literacy corresponds to a .75 standard deviation increase in Numeracy performance. This strong positive relationship suggests that students who excel in Literacy tend to also excel in Numeracy. In practical terms, the magnitude of this path coefficient implies that Literacy exerts a moderate to strong influence on Numeracy, highlighting the interconnectedness of these skills. Thus, fostering literacy development could be a critical strategy for enhancing numeracy outcomes among students.

Table 5 Correlation coefficients among literacy, numeracy, critical thinking, and higher-order thinking skills

Variable	Literacy	Numeracy	Critical Thinking	Higher-order Thinking Skills
Literacy	1.00			
Numeracy	0.75**	1.00		
Critical Thinking	0.68**	0.65**	1.00	
Higher-order thinking skills	0.70**	0.72**	0.75**	1.00

Note: **p < .01

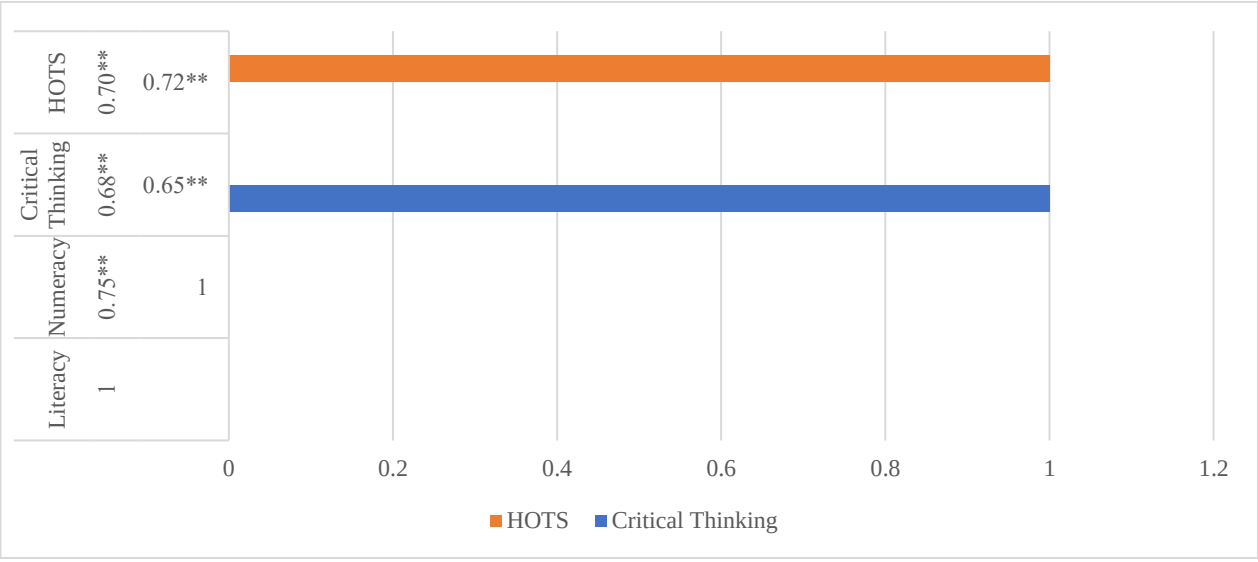


Figure 1 Relationships between key skills: literacy, numeracy, and thinking

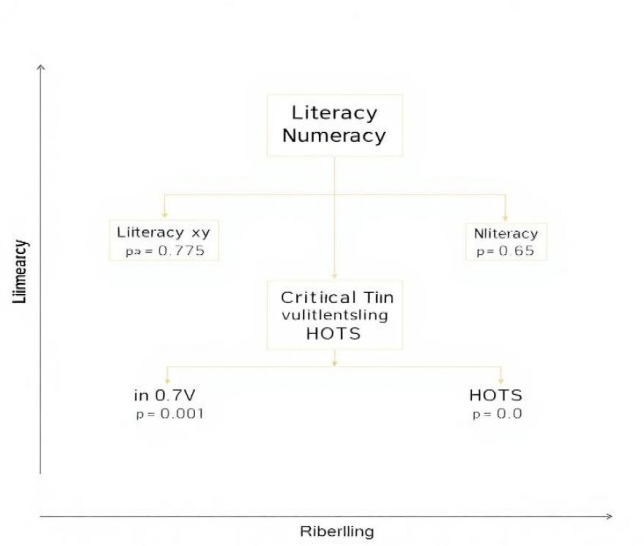


Figure 2 Structural equation model of literacy, numeracy, critical thinking, and higher-order thinking skills

The study's path coefficients reveal strong, positive relationships among literacy, numeracy, and critical thinking. Specifically, Literacy significantly influences Numeracy (β = .75, p < .01), highlighting the importance of literacy instruction as a foundation for developing numeracy skills. Additionally, literacy also positively impacts Critical Thinking (β = .68, p < .01), emphasizing the need to incorporate literacy activities that promote analytical and evaluative skills. The connection from Numeracy to Critical Thinking is also significant (β = .65, p < .01), indicating that strong numeracy skills enable better problem-solving and reasoning abilities. These findings suggest that literacy and numeracy are essential, interconnected skills that collectively support the development of critical and higher-order thinking skills. Therefore, educational strategies should focus on nurturing these competencies holistically, integrating literacy and numeracy across curricula to foster students' comprehensive cognitive development.

Table 6 Results of Common Method Bias (CMB) test

Model	χ2	df	χ2/df	CFI	RMSEA
Original model	235.12	120	1.96	0.92	0.06
Model with ULMC	210.15	115	1.83	0.94	0.05

Common Method Bias (CMB) Testing

To examine the potential impact of common method bias (CMB) on the results, we conducted a CMB test using the unmeasured latent method construct (ULMC) technique (Podsakoff et al., 2003). This technique involves adding a latent method factor to the structural equation model and examining the change in the model's fit indices (Table 6).

The results of this study show that younger high school students in Indonesia demonstrate literacy and numeracy skills, critical thinking and higher-level thinking skills. However, there are areas where improvements are needed, especially in the implementation of reasoning and problem solving. Important positive links between literacy, computational skills, critical thinking, and higher-order thinking skills suggest that improving students' literacy and computational skills can improve critical thinking and higher-level thinking abilities.

The results of this study provide valuable information for the assessment of literacy and numeracy skills using a STEAM-based approach. The results underscore the importance of integrating critical thinking and higher-level thinking skills into educational practices to improve students' overall academic performance. The use of visual aids such as tables and figures has facilitated a clearer understanding of the data, ensuring that the results are directly related to research issues. Future research should continue to explore these relationships and develop effective strategies to improve literacy and numeracy skills in Indonesia.

Discussions

The study identifies three key insights: first, a strong link between literacy skills and decision-making, indicating that improved literacy enhances critical thinking and problem-solving. Second, creativity significantly predicts higher-order thinking skills, emphasizing the importance of fostering creativity within education to strengthen critical thinking abilities. Third, STEAM education positively impacts literacy and numeracy by integrating real-world applications, helping students connect theory with practice and increasing engagement. To promote these skills, the study recommends embedding critical thinking and creativity into primary and secondary curricula through strategic reforms aligned with 21st-century learning needs. It also advocates for performance-based assessments that challenge students to apply knowledge authentically, moving beyond rote memorization. Additionally, faculty development in STEAM methodologies is vital for creating conducive learning environments. Given Indonesia's lag in literacy and numeracy compared to high-performing countries, these reforms are essential to address systemic challenges and improve educational outcomes.

Interpretation of Results

This study reveals a significant relationship between critical thinking, higher-order thinking skills, literacy, and numeracy among seventh- and eighth-grade students in Indonesia. The findings highlight that decision-making—an essential component of critical thinking—has a substantial impact on students' performance in literacy and numeracy assessments. Moreover, the ability to create, a vital aspect of higher-order thinking skills, significantly influences student outcomes in these areas. Specifically, the results indicate that various creative elements within higher-order thinking skills, such as generating novel solutions, enhance literacy and numeracy skills. This implies that students who think creatively and devise innovative responses to complex problems tend to demonstrate improved performance in these assessments.

Additionally, the study suggests that students who can effectively apply learned knowledge in new contexts achieve superior results in literacy and numeracy. This indicates that adaptability and contextual understanding are crucial for academic success. Encouraging students to think outside the box and consider alternative perspectives further bolsters their skills in these foundational areas. Such a practice aligns with the understanding that critical thinking and higher-order thinking skills are indispensable for navigating complex challenges and applying knowledge in real-world situations (Billah et al., 2021).

These findings resonate with Bloom's theoretical framework of cognitive development, which emphasizes the importance of higher-order thinking in facilitating deep learning. Darwis et al. (2024) also documented a strong correlation between critical

thinking and literacy/numeracy skills; however, this study expands existing literature by focusing on specific higher-order thinking skills elements that influence these foundational skills. Furthermore, the incorporation of STEAM (science, technology, engineering, arts, and mathematics) in educational assessment models illustrates the significance of interdisciplinary approaches. By promoting critical thinking and higher-order thinking skills through STEAM education, educators can enrich students' learning experiences, preparing them for complex future challenges. This strategy encourages students to apply mathematical concepts to real-life problems, design and conduct experiments for hypothesis testing, and develop innovative solutions, underscoring the lasting relevance of these skills beyond the classroom setting.

Implications

The findings of this study highlight the critical need for educators to actively incorporate critical thinking and Higher Order Thinking Skills (higher-order thinking skills) within their curricula. This integration can be effectively facilitated through diverse assessment methods that stimulate students to engage in critical and creative thinking. For example, using open-ended questions encourages students to formulate well-supported arguments, thereby developing their analytical skills. Furthermore, the implementation of project-based learning activities promotes the application of critical thinking and higher-order thinking skills in tackling real-world issues, allowing students to see the relevance of their education.

Encouraging students to design and conduct experiments, gather data, and analyze results significantly enhances their critical thinking abilities. The findings also stress the importance of education policies that prioritize these competencies to improve students' literacy and numeracy outcomes. Providing professional development opportunities for teachers can help them integrate critical thinking and higher-order thinking skills into their instructional strategies. Additionally, training educators in STEAM-based assessments is crucial, equipping them with the knowledge and tools to foster collaborative learning environments. By empowering teachers, we prepare students to navigate an increasingly complex and rapidly changing world, ultimately enhancing their problem-solving skills and adaptability.

Relation to Existing Literature

The results of this study are consistent with the existing literature, which emphasizes the critical role of higher-level thinking skills in education. Studies have shown that students engaged in critical thinking are better equipped to solve complex problems and apply their knowledge in different contexts. In addition, the integration of STEAM into education is associated with better student engagement and learning outcomes, reinforcing the need for interdisciplinary approaches to teaching. However, this study also contributes to ongoing discourse by providing empirical evidence from a specific cultural context, highlighting the unique challenges and opportunities faced by Indonesian teachers (Yazidi, 2023). It adds literature that supports the development of critical thinking and HATS as important components of modern education, especially in the face of rapid technological progress and globalization.

Limitations

While this study offers valuable insights into the relationship between critical thinking, Higher Order Thinking Skills (higher-order thinking skills), literacy, and numeracy, several limitations warrant acknowledgment. Firstly, measuring critical thinking and higher-order thinking skills poses challenges, and reliance on self-reported measures may introduce bias. Thus, future research should explore more objective assessment methods, such as performance tasks or observational assessments. Additionally, the sample size may not adequately represent the diverse educational contexts across Indonesia, particularly in rural or under-resourced areas, highlighting the need for future studies to recruit more representative samples to enhance the generalizability of findings. Lastly, the correlational design of this study restricts the ability to infer causal relationships, suggesting that future research should consider employing experimental or quasi-experimental designs to better examine the causal links among these constructs. By recognizing these limitations, we aim to foster a balanced discussion of the findings and identify areas for future inquiry.

Conclusion

This study investigated the influence of critical thinking and higher order thinking skills (higher-order thinking skills) on literacy and numeracy assessments among seventh and eighth-grade students in Indonesia, utilizing a STEAM-based approach. The main findings indicate that: Significant Influences: The ability to make decisions and synthesize information were identified as critical components of effective

critical thinking that significantly influence students' performance in literacy and numeracy assessments. Additionally, the ability to create was found to have a substantial impact on higher-order thinking skills. Integration of STEAM: The incorporation of STEAM into the assessment model enhances the development of critical thinking and higher-order thinking skills, suggesting that interdisciplinary approaches can effectively prepare students for complex real-world challenges. Assessment Design: The study highlights the need for varied assessment methods that not only evaluate basic literacy and numeracy skills but also foster higher-level thinking abilities.

Recommendations for Practice

To effectively integrate critical thinking and HOTS into the curriculum, educators should employ strategies promoting active student engagement in analysis and evaluation. Project-based learning is highly effective, as students solve real-world problems, fostering deep thinking, creativity, and practical application. Incorporating debates and discussions on complex topics like climate change or social justice develops argumentation skills and critical analysis. Using case studies exposes students to realistic scenarios, enhancing their problem-solving abilities and readiness for real-life challenges. Schools should gradually embed these activities into existing curricula with the support of professional development workshops and collaborative planning to equip teachers with necessary pedagogical tools. Establishing mentoring and peer observation practices encourages sharing best strategies among educators. Future research should explore long-term development of critical thinking and HOTS, considering socio-cultural influences and creating standardized assessment tools to improve measurement and intervention effectiveness.

Implications to Future Research

Future research should address this study's limitations by exploring how critical thinking and higher-order thinking skills can be integrated into education. Key areas include examining socio-cultural factors, such as socioeconomic status and cultural background, that influence students' skill development. It is also vital to create and validate objective assessment tools for these skills. Investigating effective strategies like project-based learning, think-aloud protocols, and STEAM-based instruction will help identify best practices. Additionally, research should assess the role of technology and the effectiveness of teacher professional development programs in fostering critical thinking, literacy, and numeracy in the Indonesian educational context.

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Conflicts of Interest

The authors declare no conflicts of interest.

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