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Integrating Bondowoso Kentrung Art into Inquiry-Based Science Learning: Effects on Critical Thinking and Collaboration Skills

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Abstract

Critical thinking and collaboration are 21st-century skills that remain a challenge in science learning. The purpose of this study was to examine the effect of integrating Kentrung Bondowoso art into inquiry-based science learning on critical thinking and collaboration. The research design used was a quasi-experimental study using a pre-test and post-test control group. In the experimental group, inquiry-based science learning was implemented that integrated scientific phenomena found in the Kentrung Bondowoso art, while in the control group, inquiry-based science teaching was conducted. Critical thinking was assessed through an essay test, and collaboration was evaluated using an observation sheet. Descriptive statistical analysis was conducted to determine the mean, standard deviation, and level of achievement gain. The ANCOVA test was applied to determine the impact of learning innovation on critical thinking and collaboration. The results of statistical tests showed that between the experimental group and the control group, there was a significant difference in critical thinking ($p < .05$), and there was no significant difference in collaboration ($p > .05$). The findings showed that integrating Kentrung Bondowoso art into inquiry-based science learning significantly influenced critical thinking but did not significantly affect collaboration. Students use the local cultural context to develop their thinking processes. This research result implies that the use of local cultural contexts, such as the Kentrung Bondowoso art form, continues to hold significant pedagogical value in science teaching, particularly in enhancing the relevance and meaningfulness of learning.

Keywords: Ethnoscience; Bondowoso kentrung art; Critical thinking; Collaboration skills

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INTRODUCTION

Critical thinking and collaboration are essential 21st-century skills and a key objective in science education. Critical thinking is a cognitive process (Bennett & Abusalem, 2024; Vincent-Lancrin, 2021) that involves reasoning and reflective thinking (Gerlich, 2025; Rivas et al., 2022). Critical thinking involves the competence to evaluate and use evidence, analyze arguments, understand implications, develop arguments, and comprehend explanations (Liu et al., 2014). These skills involve a mental process (Dinsmore & Fryer, 2023; Elen & Verburgh, 2023), with sub-skills including interpretation, evaluation, analysis, inference, explanation, and self-regulation (Facione, 2011). Meanwhile, collaboration is the ability of two or more people to work together to complete tasks and achieve shared goals by sharing roles, knowledge, and responsibilities (Sonnenwald, 2007). Collaboration refers to the process by which pupils work together in science learning to achieve a shared learning objective: the mastery of scientific concepts (Odell et al., 2023). Pupils conduct joint investigations, discuss, and engage in critical debate to build scientific knowledge (Siiman et al., 2020).

Critical thinking and collaboration offer many benefits to students. Pupils with strong critical thinking skills will have a positive impact on their cognitive abilities (Kaur et al., 2019). These skills help students to understand science concepts better (Ma et al., 2023), solve problems (Almulla, 2023; Suryana et al., 2021), practice decision-making (Heri et al., 2017), and avoid misconceptions (Yolviansyah et al., 2022). Meanwhile, collaboration also offers many benefits for students. Collaboration in science learning can help students develop a range of essential skills (Ilma et al., 2021), such as communication, cooperation, mutual respect, and responsibility. Learning processes involving collaborative activities can motivate students (Loes, 2022) and promote a sense of liability (Isnawati et al., 2018), thereby impacting their learning achievement (Chen et al., 2024).

Although it is a key competence for pupils, developing critical thinking and collaboration remains a challenge for students and teachers in science learning. Results from several studies indicate that critical thinking skills in science education remain unsatisfactory (Maharany et al., 2025; Putri et al., 2024). Pupils find it difficult to provide explanations and draw conclusions (Kranz et al., 2023). Pupils also struggle with analyzing, evaluating, and interpreting scientific concepts (Purwanto et al., 2019). Similarly, regarding collaboration skills, several studies indicate that students still struggle to discuss and work together (Yanto & Farid, 2024). These previous studies suggest that thinking skills and collaboration skills need to be continuously developed in the science learning process.

Several learning innovations have been implemented to foster thinking skills and character traits in collaboration in science, but they still face various challenges. Traditional teaching, which is teacher-centered and emphasizes rote learning, has not yet developed critical thinking skills (Prayogi et al., 2024). Several researchers have sought to apply innovative and collaborative learning models to promote thinking skills, i.e., problem-based learning approach (Anggraeni et al., 2023), discovery learning (Chusni et al., 2021), and inquiry-based teaching (Arifin et al., 2025). These teaching and learning approaches are successful in developing thinking skills and collaboration character; however, their implementation still requires adequate contextual learning resources (Annam, 2023). Other studies have sought to develop contextual science learning resources to teach critical thinking skills (Tari & Rosana, 2019; Utami, 2024) and culturally based contextual science learning resources (Rodiah et al., 2025; Sari et al., 2024). Research indicates that contextual instructional resources are effective for teaching critical thinking. Meanwhile, some researchers have sought to combine innovative teaching models with culturally-based science learning resources (Prayogi et al., 2023; Sanova & Malik, 2023), which have been shown to foster thinking skills.

Local cultural contexts have been extensively integrated into the implementation of innovative and collaborative learning models designed to teach thinking skills. One learning model widely adopted to integrate cultural contexts into teaching thinking skills is the inquiry model (Hardianti & Setiawan, 2023; Prayogi et al., 2023; Wati et al., 2021). However, integrating cultural contexts into learning often faces challenges due to a lack of curriculum examples and representations of science (Mkhwebane, 2024). On the other hand, the impact of certain local cultural contexts in Bondowoso Regency, East Java, on science learning has not yet been extensively studied. One example of local culture in the Bondowoso District is the art of Kentrung. The art of Kentrung in Bondowoso can be linked to the science curriculum content and representation of vibration and wave motion (Damayanti et al., 2025). The use of contextual, local, and cultural content in the education system can facilitate meaningful science learning experiences for students (Picardal & Sanchez, 2022). Therefore, this study tested inquiry-based science learning by integrating contextual scientific phenomena from the Kentrung art of Bondowoso to develop thinking skills and collaboration character.

The theoretical framework of this research integrates constructivism, inquiry-based learning, the ethnoscience approach, and collaborative learning. According to constructivism, students should be encouraged to construct knowledge actively and think critically through meaningful learning experiences under a teacher's guidance (Kwan & Wong, 2015). In this study, the art of Kentrung Bondowoso serves as a contextual experience closely related to students' lives, thereby facilitating the construction of scientific concepts. Inquiry-based learning facilitates this process through the stages of observation, problem formulation, data collection and analysis, and concluding, all of which require students' active involvement (Palincsar et al., 1998). The integration of the Kentrung Bondowoso art form into an ethnoscience approach makes scientific concepts more relevant and authentic, as students link local cultural phenomena to them. For collaborative learning theory, group inquiry activities encourage social interaction through communication, discussion, negotiation, and problem-solving cooperation (Yap, 2018). However, the development of collaborative skills is largely determined by how the collaborative process is designed, including the pattern of group activities, role allocation, and the quality of interaction among group members (Hall, 2014).

Based on the theoretical framework, the integration of scientific phenomena of local cultural context in science learning is expected to create a contextual and meaningful learning experience that has the potential to develop critical thinking and collaboration skills. However, empirical evidence examining the effectiveness of integrating Kentrung Bondowoso art in inquiry-based science learning, particularly in developing critical thinking and collaboration skills, is lacking compared to inquiry learning without a local cultural context. Therefore, it is necessary to examine the integration of Bondowoso Kentrung art into inquiry-based learning and its impact on critical thinking and collaboration. Utilizing local culture as an innovative, contextual learning resource can enrich the dynamics of quality science learning, thereby supporting the development of 21st-century competencies.

The issues to be examined in this study are:

1) RQ1: What is the profile of students' critical thinking and collaboration skills in inquiry-based science learning that integrates contextual scientific phenomena from the Kentrung Bondowoso art form?
2) RQ2: What is the effect of inquiry-based science learning that integrates contextual scientific phenomena from the Kentrung Bondowoso art form on critical thinking and collaboration skills?

METHOD

Research Design

The study employed a quasi-experimental design with a pretest-posttest control group. The research design is illustrated in Figure 1. In the experimental group, inquiry-based learning was implemented using contextualized science teaching on vibrations and waves found in the Bondowoso kentrung art performance. In the control group, the teacher implemented inquiry-based learning using standard activities, including experiments and discussion. Critical thinking skills were assessed twice, before and after the lessons. Collaboration skills were assessed twice: during the first and final lessons.

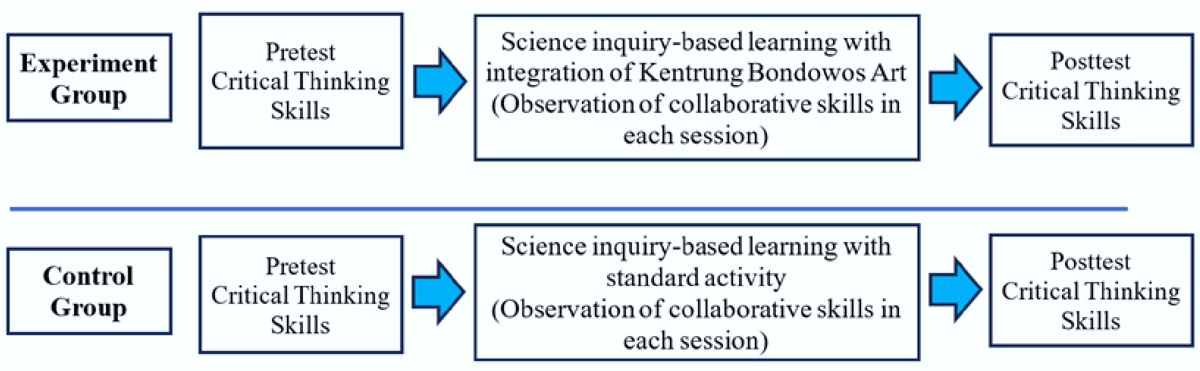

Figure 1. The Research Design

Participants

The research was conducted at a junior high school in Bondowoso, involving 176 students in class VIII, who were distributed into six study groups. The research sample was selected using cluster random sampling, yielding two groups. To ensure that the classes had comparable abilities, a one-way ANOVA was first conducted on the scores from the existing daily quizzes. The experimental group comprised 30 students, 16 female and 14 male. The control group comprised 30 students, 17 female and 13 male. The experimental and control groups were determined by drawing lots.

Experimental Units

The science curriculum related to the Kentrung Bondowoso art form focuses on vibrations and waves. This material is taught over four lessons. The science topics covered, in sequence, are vibrations, transverse waves, longitudinal waves, and sound waves. In the experimental group, science learning employs an inquiry-based approach that integrates scientific phenomena found in the Kentrung Bondowoso art form. Pupils undertake the inquiry process, starting with observation, collecting and analyzing data, formulating conclusions, and reporting results. The learning resources used in the experimental group include teaching modules, ethnoscience-based pupil worksheets, Kentrung art equipment such as tambourines, trebeng, the narrator's voice, and a guitar, as well as equipment and materials for vibration and wave experiments. In the control groups, science learning involved experiments and discussions on vibrations and waves. The learning resources used in the control group included teaching modules, student worksheets, and experimental equipment and materials for vibrations and waves. Details regarding the learning stages in both groups are shown in Table 1.

Table 1. Learning Stages

Lesson	Experiment Group	Control Group
1	Topic: vibration Inquiry process: the vibration of the trebeng beater and the vibration of the pendulum.	Topic: vibration Experiment and discussion: vibration of a pendulum.
2	Topic: transversal wave Inquiry process: strings and waves on the string.	Topic: transversal wave Experiment and discussion: waves on the string.
3	Topic: longitudinal wave Inquiry process: rebana, speaker's voice, and waves on the slinky.	Topic: longitudinal wave Experiment and discussion: waves on the slinky.
4	Topic: sound wave Inquiry process: sound waves on trebeng kendang, bass, and pethot (Kentrung musical instruments).	Topic: sound wave Experiment and discussion: sound wave.

Instruments

Critical thinking skills, comprising six sub-skills, were assessed using a written essay test comprising 12 questions. The sub-skills assessed included interpretation, analysis, evaluation, inference, explanation, and self-regulation. Each sub-skill was assessed using two questions. The assessment score is based on students' answers. Each sub-skill is scored on a 1–4 scale using an assessment rubric and then converted to a 0–100 scale to determine the critical thinking score. Before use, the critical thinking test was validated by three learning experts. The results of the content validity analysis using Aiken's V coefficient ranged from 0.67 to 1.00, indicating that the critical thinking assessment instrument is valid. The test's reliability was assessed using Cronbach's alpha, which yielded a value of 0.77, indicating reliability.

Collaborative skills, comprising three sub-skills, were measured using an observation sheet. Three observers conducted the assessments, with each observer evaluating 10 students in learning activity groups. The sub-skills measured included caring, cooperation, and sharing, with a focus on the prosocial dimension (Kurniawati, 2019). Each sub-skill was scored on a 1–4 scale using an assessment rubric and then converted to a 0–100 scale to determine the collaboration score. Prior to use, the observation instrument was validated by three science learning experts. The results of the content validity analysis using Aiken's V coefficient ranged from 0.67 to 1.00, indicating that the collaboration assessment instrument is valid. The reliability analysis using Cronbach's alpha yielded a value of 0.81, indicating that the collaboration assessment instrument is reliable.

Data Analysis

Critical thinking skills were analyzed based on each student's test scores. Collaboration skills were analyzed based on the observer's scores for each student. Based on the sub-skill scores, the mean, standard deviation, and gain level were determined. The achievement levels of sub-skills were categorized as high, medium, or low (Hake, 1998). To test the impact of the treatment on thinking and collaboration skills, an ANCOVA was conducted, preceded by prerequisite tests of normality and homogeneity. The effect size of the teaching strategy was determined using the partial eta-squared statistic.

RESULTS AND DISCUSSION

To answer research question RQ1, an analysis of the results from the critical thinking and collaboration skills assessments was conducted. The results of the assessment of sub-skills and thinking skills are shown in Table 2. The data are presented in descriptive statistical analyses, including mean scores, standard deviations, and normalized gain scores.

Table 2. Summary of Descriptive Statistics and N-Gain Critical Thinking

Skills	Experiment (N=30)					Control (N=30)				
	Pretest		Posttest		n-gain	Pretest		Posttest		n-gain
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Interpretation	3.83	0.59	6.93	0.58	0.74 (High)	3.87	0.57	6.50	0.51	0.64 (Moderate)
Analysis	2.93	0.45	5.87	0.68	0.58 (Moderate)	2.87	0.57	5.10	0.48	0.44 (Moderate)
Evaluation	2.67	0.55	5.67	0.61	0.56 (Moderate)	2.77	0.50	5.00	0.53	0.43 (Moderate)
Inference	3.60	0.56	6.70	0.65	0.70 (High)	3.57	0.50	6.03	0.56	0.56 (Moderate)
Explanation	3.73	0.45	6.87	0.63	0.73 (High)	3.80	0.55	6.33	0.48	0.60 (Moderate)
Critical Thinking	42.20	4.04	80.30	5.20	0.66 (Moderate)	42.77	4.80	72.70	4.37	0.52 (Moderate)

Table 2 shows that critical thinking achievement across all sub-skills increased. The increase was more pronounced in the experimental group than in the control group. In the experimental group, two thinking sub-skills were in the high category, whilst the other three were in the moderate category. In the control class, all critical thinking sub-skills remained in the moderate category. The scores indicate that the experimental group achieved better final thinking skills across all measured aspects. Thus, it can be said that science learning in the experimental group is better than in the control group for teaching sub-skills of critical thinking. For thinking skills, the initial abilities of both groups were relatively equal, but after the learning process, both groups showed improvement. Thinking skills were developed as a result of the innovative teaching strategy implemented in the experimental group. Although both were in the moderate improvement category, the experimental group's normalized gain indicated greater treatment effectiveness in developing thinking skills. The research data showed that the learning implemented in the experimental group had a more optimal impact than that in the control group.

The student collaboration competency profile is based on observational assessment results. The results of the collaboration skills assessment for both groups are shown in Table 3. The data on collaboration skills are presented in mean scores, standard deviations, and normalized gain scores.

Table 3. Summary of Descriptive Statistics and N-Gain Collaboration Skills

Sub-Skills	Experiment (N=30)					Control (N=30)				
	Pretest		Posttest		n-gain	Pretest		Posttest		n-gain
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Caring	1.53	0.57	2.80	0.48	0,51 (Moderate)	1.47	0.51	2.83	0.46	0.54 (Moderate)
Cooperative	1.77	0,43	3.43	0.57	0,75 (High)	1.80	0.48	3.37	0.56	0.71 (High)
Sharing	2.17	0.46	3.27	0.45	0.60 (Moderate)	2.17	0.46	3.30	0.53	0.62 (Moderate)
Collaboration	45.53	9.97	79.20	10.20	0.62 (Moderate)	45.27	9.95	79.43	9.70	0.62 (Moderate)

Table 3 shows that collaboration outcomes across all skill areas improved following the intervention. Both groups showed relatively similar improvements in collaboration skills. Improvements in the sub-skills of cooperation and sharing reached the high category, whilst caring and collaboration fell into the moderate category. No significant differences were observed between the two groups, as the normalized gain scores for each aspect were almost identical. The research results indicate that inquiry-based science learning integrated with local culture is similar to inquiry-only classes in terms of teaching collaboration. The use of local cultural context did not significantly increase collaboration.

To answer research question RQ 2, the critical thinking and collaboration scores achieved by both groups need to be statistically tested. To this end, normality and homogeneity tests must be conducted as prerequisites for performing parametric statistical tests. The results of the descriptive statistical tests, including mean scores, standard deviations, and data normality and homogeneity, are shown in Table 4.

Table 4. Results of Normality and Homogeneity Tests

Skills	Test	Group	N	Normality	Homogeneity
Critical thinking	Pretest	-Experiment	30	0.179	0.572
		-Control	30	0.293	
	Posttest	-Experiment	30	0.234	0.281
		-Control	30	0.187	
Collaboration	Pretest	-Experiment	30	0.083	0.972
		-Control	30	0.087	
	Posttest	-Experiment	30	0.075	0.144
		-Control	30	0.092	

Table 4 shows that all data on critical thinking and collaboration skills in both groups follow a normal distribution. The results of the analysis indicate that the significance value of the normality test is greater than 0.05. A normal distribution indicates that students' scores are symmetrical and do not exhibit extreme outliers; consequently, the data are considered representative of students' overall abilities. With these assumptions, the data are suitable for parametric statistical analysis. The results of the ANOVA tests on critical thinking and collaboration are presented in Tables 5 and 6, respectively.

Table 5. Results of The ANCOVA Test of Critical Thinking

Source	Sum of sqr.	df	Mean sqr.	F	Sig.
Corrected model	1988.522	2	994.261	261.795	0.000
Intercept	740.675	1	740.675	195.024	0.000

Source	Sum of sqr.	df	Mean sqr.	F	Sig.
Pretest	1122.122	1	1122.122	295.462	0.000
Group	994.997	1	994.997	261.989	0.000
Error	216.478	57	3.798		
Total	353340.000	60			
Corrected total	2205.000	59			

Table 6. Results of The ANCOVA Test of Collaboration

Source	Sum of sqr.	df	Mean sqr.	F	Sig.
Corrected model	5491.225	2	2745.612	616.727	0.000
Intercept	3261.038	1	3261.038	732.504	0.000
Pretest	5490.408	1	5490.408	1233.271	0.000
Group	3.657	1	3.657	0.822	0.369
Error	253.759	57	4.452		
Total	383213.000	60			
Corrected total	5744.983	59			

Table 5 shows that there was a significant difference in critical thinking skills between the two groups following inquiry-based learning that integrated Bondowoso Kentrung art, with $F = 261.989$ ($p < .05$). The covariate variable (pre-test) contributed to critical thinking skills following the learning process, with $F = 295.462$ ($p < .05$). These findings indicate that the implementation of inquiry-based learning integrating Bondowoso Kentrung art in the experimental group was effective in developing critical thinking skills when compared to standard inquiry-based learning in the control group.

Table 6 shows that there was no significant difference in collaboration between the two groups following inquiry-based learning that integrated Bondowoso Kentrung art, with $F = 0.822$ ($p > .05$). However, the covariate (pre-test) contributed to collaboration following the learning process, with $F = 1233.271$ ($p < .05$). These findings indicate that the implementation of inquiry-based learning integrating Bondowoso Kentrung art in the experimental group was no more effective than standard inquiry-based learning in the control group in developing collaboration.

The results indicate that integrating the Bondowoso Kentrung art event into inquiry-based science learning significantly promotes the thinking skills. These findings suggest that local cultural contexts, when combined with the inquiry process, can serve as an effective learning tool for teaching thinking skills. Inquiry-based learning positions pupils as actors in the discovery of scientific knowledge. Pupils engage in the inquiry process by observing phenomena, identifying problems, asking questions, analyzing information, and drawing conclusions based on evidence. When the inquiry process is integrated with the context of Bondowoso Kentrung art, pupils do not merely learn scientific concepts in the abstract but relate them to real-world phenomena close to their lives and culture, thereby making the thinking process more meaningful. This real-world context helps pupils connect scientific concepts to empirical experiences, thereby fostering meaningful learning (Sari et al., 2024).

Bondowoso Kentrung art serves as a contextual stimulus that sparks students' curiosity. When students observe the sound of the tambourine in a Kentrung performance, they are confronted with a real-world phenomenon that can be scientifically examined: the transverse waves on the instrument's membrane and the longitudinal waves in the propagation of sound through the air. Direct observation and analysis of real-world scientific phenomena can help students engage in complex thinking processes (Pahome, 2023). Pupils can explain that a harder strike on the tambourine produces a greater amplitude of vibration, making the sound louder. Pupils can conclude that the differences in sound between tambourines are caused by differences in the size of the instrument, the tension of the drumhead, or the way they are struck. Pupils can also evaluate whether conclusions drawn from their observations are consistent with scientific theory.

These findings support the constructivist theory, which states that knowledge is actively constructed through experience and interaction with the environment. The integration of local culture provides prior knowledge that is more closely aligned with students' experiences, thereby facilitating the process of constructing new concepts (Jufrida et al., 2025). Furthermore, the results of this study are relevant to the ethnoscience strategy, which emphasizes linking science with local cultural knowledge and practices to make learning more relevant and contextual (Mulyono et al., 2024). The Kentrung Bondowoso art performance relates to scientific knowledge about vibrations and waves.

The results of the study indicate that integrating the Kentrung Bondowoso art context into inquiry-based science learning does not have a significant effect on students' collaboration skills compared to inquiry-based learning without this integration. These findings suggest that improvements in collaboration skills are influenced more by the characteristics of inquiry-based learning than by the learning context used. In inquiry-based learning, students were equally involved in group activities such as identifying problems, discussing hypotheses, making observations, analyzing data, and drawing conclusions together. This series of activities naturally requires social interaction, communication, task sharing, negotiation of ideas, and shared responsibility, all of which are main components of collaborative skills (Sam, 2024). Therefore, both groups had relatively equal opportunities to develop collaborative skills, so the addition of the Kentrung Bondowoso art context did not result in a statistically significant difference.

The lack of significance of cultural context can also be explained by the view that the learning context acts more as a catalyst for cognitive engagement than as the primary determinant of social interaction. In this study, the Kentrung Bondowoso art form served as an authentic context that helped students master science topics in a more tangible and meaningful way, thereby more strongly encouraging the development of thinking skills. However, collaboration skills depend more on the design of group activities, task structure, role distribution, and the quality of interactions among group members than on the type of learning context (Han et al., 2025). Unlike cognitive abilities, which can change within a relatively short period, collaborative skills are social skills that develop gradually through consistent and repeated practice (Buser et al., 2026). Consequently, integrating local cultural contexts requires a longer implementation period for the impact on collaboration to become more evident.

These findings provide implications that the use of local cultural contexts, such as the Kentrung Bondowoso art form, continues to hold significant pedagogical value in science teaching, particularly in enhancing the relevance and meaningfulness of learning; however, it does not necessarily directly improve all 21st-century skills simultaneously. To optimize the development of collaboration skills, the integration of local culture should be supported by learning strategies explicitly designed to foster collaboration, such as project-based assignments, structured role-sharing, peer assessment, and collaborative problem-solving. Thus, the findings of this study confirm that the local cultural context enhances the quality of the learning experience, whilst the development of collaborative skills is more strongly determined by the design of interactions within the learning model. Consequently, it is not enough for teachers to incorporate the local context into their teaching; they must also design structured collaborative mechanisms to maximize the potential for developing pupils' collaborative skills.

The strength of this study, compared with previous research, lies in its use of local performing arts as a context for science learning. Previous studies have generally used the natural environment or everyday problems as contexts, whereas this study demonstrates that local cultural arts, such as Kentrung Bondowoso, can also serve as an effective learning resource. This result reinforces the idea that integrating local culture not only contributes to cultural preservation but also enhances the quality of science learning. Thus, the findings of this study confirm that inquiry-based science learning integrated with local culture, particularly through the context of the Kentrung Bondowoso art form, is an effective and innovative alternative for learning, especially in developing thinking skills. The integration of local culture into learning not only makes scientific concepts more contextual, relevant, and easier to understand but also encourages students to connect scientific knowledge with the socio-cultural realities of their environment (Mulyono et al., 2024). This result supports meaningful learning, as students do not merely accept concepts on a theoretical level but construct their own understanding through authentic learning experiences. From a pedagogical perspective, this approach reinforces the role of inquiry-based learning as a strategy that stimulates higher-order thinking through observation, analysis, data interpretation, and evidence-based conclusion-drawing. In practical terms, the findings of this study suggest that teachers need to be more creative in utilizing the potential of local culture as a learning resource to create innovative, adaptive, and student-centered science lessons. Furthermore, this study contributes to improving the ethnoscience approach in science education by demonstrating that local traditional arts serve not only as a medium for cultural preservation but also as an effective pedagogical tool to improve the quality of the learning process and students' 21st-century thinking skills.

CONCLUSION

This study examined the effect of integrating scientific phenomena into Kentrung Bondowoso art on critical thinking and collaboration. Inquiry-based science learning, integrated with Kentrung Bondowoso art, effectively enhances thinking skills in the experimental group. Different results occurred in collaboration skills: students' collaboration skills in the experimental group did not differ significantly from those in the control group. With inquiry learning, students are active in observing phenomena, identifying problems, asking questions, analyzing information, and drawing conclusions based on evidence, thereby developing their interpretation, analysis, evaluation, and inference skills. Meanwhile, collaboration skills are more influenced by the features of inquiry-based learning itself than by the science context used.

The findings imply that the use of local cultural contexts, such as Kentrung Bondowoso art, still has important pedagogical value in science learning, but does not necessarily directly enhance all 21st-century competencies simultaneously. Furthermore, the integration of local culture should be supported by learning strategies explicitly designed to foster collaboration, such as project-based assignments, structured role-sharing, peer assessment, and collaborative problem-solving. A limitation of this study is the relatively short learning duration, which prevented the optimal development of the influence of local culture on collaboration in inquiry-based learning. Collaboration as a character trait requires intensive development and ongoing practice. Another limitation is the small size and scope of the study sample, which was restricted to one grade level in one school. Therefore, generalizing the research results to broader educational contexts requires caution. Future research is therefore recommended to investigate the integration of local cultural contexts into science learning over a longer period and across a wider range of students and schools.

RECOMMENDATION

Some of the recommendations made are: 1) conducting research with a longer implementation period; 2) involving a larger sample from a variety of schools; 3) developing a learning design that provides opportunities for more intensive and repeated collaboration.

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AUTHOR CONTRIBUTIONS STATEMENT

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Supeno	✓	✓	✓	✓			✓	✓		✓	✓			✓
Iis Nur Asyiah	✓	✓	✓	✓										✓

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

DATA AVAILABILITY
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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