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BRIDGING STEM AND CULTURE: THE ROLE OF ETHNOSCIENCE IN DEVELOPING CRITICAL THINKING AND CULTURAL LITERACY

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ABSTRACT

The lack of integration between science and local wisdom in science education remains a challenge in developing students' critical thinking skills and cultural literacy. This study aims to analyze the effect of STEM-based science learning integrated with ethnoscience on critical thinking skills and cultural literacy of elementary school students. This research is a quantitative study with a quasi-experimental method using a nonequivalent control group design. Samples were selected purposively and consisted of experimental and control groups. The instruments used include a critical thinking skills test and a cultural literacy questionnaire. Data analysis was performed using a paired sample t-test. The results showed a significant difference in posttest scores between the experimental and control groups, with a significance value of 0.000 <0.005. The average difference was 19.78 points for critical thinking skills (81.14 - 61.36) and 16.86 points for cultural literacy (82.50 - 65.64). This finding suggests that integrating STEM-based science learning with ethnoscience can significantly enhance students' critical thinking skills and cultural literacy. The novelty of this study lies in the learning approach that combines the STEM framework with local ethnoscience values, providing an innovative alternative for shaping students who think reflectively while developing cultural awareness from an early age.

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INTRODUCTION

Today's global science education faces serious challenges in producing learners who are not only conceptually proficient but also capable of critical thinking and cultural literacy. STEM-integrated learning is now a significant issue in Indonesia, with potential positive impacts on the future of science learning. Several countries in Asia, Europe, and Australia have implemented STEM (Preuß et al., 2025), and Indonesia is also developing this model to improve its education system (Sumarni et al., 2022). This effort aligns with the fourth goal of the Sustainable Development Goals (SDGs), which emphasizes inclusive and equitable quality education, as well as the promotion of lifelong learning opportunities for all. STEM-based learning can contribute directly to this goal by strengthening students' 21st-century competencies and preparing them for a sustainable future.

In the 21st century, education requires students to master critical thinking, collaboration, communication, and creativity skills (Lavi et al., 2021; Adams, 2021; Muttaqiin, 2023), which can all be developed through STEM-based learning (Chen et al., 2023; Küçükaydın et al., 2024). The

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hallmark of STEM learning is the focus on the process of design, engineering, and solution development (Lavi et al., 2021; Akgunduz & Mesutoglu, 2021). Through STEM learning, students are exposed to problem contexts that prompt them to initiate or conduct investigations (Denton et al., 2020). This phase also serves to connect what is already known with what needs to be learned further (Ugwuanyi & Okeke, 2020). The STEM approach offers problem- and project-based learning experiences, enabling students to develop critical thinking skills.

Critical thinking skills are a fundamental aspect of modern education (Chen et al., 2025; Chang & Huang, 2025), serving as a key competency that influences student performance, as well as an essential skill needed to face the challenges of everyday life (Jabali et al., 2024). Critical thinking involves the process of analyzing, evaluating, and synthesizing information to make rational and effective decisions (Tang et al., 2020; Afikah et al., 2022; Lee et al., 2024) based on evidence and focuses on argumentation and reasoning (Landa-Blanco & Cortes-Ramos, 2021). Critical thinking in education helps students develop in-depth analysis, solve problems, make wise decisions, and be open to new ideas (Nawolska, 2021; Anggriani et al., 2022) so that they can consider multiple perspectives and argue with a solid foundation (Giacomazzi et al., 2022; Huerta et al., 2022; Rombout et al., 2022). Critical thinking has become a widely accepted goal in 21st-century education systems (Dishon & Gilead, 2020; Thornhill et al., 2023).

However, data from various studies indicate that Indonesian students' critical thinking skills remain low. Many students struggle with analyzing, evaluating, and synthesizing information in depth. As a result, they struggle to solve problems, make informed decisions, and build strong arguments. Learning often only focuses on delivering information without involving in-depth discussion or analysis, so students are not trained to think critically and connect knowledge to a broader context. This condition prevents students' critical thinking skills from developing optimally. This phenomenon is exacerbated by learning models that are still oriented towards memorization and content mastery (Alsaleh, 2020), without providing space for exploration and reasoning. Additionally, there remains debate about how to effectively teach critical thinking in the classroom (Ellerton et al., 2024). Some literature suggests that teaching critical thinking should be explicit and structured to be effective (Wibowo et al., 2024; Leibovitch et al., 2025).

On the other hand, there is also the equally pressing issue of declining cultural literacy among the younger generation, who are increasingly alienated from their cultural roots. The wave of globalization, which brings popular culture such as K-pop and anime, increasingly shifts students' attention away from the richness of local culture. The concept of cultural literacy has been the subject of growing discussion among academics since the late twentieth century to the present day (Kobakhidze & Jakavonytė-Staškuvienė, 2023). Its main goal is to promote harmonious coexistence in a multicultural society through value-based teaching (Sanmee et al., 2021; Aricindy et al., 2023). Thus, cultural literacy plays a crucial role in strengthening the collective identity of society, especially in the context of a culturally diverse country like Indonesia.

Unfortunately, formal education often marginalizes the value of local culture and prioritizes academic performance over cultural relevance (Parmiti et al., 2021). In fact, local culture has great potential to enrich learning and shape students' cultural identity (Sakti et al, 2024; Mahrinasari et al., 2024). In accordance with Permendiknas No. 22 of 2006, education should be tailored to local potential and culture. In this context, ethnoscience is a relevant approach because it makes culture a meaningful and contextual learning resource (Wiyarsi et al., 2023; Majumdar & Chatterjee, 2021). The integration of ethnoscience in science learning can bridge the gap between scientific knowledge and local wisdom (Parmin & Fibriana, 2020; Yasir et al., 2022) while strengthening students' understanding and cultural identity (Sotero et al., 2020; Hariyono et al., 2023). Therefore, teachers are expected to develop learning that utilizes ethnoscience as a learning resource.

However, based on the literature review, few studies empirically integrate STEM and ethnoscience approaches to examine their impact on two important aspects: critical thinking and cultural literacy. Previous studies have focused more on the motivational aspect or conceptual understanding alone (Parmin & Fibriana, 2020), and only a few have empirically evaluated the dual impact of integrating both on students' cognitive and cultural development simultaneously. Moreover, there is almost no research that specifically tests the effectiveness of this approach in the context of science learning in elementary schools. Furthermore, most existing research lacks a robust methodological framework or comparative analysis across contexts (Zhang et al., 2024; Ellerton et al., 2024).

Based on this gap, the urgency of this research is very high. In the midst of the need for science education that is not only globally oriented but also locally rooted, a learning framework is needed that can bring students closer to their own culture while equipping them with higher-order thinking skills. Therefore, this research becomes significant in addressing two major challenges of Indonesian education simultaneously: strengthening critical thinking skills and preserving cultural literacy.

The novelty of this research lies in the simultaneous integration of STEM and ethnoscience within a single science learning framework in elementary schools. Unlike previous studies that tend to separate cognitive and cultural aspects, this research offers new conceptual contributions and empirical evidence on how both can be developed in an integrated manner within the context of science learning. This study not only develops a contextual learning approach but also empirically measures the dual impact of the approach on students' cognitive and cultural competencies.

Thus, this study aims to measure and analyze the impact of integrating STEM-based science learning and ethnoscience in improving critical thinking skills and cultural literacy among elementary school students. With this approach, the study is expected to address the limitations of previous studies that tend to separate cognitive and cultural aspects, and to provide a new conceptual and empirical framework that supports the development of contextual and locally based science education.

METHODS

This study was conducted at an elementary school in Yogyakarta, utilizing a quasi-experimental design with a nonequivalent control group (Fraenkel & Wallen, 2008). The independent variable in this study was STEM-based science learning integrated with ethnoscience, while the dependent variables were students' critical thinking skills and cultural literacy.

The selection of schools and classes in this study was conducted purposively, considering several criteria to ensure validity and comparability between groups. These criteria include (1) schools having at least two classes at the same level to allow for the division of experimental and control groups; (2) schools with A accreditation as an indicator of institutional quality; (3) teachers in both classes having comparable educational backgrounds and teaching experience (at least 5 years); and (4) students in both classes having relatively equivalent academic abilities based on school data.

Two classes that met the criteria were then selected as research samples, with one class designated as the experimental group and the other as the control group. Supporting information was obtained through school documentation and consultation with class teachers to ensure basic homogeneity between groups. Ethical approval was obtained from the school and the teachers involved. All participant data were kept confidential with anonymous coding and secure data storage, in accordance with the ethical principles of educational research.

The research instruments consisted of a critical thinking skills test and a cultural literacy questionnaire, which had been validated by experts and went through an initial trial phase to ensure construct validity and reliability. Pretests and posttests were given to both groups to measure changes in skills after treatment.

In implementing the intervention, the experimental group received treatment in the form of STEM-based science learning integrated with ethnoscience. In contrast, the control group followed conventional learning commonly used in schools, namely lectures and question-and-answer sessions, without a STEM approach or local cultural content.

Although quasi-experiments have advantages, such as the ability to compare control and experimental groups directly, they also have some limitations. One potential issue is the presence of confounding variables, such as environmental factors, differences in student background, or teacher experience, that could impact the study's results. To minimize potential bias, researchers ensured that teaching materials and learning time allocation were equated between the two groups. The learning environment was also carefully controlled to ensure that the learning process occurred in a neutral and uninterfered-with situation.

Thus, although the quasi-experimental design has limitations, the implementation of STEM-based science learning integrated with ethnoscience still offers promising opportunities to enhance students' critical thinking skills and cultural literacy, provided that external variables can be effectively controlled. The research design is outlined in Table 1.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	STEM-oriented science learning integrated with ethnoscience	O_2
Control	O_3	Conventional learning	O_4

As shown in Table 1, the experimental group received a treatment in the form of science learning that integrated the STEM approach with local ethnoscience content, whereas the control group continued to undergo conventional learning as typically done in the classroom. Pretests and posttests were administered to both groups to measure changes in critical thinking skills and cultural literacy. Based on this design, the steps of the research procedure are systematically described in Figure 1.

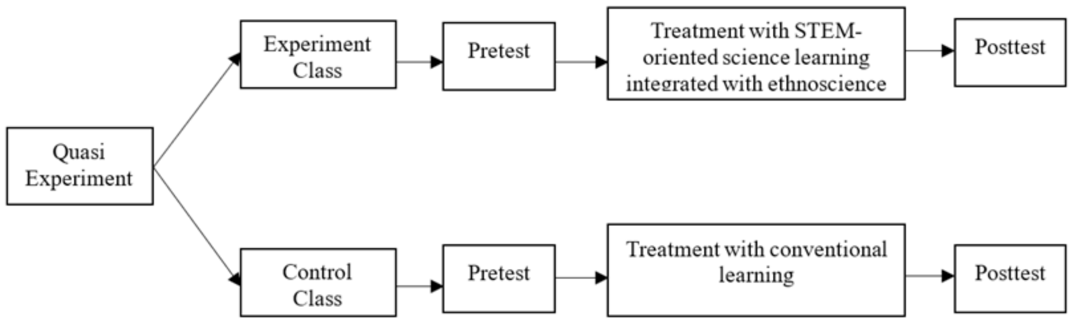

Figure 1. Research Procedure

This research utilizes several types of data collected through various techniques and instruments. Each type of data has an appropriate data collection instrument to achieve valid results and can be analyzed appropriately. The following is a comprehensive summary of the types of data, data collection techniques, and instruments used in this study, as presented in Table 2.

Table 2. Summary of Data Collection

Data Type	Data Collection Technique	Data Collection Instruments
Students' critical thinking skills	Test	STEM and ethnoscience-based critical thinking test questions
Student cultural literacy	Likert scale questionnaire	Cultural literacy questionnaire (Likert scale)
Implementation of learning (attitude change)	Observation	Learning activity observation sheet
Understanding of science concepts	Test	STEM-ethnoscience-based test (multiple choice/explanation)
Teacher and Student Perceptions of Learning	Interview	Open-ended/semi-structured interview guide
Documentation of learning activities	Documentation	Camera, field notes, or activity reports

Table 2 above shows the data collection techniques and instruments for the various variables in the study. Critical thinking skills were assessed using STEM and ethnoscience-based tests, while cultural literacy was evaluated with a Likert scale questionnaire. The implementation of learning was observed using structured observation sheets. The observation focused on four main aspects: (1) the implementation of the stages of the model according to the syntax; (2)

the active involvement of students in the learning process; (3) teacher activities in facilitating and linking material with local cultural contexts; and (4) changes that occur during learning, such as increased student participation and positive attitudes. Understanding of science concepts was assessed using multiple-choice tests and/or open-ended questions, while teacher and student perceptions of the learning process were obtained through interviews. Learning activities were also documented using cameras, field notes, or activity reports. The instruments used to measure critical thinking and cultural literacy variables are presented in Tables 3 and 4.

Table 3. Aspects and Indicators of Critical Thinking Skills

Aspects of Critical Thinking Skills	Indicator
Clarification of Issues	Clearly identify the main problem or question.
	Understand the purpose of the analysis or discussion.
	Gather relevant information to understand the context of the problem.
Information Analysis	Distinguish between facts, opinions, and assumptions in an argument.
	Identify cause-and-effect relationships or specific patterns in the data.
	Determine the relevance and accuracy of the information.
Argument Evaluation	Evaluate evidence or data to support or reject a claim.
	Assess the strengths and weaknesses of the arguments presented.
	Identify biases or logical fallacies in arguments.
Inference (Concluding)	Draw conclusions based on evidence and logic.
	Make predictions based on patterns or available information.
	Integrate information from various sources to form a complete understanding.
Explanation	Provide reasons or justifications for decisions or conclusions drawn.
	Explain concepts, procedures, or data in a logical and organized manner.
	Use examples or evidence to support arguments.
Self-Regulation	Revisit the thinking process to find errors or biases.
	Adjust views or strategies in response to new information or feedback.
	Assess the effectiveness of the solution applied to a problem.

The critical thinking test instrument, as shown in Table 3, was used to measure students' cognitive development in relation to the applied learning model. The next instrument, shown in Table 4, was used to assess students' cultural literacy level through a Likert scale questionnaire.

Table 4. Aspects and Indicators of Cultural Literacy

Aspects of Cultural Literacy	Indicator
Cultural Understanding	Understand local and global cultural values, norms, customs, and traditions.
	Recognize the history, symbols, and cultural practices of a particular society.
	Identify cultural elements, including language, art, and beliefs.
Respect for Diversity	Demonstrate an attitude of tolerance towards other cultures.
	Respect cultural practices that differ from one's own.
	Appreciate the contribution of other cultures in daily life.
Intercultural Communication Skills	Use language or symbols of other cultures appropriately in communication.
	Adapt to other cultural norms in social interactions.
	Build strong relationships with people from diverse cultural backgrounds.

Cultural Identity	Able to explain their own local culture.
	Identify and maintain local cultural traditions and values.
	Practicing local culture as part of daily life.
Critical Thinking on Culture	Identify the positive and negative impacts of a particular culture.
	Filter out the influence of global culture without abandoning local cultural identity.
	Take a critical stance towards cultural stereotypes.
Participation in Culture	Contribute to cultural events, such as traditional festivals or celebrations.
	Support local cultural preservation initiatives.
	Using local cultural products or practices in daily life.

Before the above instruments were used in data collection, all instruments were validated by three experts in the field of science learning development. Empirical validation was also conducted through trials on groups of students with similar characteristics. The results of the validity and reliability tests showed that all items in the instruments were valid and reliable. With the acquisition of valid and reliable instruments, the data collected from the learning implementation process can be analyzed in greater detail.

Next, the collected data were analyzed through several stages. Before testing the hypothesis, a prerequisite test was conducted to ensure that the data met the parametric assumptions. The normality test was performed using the Kolmogorov–Smirnov method, while the homogeneity of variance test was performed using the Levene test. These two tests were used to ensure normal data distribution and equal variance between groups, as prerequisites for the use of parametric statistical tests.

After the data was declared to meet these assumptions, hypothesis testing was continued using a paired sample t-test with the help of SPSS version 25 software and a significance level of 0.05. This test was used to measure significant differences between pre- and post-treatment scores within the same group. The results of this analysis serve as the basis for evaluating the effectiveness of the STEM-based science learning model integrated with ethnoscience in improving students' critical thinking skills and cultural literacy.

RESULTS AND DISCUSSION

This study aims to examine the influence of science learning oriented towards the STEM (Science, Technology, Engineering, and Mathematics) approach, integrated with ethnoscience. Ethnoscience refers to the knowledge and systems developed by people based on their experiences and interactions with their surrounding environment, particularly within the context of local culture. This study focuses on integrating science concepts with traditional food, community activities, and local culture in Yogyakarta. Table 5 presents the linkages between the elements of science, traditional foods, community activities, and local culture in the Yogyakarta region that are part of this study.

Table 5. Linkage of Science Elements with Local Culture in Yogyakarta

Category	Science Elements	Local Culture of Yogyakarta People
Traditional Food	Chemistry (Maillard reaction)	The caramelization process in gudeg gives a brown color to young jackfruit using palm sugar.
	Physics (heat transfer)	The technique of slow cooking gudeg uses convection heat.
	Biology (fermentation)	The production of tempeh and green glutinous rice tape uses microorganisms such as Rhizopus and Saccharomyces.
	Chemistry (acid-base in cooking)	The use of lime water to soak the bakpia ingredients for crispy skin.

Community Activities	Ecology (rice field management)	An organic farming system on the slopes of Merapi that utilizes natural fertilizers and maintains the fertility of the volcanic soil.
	Physics (mechanical energy)	A traditional irrigation system for rice fields that uses the principle of gravity.
	Chemical (combustion process)	The making of Kasongan pottery involves the use of clay and firing to strengthen the structure of the pottery.
	Biology (environmental conservation)	A customary forest reforestation program in the Imogiri area is to maintain the local ecosystem.
Local Culture	Astronomy (Javanese calendar)	The timing of farming and traditional celebrations, such as Sekaten, is based on the movement of the moon and sun.
	Physics (acoustics of musical instruments)	The principle of resonance in gamelan musical instruments is used to produce harmonic tones.
	Geology (resource utilization)	Crafting temples and ornaments from volcanic rocks is a characteristic of Merapi, as seen in Prambanan and Ratu Boko.
	Chemical (natural coloring)	Batik making utilizes natural dyes derived from plants, such as indigo leaves and secang bark.

Based on Table 5, it can be concluded that elements of science, such as chemistry, physics, biology, and astronomy, are closely integrated into the lives of the people of Yogyakarta, particularly in aspects of traditional food, community activities, and local culture. The cooking process of gudeg, for example, involves chemical principles, such as the Maillard reaction, which creates the distinctive color and taste, and physics, in terms of slow heat transfer, to produce the soft texture of jackfruit. Tempeh making, meanwhile, utilizes fermentation by the Rhizopus fungus, which increases the nutritional value of soybeans. In agriculture, the mineral-rich volcanic soil around the slopes of Merapi supports organic farming, demonstrating the close relationship between ecology and the sustainability of food production. In addition, pottery making in Kasongan illustrates the application of chemistry in the clay firing process to create a harder and more durable material. In the context of local culture, the Sekaten celebration exemplifies the use of astronomy in timing, based on lunar and solar cycles, while the gamelan, a traditional musical instrument, demonstrates the application of acoustic principles to produce harmonious resonance. The traditional batik dyeing process also involves chemical knowledge, with the use of alkaline solutions to help natural dyes adhere to the fabric. This demonstrates that scientific knowledge is deeply ingrained in the daily lives of the people of Yogyakarta, providing a strong foundation for developing culture-based science learning.

Furthermore, based on data from research conducted on students in one of Yogyakarta's elementary schools, information on students' critical thinking skills and cultural literacy was obtained. The description of these two aspects is presented in detail in Figure 2.

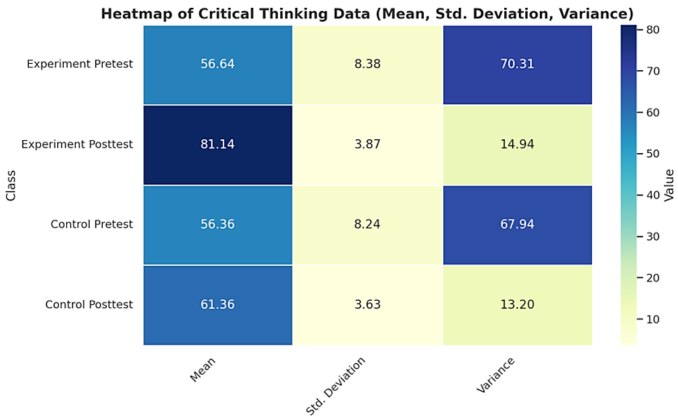

Figure 2. Description of Critical Thinking Data

Based on Figure 2, before the treatment was administered, the experimental group had a mean of 56.64, with a standard deviation of 8.385 and a variance of 70.31. These values indicate that the participants' critical thinking skills were still low, with a fairly large spread, indicating high variation in ability among participants.

After the treatment, the mean increased significantly to 81.14, while the standard deviation decreased to 3.865 and the variance to 14.94. This shows that the treatment had a positive impact on improving critical thinking skills while also making the participants' results more consistent.

In the control group, the pretest mean was 56.36, nearly the same as the experimental group, with a standard deviation of 8.243 and a variance of 67.94. This indicates that the initial conditions of both groups were relatively equivalent, with a fairly wide distribution of scores.

After the posttest, the control group experienced a slight increase in the mean to 61.36, with the standard deviation decreasing to 3.633 and the variance to 13.20. Although the results were more consistent, the improvement in critical thinking skills was not as significant as in the experimental group. This indicates that without special intervention, the development of critical thinking skills tends to be limited. Overall, the comparison between the experimental pretest and experimental posttest revealed a more significant increase than the control group.

Before testing the hypothesis, the data on students' critical thinking skills were first tested for prerequisites, namely normality and homogeneity tests. After the data is collected, the next step is to analyze the data. The first step taken is the normality test to ascertain whether the data is normally distributed, so that it can be used in parametric statistical analysis. The criterion for accepting normality is that the significance value of the calculation results is greater than $\alpha = 0.05$; then, the data distribution is considered normal. Conversely, if the significance value is smaller than $\alpha = 0.05$, the data distribution is declared abnormal. The results of the normality test for the critical thinking data are presented in Table 6.

Table 6. Critical Thinking Normality Test

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Critical Thinking	Experiment Pretest	.136	28	.200*	.934	28	.076
	Experiment Posttest	.092	28	.200*	.973	28	.650
	Control Pretest	.115	28	.200*	.941	28	.120
	Control Posttest	.110	28	.200*	.980	28	.842

Table 5 shows the results of the normality test for critical thinking data using the Shapiro-Wilk test. In the experimental group, the pretest data have a significance value of 0.076, while the posttest data have a Significance value of 0.650, both of which are greater than 0.05, indicating that the data in the experimental group are normally distributed. Likewise, in the control group, the significance value for the pretest was 0.120, and for the posttest, it was 0.842, which is also normal, as it is greater than 0.05, indicating that the data in the control group are normally distributed. Thus, the Shapiro-Wilk test results show that all data, both in the experimental and control groups, are normally distributed.

After the normality test, the next step is the homogeneity test to test the similarity of variances between groups. The results of the critical thinking homogeneity test are presented in Table 7.

Table 7. Critical Thinking Homogeneity Test

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Critical Thinking	Based on Mean	.226	1	54	.636
	Based on Median	.260	1	54	.612
	Based on Median and with adjusted df	.260	1	53.996	.612
	Based on trimmed mean	.237	1	54	.629

Table 7 shows the results of the homogeneity test for critical thinking data, with a significance value (Sig.) of 0.636. Because the Significance value is greater than 0.05 (0.636 > 0.05), it can be concluded that the variance of critical thinking data between the experimental and control groups is homogeneous

After conducting normality and homogeneity tests, the next step is to conduct a Paired Sample t-test to determine whether there is a significant difference between the pretest and posttest scores of critical thinking data in the experimental group. The results of the Paired Sample t-test on critical thinking data are presented in Table 8.

Table 8. Paired Sample t Test of Critical Thinking

Paired Samples Test						
		Paired Differences				
				95% Confidence Interval of the Difference		Sig. (2-tailed)
		Mean	Std. Deviation	Lower	Upper	
Pair 1	Pre-Post Experiment	-24.50000	9.09008	-28.02477	-20.97523	.000
Pair 2	Pre-Post Control	-5.00000	8.98559	-8.48425	-1.51575	.007

Based on Table 8, the Sig. (2-tailed) for pre-pre-post experiment, the p-value is 0.000 <0.05. Therefore, based on the decision made using the Paired Sample t-test, it can be concluded that H0 is rejected and H1 is accepted. This indicates a significant difference between the average pretest and posttest scores in the experimental group, which utilized ethnoscience-integrated STEM-based science learning. This indicates that ethnoscience-integrated STEM-based learning has a positive impact on improving students' critical thinking skills.

Following the presentation of the student's critical thinking data test results, the next section, detailing the student's cultural literacy data, is presented in Figure 3.

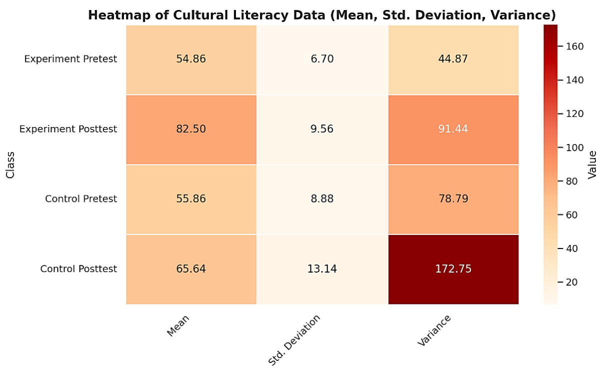

Figure 3. Description of Cultural Literacy Data

Based on Figure 3, the experimental group had a mean of 54.86 at the pretest, with a standard deviation of 6.698 and a variance of 44.87. These values indicate that the participants' cultural literacy skills remained moderate, and the results were relatively varied, although not too extreme.After the treatment, the mean value of the experimental group increased sharply to 82.50, with the standard deviation rising to 9.563 and the variance to 91.44. This increase in the mean indicates that the treatment had a very positive impact on improving cultural literacy. Although the spread of values also increased, this could be due to individual variations in responding to the treatment. Meanwhile, in the control group, the pretest mean value was 55.86, slightly higher than the experimental group, with a standard deviation of 8.876 and a variance of 78.79. This indicates that, prior to treatment, both groups were at a relatively equivalent level of cultural literacy, with considerable variation in results among individuals.

After the posttest, the control group experienced a mean increase of 65.64, which was significantly smaller than that of the experimental group. The standard deviation increased to 13.144, and the variance jumped to 172.75, indicating that despite the average increase, the results among participants became much more varied. This suggests that without special intervention, improvements in cultural literacy are less optimal and uneven. Overall, the comparison between the experimental pretest and experimental posttest revealed a more significant increase than the control group. Before testing the hypothesis, students' cultural literacy data were first tested for prerequisites, namely normality and homogeneity tests. The first step is the normality test to ascertain whether the data is normally distributed. The results of the cultural literacy normality test are presented in Table 9.

Table 9. Normality Test for Cultural Literacy

Tests of Normality							
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Class	Statistic	df	Sig.	Statistic	df	Sig.
Cultural Literacy	Experiment Pretest	.147	28	.128	.950	28	.195
	Experiment Posttest	.146	28	.131	.929	28	.059
	Control Pretest	.133	28	.200*	.973	28	.654
	Control Posttest	.143	28	.151	.955	28	.262

Table 8 above shows the results of the normality test for cultural literacy data using the Shapiro-Wilk test. In the experimental group, the pretest data has a significant value of 0.195, while the posttest data has a significance value of 0.059, both of which are greater than 0.05, indicating that the data in the experimental group are normally distributed. Likewise, in the control group, the significant values for the pretest and posttest were 0.654 and 0.262, respectively, both of which were greater than 0.05, indicating that the data in the control group were normally distributed. Thus, the results of the Shapiro-Wilk test show that all data, both in the experimental and control groups, are normally distributed.

After the normality test, the next step is the homogeneity test to test the similarity of variances between groups. The results of the cultural literacy homogeneity test are presented in Table 10.

Table 10. Homogeneity Test for Cultural Literacy

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Cultural Literacy	Based on Mean	2.963	1	54	.091
	Based on Median	2.169	1	54	.147
	Based on Median and with adjusted df	2.169	1	48.112	.147
	Based on trimmed mean	3.007	1	54	.089

Table 10 shows the results of the homogeneity test for cultural literacy data, with a significance value (Sig.) of 0.091. Since the Significance value is greater than 0.05 (0.091 > 0.05), it can be concluded that the variance of cultural literacy data between the experimental and control groups is homogeneous.After testing normality and homogeneity, the next step is to conduct a Paired Sample t-test to determine whether there is a significant difference between the pretest and posttest scores of cultural literacy data in the experimental group. The results of the Paired Sample t-test on students' cultural literacy data are presented in Table 11.

Table 11. Paired Sample t Test of Cultural Literacy

Paired Samples Test						
		Paired Differences				Sig. (2-tailed)
		Mean		95% Confidence Interval of the Difference		
			Std. Deviation	Lower	Upper	
Pair 1	Pre-Post Experiment	-27.64286	10.12593	-31.56928	-23.71643	.000
Pair 2	Pre-Post Control	-9.78571	16.61181	-16.22710	-3.34433	.004

The results of the Paired Sample t-test show that the significance (2-tailed) value is 0.000 < 0.05, indicating a significant difference between the pretest and posttest scores in the experimental group. Thus, the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. These results provide evidence that STEM-based science learning integrated with ethnoscience has a positive impact on improving critical thinking skills and cultural literacy among elementary school students.

This statistical improvement is supported by student performance on each indicator. In terms of critical thinking skills, students showed progress in all five assessed aspects, as outlined in Table 3. In the clarification of issues aspect, most students were able to clearly identify the main problem and understand the purpose of the discussion. They also began to develop the skill of gathering relevant information to understand the context of the problem. In information analysis, students were able to distinguish between facts and opinions and identify patterns of cause-and-effect relationships more systematically. In argument evaluation, students were able to assess the strengths and weaknesses of arguments and recognize biases or logical fallacies. The inference aspect also showed positive results; students were able to draw logical conclusions, predict based on available information, and synthesize information from various sources. Finally, in the self-regulation aspect, there is an increase in students' awareness in evaluating their thinking process, as well as adjusting their views based on new input or data obtained during learning.

In terms of cultural understanding, students were able to recognize local cultural values, symbols, and practices and relate them to their personal experiences. In the aspect of respect for diversity, students showed a more open and tolerant attitude towards other cultures and appreciated differences without prejudice. In intercultural communication skills, some students have begun to demonstrate adaptability in their communication by considering different cultural norms. Significant improvement is also observed in cultural identity, where students can explain their own local culture, maintain traditions, and apply them in their daily lives. In the aspect of critical thinking on culture, students began to be able to selectively filter the influence of global culture without losing their local cultural identity. The aspect of participation in culture also yields positive results, as evidenced by student involvement in cultural activities such as festivals, art, or the utilization of local products. This demonstrates that integrative learning between STEM and ethnoscience not only impacts the development of cognitive aspects but also fosters reflective and contextual cultural awareness.

Meanwhile, the analysis of the learning implementation observation sheet also supports the quantitative findings. The observation was conducted to assess the implementation of the STEM-ethnoscience learning model by looking at four main aspects: (1) model syntax implementation, (2) students' active involvement, (3) teachers' activities, and (4) students' attitude change during learning. The observation results showed that each learning stage was well implemented in accordance with the design. Students appeared to be actively engaged in discussions, working on projects, and connecting science materials to local culture. Teachers were also actively involved in facilitating learning, guiding discussions, and contextually linking teaching materials with ethnoscience contexts. In addition, there were positive attitude changes among students, including increased curiosity, participation, and appreciation for local cultural values. The alignment between observation results and quantitative data strengthens the finding that this learning is transformative, not only in terms of cognition but also attitudes and values.

This finding also makes a theoretical contribution, positioning ethnoscience not only as complementary material but also as an epistemological framework that enriches the science learning experience. The integration of STEM and local knowledge provides a contextual and meaningful learning experience, as students understand science through the lens of their cultural perspective. These results support previous research that the STEM approach is able to improve critical thinking skills (Deng et al., 2025; Küçükaydın & Ayaz, 2025), strengthening cognitive structures (Rosenzweig et al., 2021; Mercan et al., 2022), increasing interest in learning (Zhou et al., 2024), and developing 21st-century skills (Atmojo et al., 2025).

Furthermore, the findings of this study reinforce the role of STEM education in developing students' reflective thinking and metacognitive skills (Küçükaydın et al., 2024; Archer et al., 2025; Atmojo et al., 2024). The learning process with the STEM-ethnoscience approach in this study begins with the presentation of contextual problems derived from local cultural phenomena, which are then processed through the stages of scientific exploration, modeling, and collaborative problem-solving. Learning activities are designed not only to be science-based but also to reflect cultural values and practices that are familiar to students. When the science learning context is enriched with elements of local culture through ethnoscience, students not only demonstrate deeper conceptual understanding but are also able to build meaningful connections between their learning experiences and their social reality and cultural identity. This finding confirms that STEM is not only technical and objective, as traditionally characterized (Taylor et al., 2024), but also contextual and cultural when designed to be relevant to students' learning environments.

In this context, STEM education integrated with local cultural values has been shown to create a more vibrant and practical learning environment (Sumarni et al., 2022). This finding suggests that a shift from a rote learning approach to a critical thinking-based approach can indeed occur if teachers are supported in creating learning spaces that encourage exploration and reflective dialogue (Moghadam et al., 2023; Yasir & Alnoori, 2020). Teachers who can demonstrate critical thinking skills play a crucial role in stimulating students' scientific attitudes and bridging STEM concepts with students' local understanding (Aouaf et al., 2023; Jabali et al., 2024).

The novelty of this research lies in its perspective on ethnoscience, not merely as additional content in learning, but as an epistemological framework that enriches the STEM learning experience. This approach specifically allows students to view science not only as a collection of objective facts but also as a sociocultural construct that develops across contexts (Putra, 2021). By integrating the four disciplines of science, technology, engineering, and mathematics within a local cultural context, students can develop both scientific literacy and cultural literacy (Borunda & Murray, 2019). This is highly relevant in addressing future needs, where 80% of jobs will require STEM-based skills (Sumarni et al., 2022), while also responding to the need for a more transformative curriculum rooted in local wisdom (Li et al., 2020; Zhang et al., 2024; Wang et al., 2022; Anning, 2025).

Thus, the findings of this study not only enrich the discourse on STEM integration in elementary education but also open up space for innovation in more inclusive, contextual, and meaningful learning models. The emphasis on the interconnection between culture and science presented in the ethno-STEM approach demonstrates that educational transformation does not have to abandon local values; instead, it can grow from them (Denton et al., 2020). Overall, the implementation of STEM-based science learning integrated with ethnoscience is effective in improving students' critical thinking and cultural literacy. The study's results show that students who learn through the integration of STEM and ethnoscience are more motivated, critical, and able to apply their knowledge in their cultural context. By incorporating elements of ethnoscience, students not only gain a deeper understanding of science but also enhance their problem-solving and critical thinking skills. This approach is highly relevant for preparing students to face global challenges while preserving and valuing local knowledge. Therefore, educators need to integrate ethnoscience into STEM education to foster more creative and adaptable students.

The results of this study indicate that STEM-based science learning, integrated with ethnoscience, has great potential to support the learning process in education. However, the research context, which is limited to elementary schools in Yogyakarta, needs to be a concern when generalizing these findings. The characteristics of the students, academic culture, local culture, and educational environment in these schools may differ from those of other educational institutions at the local, national, and international levels. These differences may affect the way the teaching materials are implemented and the resulting impact, so caution is needed when applying these findings in different contexts.

To understand the relevance and applicability of these findings across different environments, it is essential to consider factors such as differences in curriculum, school readiness, and students' backgrounds. This article should provide an in-depth analysis of how the research results can be adapted or applied to other populations, including those at different levels of education, institutions with diverse resources, or environments with unique academic cultures.

Thus, while the findings of this study make an important contribution to the development of STEM-based science learning integrated with ethnoscience, further explanation of the research context's limitations and its potential applicability elsewhere is essential. This will not only enrich the academic value of the research but also open up opportunities for further research exploring the effectiveness of this approach in various educational settings. This study examined the impact of using STEM-based learning integrated with ethnoscience on students' critical thinking skills and cultural literacy. Findings showed a significant positive impact in the short term, where students who participated in this learning demonstrated improved critical, analytical, and creative thinking skills. However, one of the main limitations of this study is the absence of longitudinal data. This study focuses solely on the short-term impact, without considering the sustainability of the learning influence on students' critical thinking skills and cultural literacy. This approach does not enable us to determine whether the observed improvements can be sustained over a more extended period or whether other factors may influence the results over time. Additionally, this study has not thoroughly examined how external factors, such as teacher support, learning environment, and parental involvement, may impact the sustainability of STEM and ethnoscience-based science learning. Support from these parties can play a crucial role in fostering students' cultural awareness and promoting the application of critical thinking skills in various learning contexts.

Therefore, although the findings of this study make a significant contribution to the development of STEM and ethnoscience-based science learning, the limitations indicate the need for further research. A research design that incorporates longitudinal analysis and considers the impact of external factors will provide a more comprehensive understanding of the effectiveness of STEM and ethnoscience-based science learning in the short term, as well as its sustainability in the long term. Thus, this study presents opportunities for further exploration of how innovations in science learning can enhance the quality of education sustainably.

CONCLUSION

Based on the research results, the average posttest critical thinking skills score for the experimental class was 81.14, while the control group obtained a score of 61.36. Similarly, the average posttest student cultural literacy score for the experimental class reached 82.50, while the control group scored 65.64. These results are in line with the calculation of a Paired sample t-test, which shows a significance value of 0.000 < 0.005, indicating a significant difference between the average scores of critical thinking skills and cultural literacy among students in the experimental group and the control group, using STEM-based learning integrated with ethnoscience. From these findings, it can be concluded that STEM-based science learning integrated with ethnoscience has a significant effect on improving students' critical thinking skills and cultural literacy. The practical implications of these findings are highly relevant to the development of educational practices at the elementary school level. Teachers are expected to design science learning that is more contextual and grounded in students' local experiences, thereby simultaneously fostering their critical thinking and cultural identity. In addition, the results of this study can serve as a basis for policymakers and curriculum developers to encourage learning innovations that combine interdisciplinary approaches and local values in an effort to build a more holistic, inclusive, and sustainable education system.

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