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Stem-ethnoscience learning improves elementary students' critical thinking

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Abstract

This study aims to analyse the effect of implementing STEM-based science learning integrated with ethnoscience on critical thinking skills of elementary school students. This research is based on the importance of mastering critical thinking skills as one of the 21st-century competencies that must be developed since the elementary school level, as well as efforts to link science learning with the local cultural context through ethnoscience. The research method used was a pseudo-experiment with a pretest-posttest control group design. The research instrument was a validated critical thinking skills test. Data analysis was conducted using prerequisite tests (normality and homogeneity) and hypothesis testing with a paired-samples t-test and an independent-samples t-test using SPSS 25. The results showed that there was a significant increase in critical thinking skills in students who participated in STEM-ethnoscience-based learning compared to students who participated in conventional learning. The application of STEM-ethnoscience provides a more meaningful learning experience because it connects science concepts with local cultural practices. Thus, it can be concluded that STEM learning integrated with ethnoscience is effective in improving critical thinking skills of elementary school students and has the potential to become an innovative model in the development of culture-based science learning in the 21st-century education era.

INTRODUCTION

Background of the Study

In the 21st century era, science education plays an important role in equipping students with critical thinking skills, problem solving, and adaptive abilities needed to face an increasingly complex and technology-based world (Andriani et al., 2024; Nurhairani et al., 2026). However, in Indonesia, science learning at the elementary school level still tends to be theoretical and less contextualized, so it is limited in encouraging students' higher-order thinking skills. Monotonous assignments and minimal variation also make students less involved in analytical and evaluative thinking processes (Atmojo et al., 2025).

On the other hand, Indonesia's rich local culture offers great potential as an authentic learning resource. The Bantul region, for example, has cultural diversity that includes crafts, culinary, arts and local traditions. The utilization of cultural elements in learning allows students to relate scientific concepts to their daily experiences, while fostering an appreciation of cultural identity. One effective approach is ethnoscience, which is the original knowledge of the community that is passed down from generation to generation (Wiyarsi et al., 2023). The integration of ethnoscience in learning allows the transformation of traditional knowledge into scientific information that can be accounted for, so that students not only understand science concepts, but also develop awareness and appreciation of local wisdom (Parmiti et al., 2021).

The Problem of the Study

Although ethnoscience has great potential to bring contextual and meaningful learning, its implementation in elementary schools is still limited. Many teachers have not optimally utilized local culture as a learning resource, so the opportunity to integrate learning with students' real experiences is underutilized. This condition has an impact on the lack of development of students' critical thinking skills, which is reflected in their difficulty in analyzing phenomena, evaluating information logically, and linking scientific concepts to everyday life (Dwyer, 2023; Salazar et al., 2023; Yu & Zin, 2023).

According to Bloom's revised taxonomy, critical thinking encompasses the higher-order cognitive processes of analysis, evaluation, and creation (Moghadam et al., 2023; Sajja et al., 2025). Insufficient mastery of these skills can hinder students' academic achievement and reduce their preparedness to respond to the demands of the workforce, global competition, and continuous technological advancement (Leibovitch et al., 2025; Thornhill-Miller et al., 2023). At the primary school level, these skills often have not been the main focus of learning, so students tend to just memorize concepts without really understanding and using them reflectively. As a result, many of them still experience difficulties in developing the higher-order thinking skills needed to solve real problems. This condition is exacerbated by traditional learning methods that emphasize memorization and repetitive exercises. In fact, critical thinking skills are essential for students to be able to think reflectively, adaptively, and be ready to face the complexity of life in the 21st century (Anggriani & Atmojo, 2022; Rombout et al., 2022).

Research's State of the Art

Various studies have highlighted the role of STEM (Science, Technology, Engineering, and Mathematics) as a learning strategy that is able to connect theoretical concepts with practical applications (Deng et al., 2025; Küçükaydın et al., 2024; Zhou et al., 2024). This approach is proven to develop creativity, systematic thinking, and problem-solving skills (Archer et al., 2025). Meanwhile, research on ethnoscience emphasizes the importance of linking science with local culture, both to strengthen the relevance of learning and to foster students' appreciation of cultural wisdom (Majumdar & Chatterjee, 2021; Yasir et al., 2022).

A number of studies also show the effectiveness of ethnoscience and STEM in improving learning outcomes (Mack et al., 2021). For example, ethnoscience-based learning is proven to be able to improve students' cognitive abilities (Ilhami et al., 2021), and successfully implemented in the form of inquiry designs and student worksheets that are valid and feasible to use (Atmojo et al., 2025; Putra, 2021). However, most of these studies still focus on chemistry, biology, or physics subjects at the secondary level, with an emphasis on one approach only. STEM studies also tend to highlight motivational aspects or conceptual understanding (Chen et al., 2023; Wang & Shen, 2022), while studies that empirically evaluate the potential synergy of STEM and ethnoscience on cognitive skill development are still rare.

This condition shows that the simultaneous application of STEM and ethnoscience is still rarely researched, especially in the context of elementary schools. In fact, the integration of the two approaches from an early age is believed to be able to present science learning that is more contextual, relevant to students' lives, while strengthening the recognition of local culture. At the same time, the STEM approach at the elementary level can foster critical thinking skills that are important to face the challenges of the 21st century.

Novelty, Research Gap, & Objective

Based on this review, there is a gap in research related to the simultaneous integration of STEM and ethnoscience in science learning in elementary schools. Most of the previous studies only emphasized one of the approaches, either STEM or ethnoscience, without seeing the possibility of synergy between the two. In fact, this integration has the potential to make learning more contextual, relevant, while strengthening local cultural identity.

Therefore, this research has novelty in the effort to combine STEM and ethnoscience approaches simultaneously in learning in elementary schools. The purpose of this study is to examine the effect of STEM-ethnoscience integration-based learning in improving critical thinking skills of elementary school students. Theoretically, this research contributes to enriching the study of innovative learning by presenting an integrative model that has rarely been studied before. Practically, this research provides a reference for teachers in designing science learning that is contextual, fun, and strengthens students' local cultural identity.

METHOD

Type and Design

This research was conducted in grade V (five) in three elementary schools located in Bantul Regency, Yogyakarta Special Region. The selection of the research location considered that the three schools were located in a community environment rich in local culture, thus allowing the integration of ethnoscience elements into learning. This study used a quasi-experimental design with the type of nonequivalent control group design. The independent variable in this study is STEM-based science learning integrated with ethnoscience, while the dependent variable is the critical thinking skills of elementary school students.

The selection of schools and classes was done purposively by considering a number of criteria to maintain validity and comparability between groups. The criteria included: (1) the school has a minimum of two classes at the same level to allow the division of experimental and control groups; (2) the school has a minimum accreditation of B as an indicator of institutional quality; (3) teachers in both classes have comparable educational backgrounds and teaching experience (at least 5 years); and (4) students in both classes have relatively equal academic abilities based on school data.

Based on these criteria, one class each was assigned as the experimental group and one class as the control group in each school. Furthermore, all data from the three schools were combined to form two large groups, namely one experimental group with 75 students and one control group with 75 students. Furthermore, the stages of the research procedure are described systematically in Figure 1 below.

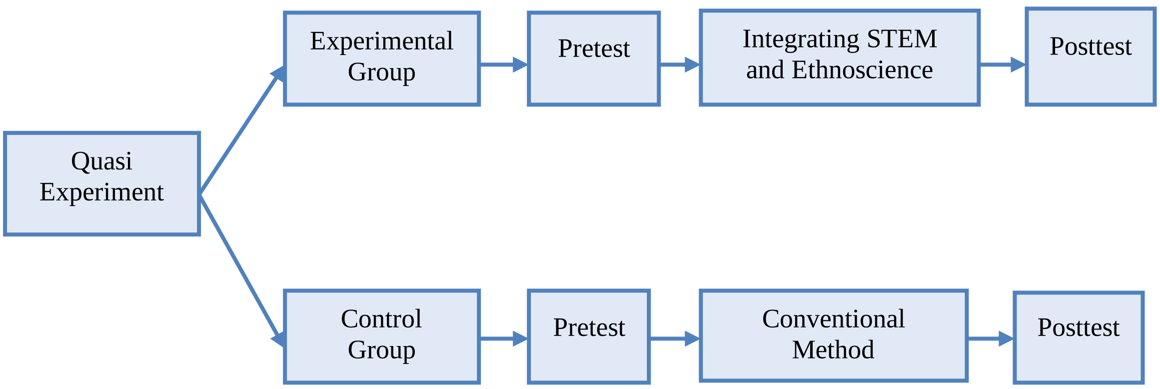

Figure 1. Research Procedure

Data and Data Sources

The data in this study consisted of primary data and secondary data. Primary data was obtained directly from the learning implementation process in class V (five) at three elementary schools located in Bantul Regency. Primary data includes the results of observations of teaching and learning activities and the results of students' critical thinking tests. Observations were made to find out how the implementation of the ethnoscience integrated STEM learning model in a real context, while the test was used to measure the improvement of students' critical thinking skills. In addition to primary data, this study also used secondary data obtained from various supporting documents, such as school curriculum, learning tools, and literature related to STEM, ethnoscience and the development of critical thinking skills in elementary schools. Furthermore, the source of data in this research is fifth grade students, who are the main subject of the research as well as the source of data regarding critical thinking skills through test results.

Data Collection Technique

The types of data in this study consisted of three forms, namely data from the test results of students' critical thinking skills, data from observations of learning activities, and documentation data of learning activities. Critical thinking skills test data were obtained through tests. This test was designed to measure the ability of fifth grade students to analyze, evaluate, and connect science concepts with everyday life rooted in local wisdom.

The critical thinking skills test instrument was prepared by referring to the indicators proposed by Ennis, namely: (1) *elementary clarification*, which measures students' ability to understand and explain problems clearly; (2) *basic* skills (*basic support*), which assesses the ability to use facts or evidence to support arguments; (3) *inference*, which measures the skill of drawing logical conclusions from available information; (4) *advanced clarification*, which emphasizes deeper analysis of assumptions or arguments; and (5) *strategies and tactics*, which assesses the ability to formulate problem-solving steps and choose the right strategy. By referring to these five indicators, the instrument is able to measure students' critical thinking skills comprehensively.

In addition, observation data was obtained through the use of a systematically organized learning activity observation sheet. These observations focused on student participation, interaction between teachers and students, and the dynamics of implementing STEM and ethnoscience-based learning models in the classroom. Meanwhile, documentation data was collected to complement the test and observation results. Documentation includes photos, video recordings and field notes.

Data Analysis

Data analysis in this study was conducted through two stages, namely descriptive analysis and inferential analysis. Descriptive analysis was used to provide an overview of the research data, such as the mean value, standard deviation, variance of students' critical thinking skills. Furthermore, inferential analysis was conducted to test the research hypothesis. Before conducting hypothesis testing, prerequisite tests were first carried out which included normality test and homogeneity test. The normality test aims to determine whether the data distribution is normally distributed, while the homogeneity test is carried out to ensure that the data variance in the experimental group and control group is the same.

After the prerequisite test is met, proceed with hypothesis testing using paired sample t-test and independent sample t-test. The paired sample t-test was used to determine differences in students' critical thinking skills before and after treatment in the experimental group. Meanwhile, the independent sample t-test was used to compare the results of critical thinking skills between the experimental and control classes after the treatment was given. The entire data analysis process was carried out with the help of SPSS version 25 software.

RESULTS

This study aims to examine the effect of science learning oriented to the STEM (Science, Technology, Engineering, and Mathematics) approach integrated with ethnoscience in improving critical thinking skills of elementary school students. Ethnoscience is understood as knowledge and systems that develop in society based on experience and interaction with the surrounding environment, especially those related to local wisdom and culture. Through the application of this approach, students are not only directed to understand scientific concepts in the abstract, but also trained to examine the relationship between science and culture that is familiar in everyday life.

Based on the results of the research that has been carried out, data on students' critical thinking skills were obtained before and after the learning intervention, both in the experimental and control groups. The description of these results is presented in Table 1, and visualized in the form of Figure 2 to provide a clearer picture of the comparison of achievements between groups.

Table 1. Description of Critical Thinking Skills Data

Variable	Group		Statistic
Critical Thinking	Pretest Experiment	Mean	67.3067
		Median	70.0000
		Variance	177.567
		Std. Deviation	13.32542
	Experiment Posttest	Mean	90.8400
		Median	92.0000
		Variance	45.352
		Std. Deviation	6.73442
	Control Pretest	Mean	66.5333
		Median	68.0000
		Variance	105.198
		Std. Deviation	10.25662
	Control Posttest	Mean	77.2533
		Median	76.0000
		Variance	72.057
		Std. Deviation	8.48861

To clarify the results of the descriptive analysis in Table 1, the data is then visualized in the form of a heatmap. This visualization provides a more intuitive picture of the comparison of mean values, standard deviations, and variances between groups through color gradations. The results of the visualization can be seen in Figure 2.

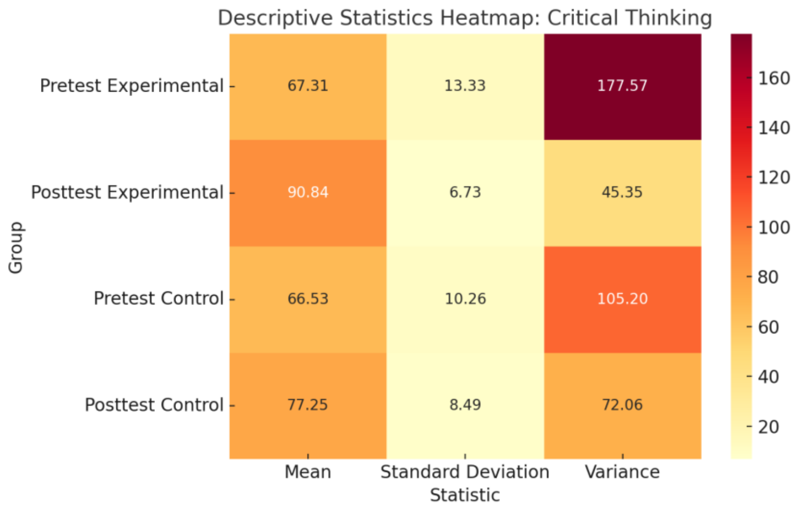

Figure 2. Comparison of experimental and control group data

Based on Figure 2 and Table 1, descriptive statistical analysis shows a clear difference in *critical thinking* scores between the experimental and control groups, both at the *pretest* and *posttest* stages. In the experimental group, the *pretest* results showed an average score of 67.31 with a standard deviation of 13.33 and a variance of 177.57. This shows a fairly large spread of values at the beginning of the measurement. After the treatment, the *posttest* score increased significantly to 90.84 with a standard deviation that decreased to 6.73 and a variance of 45.35. The increase in the average score accompanied by a decrease in the standard deviation and variance indicates that the learning provided not only improves the participants' critical thinking skills, but also produces a more homogeneous distribution of values.

Meanwhile, in the control group, the *pretest* score had an average of 66.53 with a standard deviation of 10.26 and a variance of 105.20. In the *posttest*, there was an increase in the average to 77.25, with a standard deviation of 8.49 and a variance of 72.06. Although there was an increase in scores, the magnitude of the increase was not as great as that in the experimental group, and the distribution of data also did not experience a significant decrease as in the experimental group.

When compared as a whole, the experimental group experienced an average increase of 23.53 points, while the control group only increased by 10.72 points. The visualization of Figure 2 also corroborates this finding, where the *mean* column in the experimental group's *posttest* has a deeper orange color indicating high scores, while the *variance* column shows a paler color, reflecting a decrease in the variation of scores.

Furthermore, to ensure that the statistical analysis used in the next stage can be carried out appropriately, a data normality test was first conducted. This test aims to determine whether the research data is normally distributed or not. The results of the normality test are presented in Table 2.

Table 2. Normality Test Results

Variable	**Group**	**Kolmogorov-Smirnov[a]**		
		Statistic	**df**	**Sig.**
Critical Thinking	Pretest Experiment	.100	75	.060
	Experiment Posttest	.100	75	.062
	Control Pretest	.099	75	.068
	Control Posttest	.093	75	.173

Based on Table 2, the Kolmogorov-Smirnov normality test results show that all data have a significance value (*Sig.*) above 0.05. The significance value for the experimental group *pretest* is 0.060, the experimental group *posttest* is 0.062, the control group *pretest* is 0.068, and the control group *posttest* is 0.173. Thus, all data can be declared normally distributed according to the Kolmogorov-Smirnov test criteria.

After the data is declared normally distributed based on the Kolmogorov-Smirnov test in Table 2, the next step is to conduct a variance homogeneity test to ensure the similarity of variance between groups. This test is important before proceeding to parametric analysis. The results of the variance homogeneity test are shown in Table 3.

Table 3. Homogeneity Test Results

		Levene Statistic	**df1**	**df2**	**Sig.**
CT	Based on Mean	3.874	1	148	.051
	Based on Median	3.611	1	148	.059
	Based on Median and with adjusted df	3.611	1	142.071	.059
	Based on trimmed mean	3.830	1	148	.052

Based on Table 3, the results of the homogeneity of variance test with the *Based on Mean* method show a *Levene Statistic* value of 3.874 with a significance (*Sig.*) of 0.051. Since the significance value is greater than 0.05, it can be concluded that the data variance between groups is homogeneous. This condition fulfills one of the basic assumptions in parametric analysis, so that the analysis of mean differences can be done with the *t* test.

After knowing that the data is normally distributed (Table 2) and has a homogeneous variance (Table 3), the analysis can proceed to the hypothesis testing stage. The test was conducted using *paired sample t-test* to see the average difference in *critical thinking* scores between *pretest* and *posttest* results in the experimental group. The results of the paired sample t-test can be seen in Table 4.

Table 4. Paired Sample t-test Test Results

	Paired Differences			t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean			
CT - Class	77.57333	15.44349	1.26096	61.519	149	.000

Based on Table 4, the *paired sample t-test* results show a significance value (*Sig.* 2-tailed) of 0.000, which is far below the α = 0.05 limit. This indicates a significant difference between the *pretest* and *posttest* scores of students' *critical thinking* skills. This finding strengthens the assumption that the application of learning that integrates the STEM approach with local wisdom (*ethnoscience*) can have a real impact on the development of critical thinking skills of elementary school students.

After the *paired sample t-test* was conducted on the experimental group and the results showed that there was a significant difference between the *pretest* and *posttest* scores, the analysis continued with the *independent sample t-test*. This test was used to compare the *posttest* scores between the experimental group that received ethnoscience-based STEM learning and the control group that used conventional learning. The purpose of this test is to determine whether the application of ethnoscience-based STEM learning is able to have a significantly greater effect on improving students' *critical thinking* skills than the usual learning method. The results of the *independent sample t-test* can be seen in Table 5.

Table 5. Results of *independent sample t-test*

		Levene's Test for Equality of Variances		t-test for Equality of Means			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
CT	Equal variances assumed	3.874	.051	10.859	148	.000	13.58667
	Equal variances not assumed			10.859	140.720	.000	13.58667

Based on the results of the *independent sample t-test* in Table 5, the significance value (*Sig.* 2-tailed) is obtained at 0.000, which is smaller than 0.05. This shows that there is a significant difference between the *posttest* scores of the experimental group and the control group. Thus, ethnoscience-based STEM learning is proven to have a greater influence on improving students' *critical thinking* skills than conventional learning.

DISCUSSIONS

The results of this study show that ethnoscience-based STEM learning is able to provide a significant increase in the *critical thinking* ability of elementary school students. This improvement is identified through a series of analyses, ranging from descriptive statistics, testing the assumptions of normality and homogeneity, to hypothesis testing using *paired sample t-test* and *independent sample t-test*. Overall, the results of this study are in line with the initial assumption that learning that combines the STEM approach with the context of local wisdom will be able to present a more meaningful, relevant and effective learning process in developing higher order thinking skills.

Descriptive analysis showed that the experimental group's average *pretest* score of 67.31 increased to 90.84 in the *posttest*. This increase was accompanied by a decrease in variance from 177.57 to 45.35, indicating that students' scores not only increased but were also more evenly distributed after the treatment. In contrast, the control group only experienced an increase from 66.53 to 77.25 with an insignificant decrease in variance. This difference in trend is an early indication that ethnoscience-based STEM learning has a greater influence than conventional learning. This finding is in line with the views of experts who state that STEM learning designed with real contexts can facilitate 21st century skills, including structured critical thinking abilities (Lavi et al., 2021; Adams, 2021; Muttaqiin, 2023; Küçükaydın et al., 2024; Chen et al., 2023), improving understanding of science concepts (Surjawati et al., 2025) and students' affective and applying what they have learned (Chen et al., 2023; Zhou et al., 2024).

With the assumptions of normality and homogeneity fulfilled, the analysis can proceed using parametric methods. In the *paired sample t-test* test conducted specifically on the experimental group, the significance value of 0.000 indicates a significant difference between the *pretest* and *posttest* scores. Furthermore, the *independent sample t-test* showed that there was a significant difference between the *posttest* scores of the experimental group and the control group with a significance value of 0.000. The findings of this study provide a significant theoretical contribution by emphasizing that ethnoscience can not only be positioned as additional material in learning, but can also function as an epistemological framework that enriches the science learning experience more deeply. The integration of STEM with local knowledge presents a contextualized, authentic, and meaningful learning experience, because students are given the opportunity to interpret scientific phenomena through a cultural perspective that is close to their daily lives.

The results of this study also reinforce previous empirical evidence showing that STEM approaches consistently contribute to improving critical thinking skills (Deng et al., 2025; Küçükaydın & Ayaz, 2025) as well as strengthening students' cognitive structures (Mercan et al., 2022; Rosenzweig et al., 2021). In the context of this research, STEM-ethnoscience-based learning is implemented through structured stages, starting with the presentation of contextual problems raised from local cultural phenomena (Atmojo et al., 2025). The phenomenon not only serves as an illustration, but also a starting point for students to explore scientific concepts through exploration, experimentation, and modeling activities, so that students not only understand science conceptually, but also develop the ability to work together, scientific reasoning, and connect between theory and practice in their socio-cultural framework (Helda & Rose, 2025; Kobakhidze & Jakavonytė-Staškuvienė, 2023; Kumar et al., 2024).

The implications of these results are wide-ranging, both in practical and policy terms. For teachers, the findings provide evidence that learning strategies that integrate STEM with ethnoscience can be an effective alternative for developing students' critical thinking skills, especially at the primary school level where the introduction of scientific concepts needs to be adapted to the context of everyday life. For policymakers, this model is in line with the *Freedom to Learn* policy that emphasizes teachers' freedom to design creative, contextual and student-centered learning. By adopting this approach, schools can more easily achieve the 21st century education goals that require students to be able to think critically, creatively, and adaptively to change (Anggriani & Atmojo, 2022) .

Although the results of this study provide strong evidence of the effectiveness of ethnoscience-based STEM learning, future research could expand the scope of the study to other skills such as *creative thinking*, collaborative problem-solving ability, or science literacy. In addition, implementing this model in different regions with different cultural backgrounds can enrich the understanding of the extent to which the local context influences the effectiveness of this approach. Further research with a *mixed-method* design can also explore qualitative aspects such as student and teacher perceptions of this learning, thus providing a more complete picture of its impact and application in the field.

Thus, the results of this study not only support the hypothesis that ethnoscience-based STEM learning is effective in improving students' critical thinking skills, but also contribute to the educational literature on the importance of integrating science with local culture. This approach has great potential to be widely adopted in an effort to create a generation of learners who are critical, creative, and rooted in their cultural identity, while being ready to face global challenges.

CONCLUSION

This research shows that ethnoscience-based STEM learning has a significant effect on improving the critical thinking skills of elementary school students. The results of the comparison between the experimental and control groups confirmed that the integration of the STEM approach with local wisdom is able to create a more contextual and meaningful learning process, thus encouraging students to analyze, evaluate and conclude information more deeply. This finding implies that the application of ethnoscience-based STEM learning can be used as an alternative learning strategy to foster a generation that thinks critically, creatively, and adaptively, while remaining firmly rooted in local cultural identity.

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