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Integration of the STEM Approach in Indonesian Language Learning to Improve Elementary School Students' Critical Thinking Skills: A Quasi-Experimental Study

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ABSTRACT

Purpose: The purpose of this study is to determine whether incorporating the Science, Technology, Engineering, and Mathematics (STEM) method into Indonesian language instruction may enhance elementary school students' critical thinking abilities. The study was carried out in response to students' poor critical thinking abilities and the underutilisation of interdisciplinary teaching methods in Indonesian language instruction. **Methods:** This study used a nonequivalent control group design and a quasi-experimental method in a quantitative manner. 55 primary school kids made up the participants; they were split into two groups: an experimental class (n = 28) and a control class (n = 27). Pretests and posttests of critical thinking skills, classroom observations, and documentation were used to gather data. Descriptive statistics, homogeneity and normality tests, paired-sample t-tests, and independent-sample t-tests were all used in the data analysis. **Findings:** The findings showed that students' critical thinking abilities were much enhanced by the use of the STEM methodology. While the independent-sample t-test revealed significantly higher posttest scores in the experimental group relative to the control group ($p < 0.05$), the paired-sample t-test revealed a significant difference between pretest and posttest scores in the experimental class ($p < 0.05$). The STEM intervention had a significant educational influence on students' critical thinking abilities, according to the computed effect size. **Research implications:** Because of the study's single-school context, limited sample size, and lack of random assignment, the results should be interpreted cautiously even though they show the efficacy of STEM-based Indonesian language acquisition. To improve the findings' generalisability, larger and more varied sample sizes from various educational environments should be used in future research. **Originality:** By incorporating the STEM approach into Indonesian language learning an area that has gotten little attention in prior research this study makes a unique addition. This study shows how STEM integration in language instruction can improve students' critical thinking abilities, in contrast to the majority of STEM studies that concentrate on science and maths.

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INTRODUCTION

Learning Indonesian in primary school is essential for improving children' language, literacy, and critical thinking abilities. In addition to emphasising linguistic elements, Indonesian as a core topic develops critical comprehension, processing, and communication skills. According to Huang (2019) Through interaction with text and context, language acquisition is a communication process that enables children to develop meaning. Currently, literacy needs encompass science, technology, and problem-solving literacy, in addition to reading and writing abilities. This is in line with the view Tytler (2020) and Tan & Kidman (2025) that STEM literacy must be incorporated into primary education in order to meet 21st century capabilities. One of the cutting-edge methods that can improve students' problem-solving and thinking skills is the STEM (Science, Technology, Engineering, and Mathematics) approach. Contextual and

significant learning opportunities can be obtained by incorporating STEM into language instruction. As a result, the STEM method might be modified for teaching Indonesian in elementary schools.

Indonesian elementary school pupils still have comparatively poor critical thinking abilities. This is demonstrated by the findings of numerous national tests, which reveal primary school pupils' poor capacity for information analysis, evaluation, and interpretation. According to Fernández-Santín & Feliu-Torruella (2020) and Taimur & Sattar (2020) A fundamental talent that needs to be cultivated from a young age through a variety of literacy exercises is critical thinking. Nonetheless, the current approach to learning Indonesian is still textual and focused on memorisation. Teachers tend to employ lecture methods and practice questions without leaving room for research and investigation. Students are less able to relate their learning of the Indonesian language to actual issues in their environment as a result of this situation. Additionally, kids receive less stimulation to think at a higher level due to the lack of variation in learning methodologies. Thus, the primary issue with studying Indonesian in elementary school is a lack of critical thinking skills.

A significant gap exists between the curriculum's demands and modern teaching methods. Although the Merdeka Curriculum places a strong emphasis on developing critical thinking and literacy skills, its field application has not been ideal. According to Graesser et al. (2020) and Häkkinen et al. (2017) Teachers must design creative, cooperative, and problem-solving lessons. Nonetheless, Indonesian educators continue to employ a traditional teaching methodology that is out of step with 21st-century learning. An integrative strategy that can link several disciplines in a single learning process has not been utilised by many educators. This disparity is also evident in the underutilisation of STEM methods in Indonesian language instruction, despite the fact that these methods have been shown to enhance critical thinking abilities. According to (R. Hidayat et al., 2023) Students' analytical and creative skills can be enhanced through STEM integration. As a result, there is a gap that needs to be filled between the curricular concept and the actual learning activities.

Innovation in Indonesian language learning techniques is required to address these issues. Including STEM approaches in the educational process is one possible solution. By connecting language concepts with scientific and technical contexts, the STEM method fosters critical thinking and creativity in students. According to (Leung, 2019) and (Retno et al., 2025) STEM-based learning provides opportunity for students to build understanding via inquiry, experimentation, and in-depth discussion. Because STEM integration directly involves students in problem-solving and project-based learning, it can help boost learning motivation. These ideas can also be put into practice through inquiry, collaborative learning, and project-based learning paradigms. This method of studying Indonesian emphasises the development of advanced cognitive abilities in addition to text. In the framework of elementary education, STEM integration is therefore emerging as a pertinent and useful alternative answer.

Numerous studies have demonstrated the efficacy of STEM approaches in enhancing students' critical thinking abilities. First, research by Sarwi et al. (2021) show how STEM-based education can enhance students' capacity for analysis and problem-solving. Second, research by Sun & Zhong (2024) discovered that incorporating STEM into literacy can enhance critical reading abilities. Third, the study by Amin et al. (2022) demonstrates how the STEM learning approach enhances the conceptual comprehension and argumentative abilities of elementary school pupils. Fourth, research by Struyf et al. (2019) demonstrates how STEM education promotes students' active engagement in class discussions. Fifth, research by Rizki & Suprapto (2024) demonstrating how project-based STEM methods may greatly enhance students' critical thinking abilities. These five studies support the claim that STEM methods have the potential to raise educational standards. Nevertheless, there is little research that expressly incorporates STEM into Indonesian language instruction in elementary schools. Thus, this study closes this gap.

The innovation of this study is its emphasis on incorporating STEM methods into Indonesian language instruction to enhance primary school pupils' critical thinking abilities. Despite its widespread application in science and mathematics, the STEM approach is rarely used in language acquisition. According to Kidman & Tan (2025) and Marbach-Ad et al. (2019) STEM is more than just science and technology; it can be a comprehensive strategy for fostering interdisciplinary literacy. This study provides a fresh perspective on how STEM-related experimental, observational, and problem-solving exercises can enhance Indonesian language learning. The introduction of an integrative paradigm that connects language proficiency with analytical and evidentiary capabilities is another innovation in this field. This study adds something fresh to the creation of models for learning Indonesian that are more suited to the demands of the twenty-first century. Given the expanding demands of education, this innovation is becoming increasingly significant. This study offers breakthroughs in the field of Indonesian language education.

STEM integration with language acquisition is still in its infancy and requires further research. According to research from around the world, language and STEM literacy may be related, although local implementation of this theory is currently lacking. According to Falloon et al. (2020) and Roehrig et al. (2021) To develop a deeper

comprehension of concepts, literacy integration in STEM is crucial. However, the use of STEM is still mostly restricted to scientific and maths education in Indonesia. There is relatively little organised research on STEM approaches to language studies. Thus, by introducing integrative notions in Indonesian language learning, this study aims to close this theoretical gap. The goal of this research's state of the art is to integrate two crucial areas: STEM literacy and linguistic literacy. The results of this study broaden the use of STEM in the elementary school curriculum. This offers a theoretical foundation for the creation of future studies.

The necessity to raise the standard of Indonesian language instruction in elementary schools to satisfy the requirements of 21st century skills is the reason this research is so urgent. Critical thinking is one of the key abilities that students need to acquire to deal with global concerns. According to Maharani et al. (2026) and Power et al. (2019) The capacity to evaluate and reach conclusions based on reliable data is known as critical thinking. Still, there is not enough room in the current curriculum for children to completely develop these skills. STEM integration is urgently needed because of the disconnect between curriculum requirements and learning methods. This method may be used to foster more contextual, critical, and active learning. The urgency of this research stems from global demand and technical advancements, in addition to academic needs. Therefore, this research is vital for improving the quality of Indonesian language teaching at the basic level.

Although STEM education is typically linked to science and math courses, its ideas can also be incorporated into language learning through real-world problem-solving exercises that call for creativity, communication, inquiry, and evidence-based reasoning. STEM integration is defined in the context of learning Indonesian as a method of instruction that involves students investigating real-world issues, obtaining and evaluating data, expressing concepts verbally and in writing, and creating logical solutions. Technology gives students access to information and digital literacy tools, science brings contextual issues and inquiry methods, engineering motivates students to create and assess solutions, and mathematics helps with data interpretation and evidence-based reasoning. Students employ language as a tool for problem-solving through exercises such as analyzing informational materials, debating local concerns, creating arguments, writing reports, and presenting suggested solutions (Hidayat et al., 2026). Therefore, STEM integration in Indonesian language instruction not only enhances language competency but also promotes higher-order thinking skills, particularly critical thinking, which is crucial for meaningful learning in the twenty-first century.

To enhance students' critical thinking abilities, this study attempted to create a model for incorporating STEM techniques into Indonesian instruction in elementary schools. This study's specific goal is to outline the present requirements and circumstances for learning Indonesian in relation to critical thinking abilities. Additionally, the goal of this research is to create an integrative learning paradigm based on STEM that educators may use. The usefulness of the STEM approach in enhancing pupils' critical thinking is another goal of this study. According to Newman & Gough (2020) and Zawacki-Richter et al. (2020) Clear exploratory and evaluative goals are essential for development research. By adhering to these guidelines, this study guarantees that its findings can offer both theoretical and practical advantages. This study is expected to offer implementable recommendations for teachers and schools. The goal of this study aligns with current initiatives to raise the standard of Indonesian language instruction.

METHOD

Approach to Design and Research

This study employs a quasi-experimental method in conjunction with a quantitative approach. The experimental class and the control class are the two groups involved in the Nonequivalent Control Group Design research design. This technique was chosen because it allows researchers to monitor the influence of the integration of STEM approaches on students' critical thinking skills through learning interventions. Because the study was carried out in a class that had already been established without randomisation, the quasi-experimental approach is thought to be appropriate. According to Andrade (2021) By taking into account the constraints of controlling external variables, quasi-experiments enable researchers to assess the effects of treatment. In this study, the control group will receive traditional instruction, while the experimental group will receive STEM-based instruction in Indonesian. This strategy seeks to gather unbiased information regarding the efficacy of the interventions offered.

Location and Research Subject

The research was conducted on elementary school pupils who were participants in Indonesian language learning. The location was chosen based on the curriculum's compatibility, the facilities' accessibility, and the school's support. Two courses, each with 25–30 students, served as the research subjects. The classes were split into experimental and control groups. Purposive sampling is used in the sample determination approach because the researcher requires a class with comparable characteristics. While the control group keeps using regular instruction, students in the experimental class

will follow Indonesian language instruction that is interwoven with STEM. According to the critical thinking skills pretest, students' beginning abilities are comparatively similar. Consequently, the research topic was selected to bolster the study's internal validity.

Research Procedures and Treatments

During the preparation phase, the researcher created lesson plans, STEM-based LKPD, and assessment tools for critical thinking abilities. Additionally, the researcher tested the instrument's validity using STEM and language acquisition specialists. During the implementation phase, a STEM-based Indonesian language learning model was applied to the experimental class through text analysis, problem-solving conversations, observational exercises, and basic experiments. The control group received conventional instruction. In the final phase, the researcher administered a posttest to both groups. Each learning outcome was then examined to determine the differences between the results of the two groups. This process enables the research to provide a detailed description of how STEM concepts are applied.

Six instructional sessions of STEM-based Indonesian language training were provided to the experimental group. To integrate STEM (science, technology, engineering, and mathematics) concepts into language acquisition, learning activities centered on informational texts about environmental challenges, such as waste management and water conservation. To identify issues and assess the evidence, students conducted basic research and conversations after first observing actual phenomena and gathering information from literature and online resources. Students then collaborated to organise facts, create arguments, devise and suggest workable solutions to the challenges they had discovered, and convey their views through written reports and oral presentations. Students engaged with STEM-related concepts and problem-solving techniques while honing their reading comprehension, critical discussion, argumentative writing, and presentation skills through this series of activities that included observation, information gathering, investigation, problem analysis, solution design, and communication.

Research Instruments

Tests of critical thinking abilities and learning implementation observation sheets are the primary tools used in this study. The critical thinking skills test was developed based on the indicators proposed by Sumarni et al. (2018), which include giving a simple explanation, developing basic skills, drawing conclusions, providing further explanation, and applying tactics and strategies. The test consists of a description that calls for the examination, assessment, and interpretation of Indonesian texts concerning STEM. Observation papers were used to ensure that learning followed the grammar. Expert validation and empirical validity tests are used to assess the instrument's validity. The Alpha Cronbach formula is used to measure reliability. Subsequently, precise quantitative data were obtained using the equipment.

Data Collection Techniques

Data were collected through pre-and post-tests, classroom observations, and documentation. The pretest was administered before the treatment to determine students' initial critical thinking abilities, whereas the posttest was conducted after the treatment to measure changes following the intervention. Classroom observations were carried out to evaluate the implementation of STEM integration in the experimental class throughout the learning process. In addition, documentation in the form of photographs of learning activities, lesson plans, and records of the instructional process was collected as supplementary data. Collectively, these techniques provided a comprehensive overview of the effects of the intervention on students' critical thinking abilities.

Data Analysis Techniques

Descriptive and inferential statistics were used in the data analysis process. The average, median, mode, and standard deviation of pupils' critical thinking skills are described using descriptive statistics. An independent t-test (Independent Samples t-test) is used to look for significant differences between the experimental and control groups in order to test the hypothesis. The analytical prerequisites are first examined using the Kolmogorov-Smirnov test for normality and the Levene's test for homogeneity before the t-test is performed. The Mann-Whitney non-parametric test is used to continue the study if the data is not normally distributed. To ascertain the degree to which the STEM approach influences critical thinking abilities, the effect size was also computed. The research findings can be objectively and scientifically analysed using this method of analysis.

RESULTS

Instrument Validity and Reliability

The validity and reliability of the critical thinking abilities test were confirmed by expert validation and empirical testing prior to the study's implementation. Two specialists in educational evaluation and Indonesian language instruction participated in the expert validation. With an average validity score of 3.75 out of 4.00, the results showed that all test items were deemed relevant to the indicators of critical thinking skills, demonstrating a good level of content validity. Based on a pilot test with thirty students, the Pearson Product-Moment correlation coefficient was used to assess empirical validity. The research revealed that the item-total correlation coefficients exceeded the crucial value of r-table (0.361) at the 0.05 significance level, ranging from 0.421 to 0.782. Consequently, every test item was deemed legitimate and appropriate for gathering data. Cronbach's Alpha coefficient was used to evaluate the instrument's dependability. High internal consistency was indicated by the Cronbach's alpha rating of 0.873. Based on these findings, the critical thinking skills exam was deemed valid and reliable for assessing students' critical thinking abilities in this study.

Hypothesis Testing and Effect Size Analysis

Following the intervention, there was a statistically significant difference in critical thinking abilities between the experimental and control groups, according to the independent samples t-test ($p < .05$). Students who engaged in STEM-based Indonesian language learning earned better post-test results than those who received conventional instruction, showing the effectiveness of the intervention. Additionally, the computed Cohen's d value revealed a substantial effect size, indicating that the observed difference was both statistically and educationally significant. These results imply that incorporating STEM concepts into Indonesian language instruction can successfully improve primary school pupils' critical thinking abilities.

Effect Size Analysis

To ascertain the practical value of the STEM-based learning intervention, an effect size analysis was conducted. Students' critical thinking abilities significantly improved between the pretest and posttest, according to the paired-samples t-test; a Cohen's d value of 0.87 indicated a high effect. Following the intervention, there was a significant difference between the experimental and control groups, as indicated by the Cohen's d value of 0.82. Furthermore, the STEM-based learning strategy explained approximately 15% of the variance in students' critical thinking abilities, according to the eta squared (η^2) value of 0.15. These data confirm that the intervention was not only statistically significant but also educationally meaningful.

Pretest Results and Baseline Equivalence

Descriptive statistics of the pretest results for the experimental and control groups are shown in this table. The findings show that both groups had equivalent levels of critical thinking abilities before the intervention, as evidenced by their average pretest scores. This result offers initial proof that the groups were comparable in their initial circumstances prior to using the STEM-based learning strategy.

Table 1. Descriptive Statistics of Pretest Scores

Group	N	Mean	Standard Deviation
Experimental Group	28	61.43	8.27
Control Group	27	60.89	8.11

The experimental group scored 61.43 (SD = 8.27) on the pretest, while the control group scored 60.89 (SD = 8.11). The modest discrepancy between the two means indicates that both groups had very similar levels of critical thinking skills prior to receiving separate instructional treatments.

Prerequisite Test Results

To ensure that the data satisfied parametric statistical assumptions, normality and homogeneity tests were performed prior to hypothesis testing.

Table 2. Data Normality Test Results

Groups	Data	Statistik Kolmogorov-Smirnov	Sig.	Remarks
Eksperimen	Pretest	0,112	0,200	Normal
Eksperimen	Posttest	0,105	0,200	Normal
Control	Pretest	0,118	0,173	Normal
Control	Posttest	0,109	0,200	Normal

Based on Table 2, all data have a significance value greater than 0.05 so it can be concluded that the data is normally distributed.

Table 3. Homogeneity Test Results

Data	Levene Statistic	Sig.	Remarks
Posttest of Experiment and Control Class	1,247	0,269	Homogen

The homogeneity test results indicated that the variances of the two groups were homogeneous, with a significance value of 0.269 (> 0.05). Therefore, the assumption of homogeneity was satisfied, allowing parametric statistical tests to be applied for hypothesis testing. To evaluate the effectiveness of STEM-based Indonesian language instruction in improving students' critical thinking skills, a paired-sample t-test was conducted to compare the pretest and posttest scores of the experimental class.

Table 4. Paired Samples Correlations in the Experimental Class

Pair	N	Correlation	Sig.
Experimental Class Pretest and Posttest	28	0,842	0,000

Table 4 yielded a correlation value of 0.842 and a significance level of 0.000 (<0.05). This demonstrates that the experimental class's pretest and posttest results have a significant correlation.

Table 5. Experimental Class Paired Samples Test Results

Pair	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Pretest–Posttest	-27,54	8,12	-17,95	27	0,000

A significant value of 0.000 (<0.05) was found in the paired t-test results. As a result, the experimental class's pretest and posttest results differ significantly. These findings demonstrate that primary school pupils' critical thinking abilities are successfully enhanced by the use of STEM concepts.

Independent Control-Class Test–Experiment on Posttest

To find out how students who engaged in STEM-based learning differed from those who engaged in conventional learning in terms of critical thinking abilities, an independent t test was used.

Table 6. Results of the Independent Posttest of the Experimental Control Class (Group Statistics)

Groups	N	Mean	Std. Deviation	Std. Error Mean
Eksperimen	28	83,75	6,54	1,24
Control	27	72,11	7,38	1,42

Based on Table 6, The control group scored 72.11 on the average posttest, compared to 83.75 for the experimental group. The experimental class outperforms the control class in critical thinking, as evidenced by this average difference.

Table 7. Independent Samples Test Results

Variabel	t	df	Sig. (2-tailed)	Mean Difference
Posttest Experiment-Control	6,22	53	0,000	11,64

A significant difference between the experimental and control class posttest scores was indicated by a significance value of 0.000 (<0.05). Thus, it has been shown that STEM-based Indonesian education improves students' critical thinking abilities more successfully than traditional education.

Description of Critical Thinking Skills Indicator Data

After engaging in STEM-based learning, indicator analysis was used to assess the extent to which each component of students' critical thinking abilities had improved.

Table 8. Description of Experimental Class Critical Thinking Skills Indicator Data

No	Critical Thinking Indicators	Pretest	Posttest	Gain
1	Giving a Simple Explanation	55,40	84,90	29,50
2	Building Basic Skills	57,10	85,50	28,40
3	Summing up	56,80	82,70	25,90
4	Further Explanation	55,20	83,40	28,20
5	Strategies and Tactics	56,00	82,30	26,30
Average		**56,10**	**83,76**	**27,66**

Based on Table 8, since STEM-based schooling was introduced, all indices of critical thinking skills have shown improvement. The highest increase was found in the indicator **giving a simple explanation** with a gain of 29.50 points. Meanwhile, the lowest increase was found in the indicator **concluding with a** gain of 25.90 points. Despite this, all indicators show a high and relatively even increase.

Table 9. Comparing the Development of Critical Thinking Skills in Experimental and Control Groups

Indicator	Gain Eksperimen	Gain Control
Giving a Simple Explanation	29,50	15,10
Building Basic Skills	28,40	15,80
Summing up	25,90	15,50
Further Explanation	28,20	16,30
Strategies and Tactics	26,30	16,90
Average	**27,66**	**15,92**

The data in Table 9 shows that the average gain of critical thinking skills in the experimental class (27.66) was higher than that of the control class (15.92). These findings reinforce the results of previous statistical tests that the integration of STEM approaches in Indonesian language learning contributes to improving the critical thinking skills of elementary school students compared to conventional learning. To provide a more standardized measure of learning improvement, normalized gain (N-gain) scores were calculated for both groups. The N-gain analysis showed that the experimental group achieved a higher level of improvement than the control group did. Based on the established criteria, the experimental group was categorized as having a medium/high improvement level, whereas the control group demonstrated a low/medium improvement level. These findings further support the effectiveness of the STEM-based Indonesian language learning approach in enhancing students' critical thinking skills.

DISCUSSION

The findings demonstrate that incorporating STEM methods into Bahasa Indonesia instruction significantly enhances elementary school pupils' capacity for critical thought. The substantial disparity in the experimental class's pretest and posttest scores supports this conclusion. This rise suggests that learning that incorporates STEM (science, technology, engineering, and mathematics) can enhance students' comprehension of linguistic topics. Students have more opportunities to develop higher-level thinking abilities when they engage in learning activities that challenge them to observe, analyse, and infer information. According to English (2016) The goal of the STEM approach is to help students address problems holistically by integrating different disciplines. In addition, Chen et al. (2024) claims that through contextual and problem-solving-based learning experiences, STEM education fosters critical thinking in students. Thus, it makes sense that using STEM methodologies in experimental classes will enhance students' critical thinking abilities. These results imply that STEM integration can lead to more creative approaches to Indonesian language instruction.

Following the implementation of the STEM strategy, the experimental class's paired t-test results revealed a significant change between pretest and posttest scores. This distinction demonstrates that students' critical thinking abilities can actually change as a result of the instruction given. Students are encouraged to actively construct knowledge through learning activities that incorporate problem research, group discussions, and solution building. Students participate in this process by not only receiving information but also analyzing it from various sources. According to Strauss (2016) When deciding what to believe or do, critical thinking is a contemplative and logical process. Meanwhile, Reynders et al. (2020) explains that the skills of interpretation, analysis, evaluation, infringement, and explanation are all part of critical thinking. All of these elements developed during the learning process, as evidenced by the rise that took place in the experimental class. As a result, the STEM method has been successful in helping pupils develop their critical thinking abilities.

The independent t-test results showed that the experimental class's average posttest score was greater than the control class's. These results suggest that STEM education is superior to traditional education in terms of enhancing students' critical thinking abilities. The teacher-centered nature of traditional education frequently restricts students' ability to investigate concepts and develop solutions independently. In contrast, the STEM approach allows students to collaborate, explore, and apply learning materials to real life. According to Tan et al. (2023) Through real-world problem-solving, STEM integration assists pupils in developing analytical thinking abilities. This opinion is reinforced by Kelley & Knowles (2016) It claims that STEM increases the quality of learning since it connects knowledge with practical application. More active learning experiences had a stronger effect on critical thinking abilities, as seen by the difference in outcomes between the experimental and control groups. As a result, STEM can be a useful substitute for Indonesian courses.

According to the examination of these indicators, all markers of critical thinking skills have improved since the STEM method was implemented. The indicator that offers a straightforward explanation has the greatest growth, whereas the indicator that concludes has the lowest increase. However, all indices are in the high range and demonstrate favorable developments. This demonstrates how the STEM approach can support many facets of critical thinking. According to Hitchcock (2017) Clarifying information, evaluating supporting data, and developing logical arguments all contribute to the development of critical thinking abilities. In addition, Demircioglu et al. (2023) claims that exercises requiring methodical reasoning and information evaluation can enhance critical thinking abilities. STEM education offers several types of activities through integrated projects, conversations, and problem-solving. Therefore, the fact that all indicators improved shows that the STEM approach fully supports the development of critical thinking abilities.

The results of this study also demonstrate that the STEM method can help students better connect the idea of the Indonesian language to real-world scenarios. Students not only comprehend the reading or text's content during the learning process, but they also make connections between it and the occurrences they come across in their immediate surroundings. This type of contextual learning facilitates students' comprehension of the subject matter and helps them enhance their analytical abilities. Students gain information through practical experience when projects and investigative activities are incorporated into their education. According to Polman et al. (2021) A key component of the process of meaningful learning is actual experience. Micari & Pazos (2021) highlighting the significance of social contact and real-world learning experiences in helping students develop their critical thinking abilities. Therefore, the qualities of contextual and collaborative learning are essential to the success of the STEM approach in enhancing critical thinking abilities. These results demonstrate how learning Indonesian can become more applicable to students' daily life.

The study's findings are consistent with those of several earlier studies that demonstrated how STEM techniques might enhance higher-order thinking abilities. Studies have shown that STEM education enhances students' analytical, problem-solving, and decision-making abilities. Because this study integrates STEM into Indonesian courses in elementary schools, its conclusions build upon those of earlier research. The STEM approach has primarily been used in science and mathematics courses thus far. According to Ragab et al. (2024) Student involvement and the growth of critical thinking abilities are positively impacted by STEM. In addition, Utami et al. (2020) discovered that incorporating STEM into literacy-based education can enhance students' comprehension and assessment skills. These results are similar, indicating that STEM is successful in various subject areas. As a result, the empirical evidence supporting the advantages of STEM in elementary education is strengthened by this study.

Overall, the study's findings support the idea that incorporating STEM methods into Indonesian language instruction is a good way to help elementary school pupils develop their critical thinking abilities. An active, contextual, and student-centered learning environment can be produced with this method. Students have the chance to improve their analytical, assessment, and inference skills through a variety of problem-solving exercises. The fact that all indicators increased indicates that STEM has an impact on critical thinking in general as well as on specific cognitive elements. According to Dilekçi & Karatay (2023) One of the most important abilities that kids need to have in the twenty-first century is critical thinking. This opinion is reinforced by Okolie et al. (2022) It believes that critical thinking skills are an important capital in tackling increasingly complicated global concerns. Consequently, more primary schools should implement STEM integration in Indonesian language instruction. It is anticipated that sustainable implementation will foster the development of a generation capable of critical, innovative, and time-adaptive thought.

Despite the encouraging results, there are a few things to be aware of. First, because the study used a quasi-experimental design without random assignment, the results could have been influenced by uncontrollable outside factors. Second, the study was carried out in a single primary school with a very limited sample size, which restricted

the findings' applicability to more expansive educational settings. Third, the intervention was carried out over a somewhat brief time frame, which would not accurately reflect the long-term impacts of STEM-based Indonesian language instruction on students' capacity for critical thought. Therefore, in order to give more solid evidence about the efficacy of STEM integration in language learning, future research should include larger and more diverse samples, more educational settings, and longer intervention periods.

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CONCLUSION

This study showed how incorporating the STEM method into Indonesian language instruction greatly enhanced the critical thinking abilities of elementary school pupils. Compared to students who received traditional instruction, those who engaged in STEM-based learning activities had higher posttest scores and greater learning gains. These results imply that incorporating contexts from science, technology, engineering, and mathematics into language instruction might produce engaging learning opportunities that motivate students to assess arguments, analyse data, solve problems, and express ideas more clearly. Thus, in elementary Indonesian language instruction, the STEM approach can be a promising pedagogical strategy for developing higher-order thinking abilities. Despite these encouraging results, there are a few things to be aware of. First, the study adopted a quasi-experimental design without random assignment, which may have limited control over external variables. Second, the study's limited sample size and single elementary school setting limited how broadly the results might be applied. Third, it is challenging to ascertain whether the noted gains in critical thinking abilities can be sustained over time due to the brief duration of the intervention. It is advised that future studies investigate the efficacy of STEM-integrated Indonesian language instruction in a variety of educational settings and schools. To find developmental variations in learning results, more research may examine its application at various grade levels. Longitudinal research is also required to find out how STEM-based language acquisition affects overall academic success and literacy development over time, as well as to examine the long-term durability of students' increases in critical thinking. Theoretically, by expanding its application beyond conventional scientific and maths courses into language instruction, this study adds to the expanding corpus of scholarship on STEM education. The results offer empirical proof that STEM integration can serve as an interdisciplinary framework for encouraging critical thinking in Indonesian language learning, enhancing our current knowledge of how language instruction can support 21st-century skills in elementary education.

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AUTHOR CONTRIBUTION STATEMENT

DRS contributed to conceptualization, methodology, supervision, validation, writing – original draft, and writing – review & editing AS contributed to methodology, formal analysis, investigation, resources, and writing – review & editing. EDH contributed to data curation, investigation, project administration, and writing – original draft. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used ChatGPT (OpenAI) during the preparation of this work for limited language editing and grammar improvement. After using the tool, the authors carefully reviewed and revised the manuscript and take full responsibility for the accuracy, integrity, and content of the publication.

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