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Research Article

THE EFFECT OF USING THE SCIENCE ETNO-I-STEAM MODUL-EL POTTERY MAKING ON CRITICAL THINKING AND COLLABORATION SKILLS

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Abstract

The 4C skills are crucial in facing the challenges of the 21st century. However, the 2022 PISA results show that Indonesian students' critical thinking and collaboration skills are still low. The Etno-I-STEAM approach in science learning has the potential to influence these skills. This study aims to examine the effect of using Etno-I-STEAM-based science modules on (1) critical thinking skills, (2) collaboration skills, and (3) critical thinking and collaboration skills simultaneously. This study is a quasi-experiment with a nonequivalent control group design conducted at SMP Negeri 16 Yogyakarta. The sample was determined through cluster random sampling. Data were collected through pretest-posttest critical thinking skills, initial-final self-assessment and observation of collaboration skills, as well as learning implementation sheets. Data analysis includes descriptive tests, prerequisite tests in the form of normality and homogeneity tests, hypothesis tests in the form of independent sample t-tests and MANOVA tests, and effect size tests. The results showed that the use of Etno-I-STEAM-based science modules had an effect on (1) critical thinking skills in the very strong category, (2) collaboration skills in the strong category, and (3) critical thinking and collaboration skills simultaneously.

Keywords: science modules, pottery making, etno-I-STEAM approach, critical thinking skills, collaboration skills.

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INTRODUCTION

The rapid development of science, technology, and information (STI) requires individuals to have 21st-century skills, including critical thinking, creativity, collaboration, and communication, which can be developed through education. Education in Indonesia currently focuses on mastering 4C skills in the 21st century, including in science education, which aims not only to transfer knowledge but also to develop high-level skills to face future challenges and opportunities (Kain et al., 2024). In relation to 21st-century skills, the current focus of education in Indonesia is to improve students' mastery of the 4C skills required in the 21st century, including in science education (Suparya et al., 2022). Zubaidah (2019) argues that 21st-century skills, which consist of creative thinking, critical thinking, collaboration, and communication skills, can be deliberately developed through the educational process.

Based on preliminary research at SMP Negeri 16 Yogyakarta, it was found that students' critical thinking skills were still relatively low, as evidenced by their difficulty in analyzing information and drawing logical conclusions. Many students tend to memorize material without understanding the concepts in depth and rarely show curiosity or ask challenging questions. This condition has an impact on their low ability to solve problems independently and contributes to the low competitiveness of Indonesian education at the global level, as reflected in the results of international studies such as the Programme for International Student Assessment (PISA). Ideally, students should have good critical thinking skills to face the challenges of the 21st century, so a learning environment that encourages discussion, exploration, and reflection is needed for students to grow into adaptive and solution-oriented independent learners.

Collaboration skills are part of the 4C skills that are important for facing 21st-century challenges because they enable individuals to work together effectively in achieving common goals. However, preliminary research results at SMP Negeri 16 Yogyakarta show that students' collaboration skills are still low. This can be seen from ineffective group work, uneven task distribution, and minimal interaction in discussions and experiments. These low skills are caused by teacher-centered learning and a lack of training in collaborative problem solving.

The lack of technology utilization in science learning also causes students to feel bored and unmotivated (Miladanta & Muharam, 2021; Yunita, 2017). The use of technology, such as electronic modules (modul-el), can create a more innovative and engaging classroom atmosphere (Anjarsari et al, 2020). Electronic modules (modul-el) are digital learning modules that can be accessed through electronic devices such as computers, laptops, or smartphones. These modules offer high interactivity, ease of updating, and multimedia content presentation such as animations, videos, and simulations. In addition to supporting independent learning anytime and anywhere, modul-el also facilitates faster and more efficient feedback and assessment. However, the implementation of modul-el is still not optimal due to the limitations of teacher training in designing and utilizing technology. Observations at SMP Negeri 16 Yogyakarta show that learning is still dominated by textbooks and printed worksheets, which are less attractive to students.

The inquiry learning model emphasizes student activity in searching, expressing opinions, and solving problems individually or in groups. This is in line with research by Nosela et al. (2020) that science learning with inquiry has a real and more effective influence on learning activities because it can optimize the direct involvement of students. This model is effective in improving critical thinking and collaboration skills, but its application in science learning is still not optimal. Inquiry learning provides direct experiences that enable students to formulate problems, analyze results, and draw conclusions in real-life contexts.

The STEAM approach in science education aims to create holistic and interdisciplinary learning, but its implementation is still less than optimal. Learning still focuses on textbooks and conventional methods, and does not make sufficient use of the environment as a learning resource, resulting in the neglect of students' attitudes and skills. In fact, STEAM can train students to think critically, creatively, and innovatively in problem solving and improve collaboration skills. This approach also stimulates interest in learning and develops complex thinking skills, such as analysis, synthesis, teamwork, and case study-based learning (Fadilah, 2020).

Science learning should develop scientific understanding through direct experience, but in reality, this has not been fully implemented in schools. Ethnoscience is an approach that combines culture and science, allowing students to learn through a learning-by-doing approach so that they can connect the material to their daily lives (Mayasari, 2017; Alvonco, 2014). This approach trains critical thinking and collaboration skills by integrating science and local wisdom. However, the limited availability of ethnoscience-based science learning resources has resulted in low student understanding, necessitating more innovative learning resources to improve their skills.

The concepts of temperature and heat are often difficult for students to understand because they are abstract and require the ability to apply mathematical principles within a physics context. Hidayat et al. (2021) found that 65% of 120 students struggled to understand these concepts, indicating that difficulties in grasping fundamental concepts remain quite prevalent. Another study by Budiarto and Setiawan (2020) showed that the implementation of the Problem-Based Learning method increased the percentage of students who answered correctly from 40% to 75%, emphasizing that innovative learning models can have a significant impact on improving conceptual understanding. Furthermore, Cahyani and Susanto (2019) identified that low interactivity in learning and limited use of instructional media were the main factors contributing to student difficulties, with 58% of 200 students reporting these obstacles. This finding is supported by Dwi and Yulianto (2018), who found that 70% of 180 students had difficulty connecting the concepts of temperature and heat with everyday phenomena; however, the use of technology-based media was proven effective in reducing these difficulties. These previous research findings indicate that innovative, contextual, and interactive learning media and models are essential for addressing students’ challenges in understanding the concepts of temperature and heat. Nonetheless, most prior studies have focused on general learning models such as PBL or broadly on the use of technology-based media, and few have integrated local wisdom, hands-on practical activities, and interdisciplinary approaches into a single learning resource.

Pottery is part of ethnoscience, which is knowledge derived from traditional cultural practices. The pottery-making process can be integrated with the STEAM approach, which provides opportunities for students to understand scientific concepts through practical activities. In this context, pottery making can also be used as learning material related to temperature and heat because it involves heating and cooling clay to produce a product. Thus, teaching pottery not only preserves cultural heritage but also enriches science education in an interdisciplinary and contextual way.

Based on the background description above, using the ethno-I-STEAM approach science module-el is expected to have a significant effect on students' critical thinking and collaboration skills. This study examines the effect of using the ethno-I-STEAM approach to science modules for pottery making on (1) students' critical thinking skills; (2) students' collaboration skills; (3) students' critical thinking and collaboration skills simultaneously.

RESEARCH METHOD

Research Design

This study employed a quasi-experimental design with a non-equivalent control group design. The research used pretests (pre-tests and initial self-assessments) and posttests (post-tests and final self-assessments) to measure changes before and after treatment (Priadana & Sunarsi, 2021). The experimental class received science learning using science modules based on the ethno-STEAM approach through pottery making, while the control class received science learning using inquiry-based textbooks. The research design is presented in Table 1.

Table 1. Non-equivalent Control Group Design Research Design

Class	Pretest	Treatment	Posttest
Experimental	T_{A1}	Science learning using science modules with an ethno-STEAM approach to pottery making (X)	T_{A2}
Control	T_{B1}	Science learning using inquiry-based textbooks (Y)	T_{B2}

The research was conducted at SMP Negeri 16 Yogyakarta during the odd semester of the 2024/2025 academic year, specifically in November. All learning activities were carried out face-to-face in seventh-grade classrooms. This setting allowed the learning interventions and observations to be implemented directly within the school's natural learning environment.

Research Target/Subject

The population of this research consisted of 224 seventh-grade students at SMP Negeri 16 Yogyakarta. The sample was selected using a cluster random sampling technique using random sampling techniques by providing equal opportunities for each member of the population (Syahrum & Salim, 2012). Resulting in Class VII F being assigned as the experimental class and Class VII C as the control class. The independent variables in this research were the use of science modules with an ethno-STEAM approach in the experimental class and the use of inquiry-based textbooks in the control class. The dependent variables were students' critical thinking skills and collaboration skills, while the control variables included the consistency of learning materials (temperature and heat), the same educators, equal time allocation of four meetings, and the use of identical data collection instruments to ensure the validity of the research results.

Research Procedure

The research procedure consisted of several stages carried out systematically. The study began with the administration of pretests and initial self-assessments to both the experimental and control groups to measure their initial abilities. Following this, the treatment phase was implemented, where the experimental class was taught using science modules integrated with the ethno-STEAM approach through pottery making, whereas the control class received instruction using inquiry-based textbooks. Throughout the learning sessions, observers completed observation sheets to document the implementation of learning activities and students' collaboration skills. After the instructional treatments were completed, posttests and final self-assessments were administered to both groups. The final step involved analyzing and interpreting the data according to the types of instruments and the objectives of the study.

Instruments, and Data Collection Techniques

The instruments used in this study included observation sheets, test instruments, and self-assessment forms. The observation sheets were a checklist administered by observers to assess the implementation of the learning process and document students' collaborative skills during class activities. Pretest and posttest essay questions were used to measure students' critical thinking skills before and after the treatment. The self-assessment forms were questionnaires administered to capture students' reflections and self-evaluations regarding their critical thinking abilities. Data were collected through direct testing, distribution of self-assessment sheets, and structured classroom observations conducted by trained observers.

Data Analysis Technique

The data analysis process began with descriptive analysis to present percentages of learning implementation, prerequisite test results, and scores related to critical thinking and collaboration skills. Before conducting hypothesis testing, prerequisite tests were administered, including normality testing using the Shapiro–Wilk method and homogeneity testing to ensure equal variance across groups. Hypothesis testing was performed using the Independent Sample T-Test to compare outcomes between the experimental and control groups, provided that the data met the requirements of normal distribution and homogeneity. Effect size analysis was conducted using Cohen's Effect Size to determine the magnitude of the treatment's impact, with interpretations based on Cohen's established criteria. Additionally, observation and self-assessment data were analyzed descriptively using percentage calculations to provide supporting insights into the learning process and student engagement.

RESULTS AND DISCUSSION

The research data included students' critical thinking and collaboration skills. Critical thinking skills were measured through five essay-type pretest and posttest questions. The pretest was conducted before the learning material was delivered, while the posttest was conducted after the material was delivered. In addition, data on students' collaboration skills were collected through initial and final self-assessments containing twenty-five statements. The data from this self-assessment was reinforced by observation sheets filled out by observers during the learning process. The implementation of learning was also measured using observation sheets filled out by observers at each meeting during the learning process.

Data from Learning Implementation Observation

The learning process was carried out using the science module with an ethno-I-STEAM approach to making Kasongan pottery in the experimental class, while in the control class, learning was carried out with the help of textbooks and an inquiry approach. Observations were made by observers using learning implementation observation sheets. The data on the percentage of learning implementation in the experimental and control classes are presented in Table 2.

Table 2. Results of Learning Implementation Analysis

Science Learning	Average Total Meetings (%)	Criteria
Experimental Class	98	Very Good
Control Class	98	Very Good

Critical Thinking Skills Pretest and Posttest Results

The pretest and posttest instruments were developed based on Facione's critical thinking skill indicators. The pretest and posttest questions underwent content validation and empirical validation processes to ensure that they met the requirements and could be used in the study. The pretest and posttest questions were essay questions, with five questions on the topic of temperature and heat. The total score for answering all questions correctly is 20, with each question worth 4 points. The descriptive analysis of critical thinking skills in the experimental class and control class is presented in Table 3.

Table 3. Data on Critical Thinking Skills of Students Experimental Class and Control Class

Aspect	Experimental Class		Control Class	
	Pre-test	Posttest	Pre-test	Posttest
N Valid	32	32	32	32
Highest Score	80	95	80	90
Lowest Score	30	60	25	35
Average	54.22	79.84	54.06	68.75
Standard Deviation	11.508	9.877	13.645	13.912

The results of the critical thinking skills test were analyzed by calculating the average score for each aspect of critical thinking skills presented in Table 4.

Table 4. Average Scores for Critical Thinking Skills Indicators

Indicator	Experimental Class		Control Class	
	Pre-test	Posttest	Pre-test	Posttest
Interpretation	71.88	90.63	67.19	82.03
Analysis	59.38	66.41	63.28	64.07
Evaluation	52.34	78.13	50.78	59.38
Inference	47.66	75.78	53.91	69.53
Explanation	39.84	88.28	35.16	68.75

Self-Assessment Results for Collaboration Skills

Collaboration skills results were obtained through initial self-assessment (before treatment) and final self-assessment (after treatment) containing 25 statements in accordance with collaboration skills indicators. Self-assessment was given to the experimental and control classes, then analyzed descriptively. The analysis results are presented in Table 5.

Table 5. Data on Collaboration Skills Self-Assessment Results for the Experimental and Control Classes Experimental and Control Classes

Aspect	Experimental Class		Control Class	
	Initial	Final	Initial	End
N Valid	32	32	32	32
Highest Score	84	94	85	88
Lowest Score	57	74	50	61

Average	70.59	82.84	70.94	79.16
Standard Deviation	8.791	6.248	7.233	5.754

The results of the critical thinking skills test were analyzed by calculating the average score for each aspect of critical thinking skills competency presented in Table 6.

Table 6. Average Self-Assessment Scores for Collaboration Skill Indicators

Indicator	Experimental Class		Control Class	
	Initial Self-Assessment	Final Self-Assessment	Initial Self-Assessment	Final Self-Assessment
Participate actively actively	65.00	78.93	67.50	77.68
Working productive	69.55	81.70	69.20	77.59
Responsible	71.52	83.21	70.27	78.48
Flexibility and compromise	68.48	81.88	69.73	78.57
Mutual respect among members group	79.02	88.39	77.86	83.48

Collaboration Skills Observation Results

In addition to self-assessment, the measurement of students' collaboration skills also used an observation sheet created in accordance with the 5 collaboration skill indicators. The observation of collaboration skills was conducted in meetings II and III. The data from the observation of collaboration skills in the experimental and control classes are shown in Table 7.

Table 7. Data on the Average Results of Collaboration Skill Observations

Aspect	Experimental Class		Control Class	
	Session II	Meeting III	Session II	Session III
Average	72.97%	80.94%	71.99%	73.31%
Category	Poor	Good	Poor	Poor

The results of critical thinking skills were analyzed by calculating the average score for each aspect of critical thinking skills presented in Table 8.

Table 8. Average Percentage of Collaboration Skill Indicator Observations

Indicator	Experimental Class		Control Class	
	Meeting II	Meeting III	Session II	Session III
Participate actively actively	68.69%	76.16%	66.53	70.34%
Working productively	70.31%	78.91%	69.19	73.88%
Responsible	73.22	82.81%	72.44%	75.22%
Flexibility and compromise	71.66%	79.34%	69.74	74.22%
Mutual respect among members group	80.97%	86.47	79.03%	82.91%

Results of the Hypothesis Prerequisite Test

Normality Test

The normality test is used to determine whether the data obtained from the study is normally distributed or not. The normality test was conducted using IBM SPSS Statistics 25 for Windows with the Shapiro-Wilk test. The normality test was conducted on the results of critical thinking skills and self-assessment of collaboration skills.

1. Normality Test of Pretest and Posttest Data on Critical Thinking Skills.

   The results of the analysis of the normality test of the pretest and posttest data for critical thinking skills in the experimental class and control class are presented in Table 9.

Table 9. Results of the Normality Test Analysis of the Pretest and Posttest Critical Thinking Skills

Class	Test	Shapiro-Wilk	
		Sig. Value	Distribution
Experiment	Pretest	0.101	Normal
	Posttest	0.409	Normal
Control	Pretest	0.191	Normal
	Posttest	0.094	Normal

2. Normality Test of Self-Assessment of Collaboration Skills

   The results of the normality test for the initial and final self-assessment of collaboration skills of students in the experimental and control classes can be seen in Table 10.

Table 10. Results of the Normality Test Analysis of Initial and Final Self-Assessments Collaboration Skills

Class	Test	Shapiro-Wilk	
		Sig. Value	Distribution
Experiment	Initial Assessment	0.064	Normal
	Final Self-Assessment	0.060	Normal
Control	Initial Assessment	0.084	Normal
	Final Self-Assessment	0.257	Normal

Homogeneity Test

The homogeneity test aims to compare two or more data groups by first conducting a test of equality of variance or a test of equality of group data variance. The homogeneity test was conducted using IBM SPSS Statistics 25 with the Levene Statistics test. The homogeneity test was conducted on the results of critical thinking skills questions and self-assessment of collaboration skills.

1. Homogeneity Test of Pretest and Posttest Data on Critical Thinking Skills

   The results of the homogeneity test for the pretest and posttest data on critical thinking skills of the participants
   are presented in Table 11.

Table 11. Data Results of the Homogeneity Test Analysis of Students' Critical Thinking Skills Critical Thinking Skills of Students

Class		Sig.	Sig. Level	Description
Based on Mean	Pre-test of experimental class and control class	0.061	0.05	Homogeneous
Based on Mean	Posttest of experimental class and control class	0.065	0.05	Homogeneous

2. Heterogeneity Test of Self-Assessment of Collaboration Skills

   The results of the homogeneity test of the initial self-assessment data and final self-assessment data of students' collaboration skills are presented in Table 12.

Table 12. Data Results of the Homogeneity Test Analysis of Student Collaboration Skills Collaboration Skills of Students

Class	Value Sig.	Sig. Level	Description

Based on Mean	Initial self-assessment of the experimental class and control class	0.063	0.05	Homogeneous
Based on Mean	Final self-assessment of the experimental class and control class	0.190	0.05	Homogeneous

Hypothesis Testing Results

Independent Sample T-Test for Critical Thinking Skills (Hypothesis I)

The first hypothesis testing in this study used an Independent Sample T-Test to determine whether there was a difference in critical thinking skills between the experimental class and the control class. The Independent Sample T-Test was conducted using the scores obtained from the posttest. The results of the Independent Sample T-Test analysis of the posttest scores for the experimental class and the control class are presented in Table 13

Table 13. Data from the Independent Sample T-Test Posttest Analysis Critical Thinking Skills

Critical Thinking Skills	**Sig. Value (2-tailed)**	**Description**	**Interpretation**
Experimental class posttest and control class	0.000	Sig (2-tailed) < 0.05	H0 rejected and H1 accepted (there is a difference)

Independent Sample T-Test for Collaboration Skills (Hypothesis II)

The second hypothesis was tested with an Independent Sample T-Test to see the difference in collaboration skills between the experimental and control classes, using the final self-assessment scores. The results of the analysis are presented in Table 14.

Table 14. Results of the Independent Sample T-Test for Collaboration Skills

Critical Thinking Skills	**Sig. Value (2-tailed)**	**Description**	**Interpretation**
Final self-assessment of the class experimental and control classes control	0.017	Sig (2-tailed) < 0.05	H0 rejected and H1 accepted (there is a difference)

MANOVA test (Hypothesis III)

The third hypothesis in this study uses the MANOVA test to measure the effect of treatment on two dependent variables simultaneously, namely critical thinking skills and collaboration skills of students. Hypothesis testing using the MANOVA test in the IBM SPSS Statistics 25 program can be seen in the Multivariate Tests table. There are requirements before performing the MANOVA test, namely by conducting a covariance matrix homogeneity test. The covariance matrix homogeneity test uses Box's Test. Box's test can determine whether the variance/covariance matrix of a dependent variable is homogeneous or not. The results of Box's Test are presented in Table 15.

Table 15. Results of Box's Test

Box's M	4.469
F	1.437
df1	3
df2	691,920.00
Sig.	0.230

Next, a multivariate significance test was conducted to test the third hypothesis presented in Table 16.

Table 16. MANOVA Test Results for Critical Thinking Skills and Collaboration Skills

Effect	Sig	Description	Interpretation
Pillai's Trace	0,000	Sig < 0,05	H0 rejected H1 accepted
Wilk's Lambda			
Hotelling's Trace			
Roy's Largest Root			

Effect Size

The effect size test aims to determine the magnitude of the effect after treatment. The results of the effect size test for students' critical thinking and collaboration skills are presented in Table 17.

Table 17. Effect Size Test Results for Critical Thinking Skills and Collaboration Skills

Variable	Effect Size	Category
Critical Thinking Skills	0.919	Very strong
Collaboration Skills	0.613	Strong

Implementation of Science Learning with Science Modules Using an Ethno-ISTEAM Approach to Making Kasongan Pottery

The learning process took place over 4 meetings (10 JP) in the experimental and control classes. The experimental class used an ethno-I-STEAM-based science module with the integration of ethnoscience and STEAM in the making of Kasongan pottery, while the control class used a science textbook with an inquiry approach. Observers recorded the implementation of learning using observation sheets. The observation results showed that the implementation in the experimental class was 100%, 97%, 97%, and 100%, respectively, while in the control class it was 100%, 100%, 92%, and 100%. Constraints in the experimental class occurred in the second and third meetings, such as limited time for question and answer sessions and reflection. The control class also experienced similar obstacles due to reduced teaching and learning time. Thus, the average percentage of learning implementation in the experimental class was 98.5%, while in the control class it was 98%. The criteria for learning implementation in the experimental and control classes showed the same criteria, namely very good. This is in accordance with Indriyani's theory (2020), which states that if the percentage of learning implementation is 80% < K < 100%, it is classified as very good.

The Effect of Using the El Science Module with an Ethno-I-STEAM Approach to Making Kasongan Pottery on Critical Thinking Skills

Based on the results and data analysis, the use of the ethno-I-STEAM approach module for making Kasongan pottery had a significant effect on students' critical thinking skills. A comparison of the average pretest and posttest scores for the experimental and control classes is presented in Figure 1.

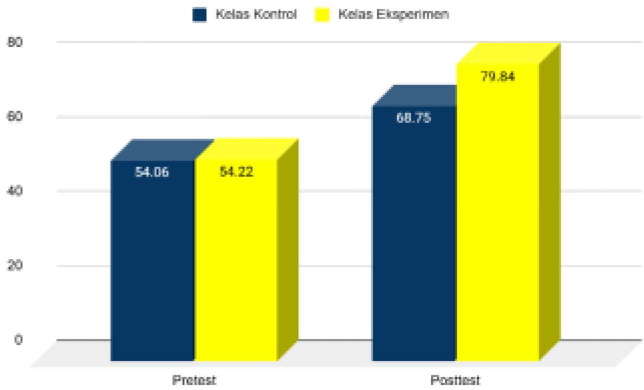

Figure 1. Comparison Diagram of Average Pretest and Posttest Scores for Critical Thinking Skills in the Experimental Class and Control Class

Based on Figure 1, it can be seen that the experimental class and the control class have different average scores. When viewed from the pretest average score, the experimental class had a score of 54.22 and the control class had a score of 54.06. This shows that the experimental class and the control class had similar initial abilities. After both classes were given different treatments, namely learning using the science module with an ethno-I-STEAM approach to making Kasongan pottery in the experimental class and learning using the science textbook with an inquiry approach in the control class, the posttest results of the experimental class had a higher average score of 79.84, while the control class only had an average score of 68.75. Both classes experienced an increase compared to the pretest scores, but there was a significant difference in the posttest average scores between the experimental class and the control class. The average posttest score of the experimental class was higher than the average posttest score of the control class by a difference of 11.09. Thus, the increase in the average posttest-pretest score of the experimental class was higher, namely 25.62, while that of the control class was 14.69.

The critical thinking skill indicators measured in this study included interpretation, analysis, evaluation, inference, and explanation, according to Facione's (2015) theory. Interpretation refers to the ability to understand and express the meaning of a problem. Analysis reflects the ability to identify relationships between various concepts or information. Evaluation assesses the credibility of statements and the relationships between concepts. Inference relates to the ability to draw conclusions based on evidence. Explanation describes the ability of students to explain the reasons behind the conclusions drawn. These indicators were measured through questions that integrated material on temperature and heat with the ethnoscience of pottery making. A comparison diagram of the posttest mean scores for critical thinking skills is presented in the following figure.

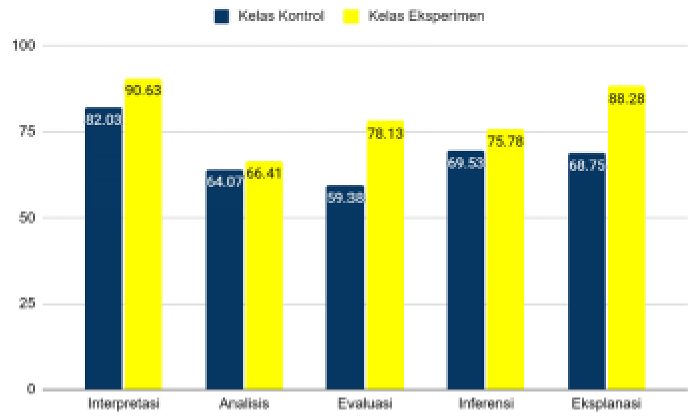

Figure 2. Comparison Diagram of Critical Thinking Skills in the Experimental Class and Control Class Control Class for Each Posttest Indicator

Based on the graph in Figure 2, the indicator with the highest score difference is explanation, with the experimental class reaching 88.28 and the control class 68.75, a difference of 19.53 points. This shows the effectiveness of the modules in improving students' ability to explain concepts in depth.

Explanation is a prominent indicator because it is directly trained in various module activities, from formulating problems to communicating learning outcomes. Each learning phase in this module is designed to encourage students to organize their thoughts and convey reasons systematically based on data, scientific concepts, and local cultural contexts.

Explanation is facilitated through several phases in the El-El Science Ethno-I-STEAM Module, specifically phases 1 (formulating problems), 2 (formulating hypotheses), 6 (drawing conclusions), and 7 (communicating and reflecting). In the first phase, students formulate problems based on ethnoscience phenomena, which requires an understanding of the context and the ability to explain the importance of a topic being studied. The findings of Ismail et al. (2023) show that this process helps students understand the urgency and relevance of the topic, resulting in more meaningful scientific explanations. Furthermore, the hypothesis formulation phase encourages students to put forward logical initial assumptions based on local experience and knowledge. This strengthens their explanatory skills, as evidenced by Izzania et al. (2023) in Ethno-STEM-based learning. In the drawing conclusions phase, students are asked to summarize their observations logically and systematically, in line with the findings of Sari & Prasetyo (2023) that the ability to draw conclusions in ethno-STEM learning is closely related to the skill of explaining the relationships between concepts and phenomena. Finally, the communication and reflection phase allows students to convey explanations of the learning process and results both verbally and in writing. Ismail et al. (2023) emphasize that reflection on the local cultural context helps students re-explain scientific concepts in a personal and contextual manner.

In general, the high explanatory indicator scores in the experimental class were due to three main factors. First, the modules were designed with a contextual and interactive approach that encouraged students to relate scientific concepts to their real-life experiences. This deepened their understanding and improved their ability to explain phenomena systematically. Sari & Prasetyo (2023) show that the integration of ethnoscience in STEM-based inquiry effectively connects abstract concepts with local cultural experiences. Second, the modules provide more space for discussion, analysis, and data-based exploration, which helps students organize their thoughts and present logical and in-depth explanations. Research by Izzania et al. (2023) confirms that Etno-STEM-based e-modules and guided inquiry are able to hone critical thinking and explanatory skills through the active involvement of students in analyzing information. Third, the ethno-I-STEAM approach increases student engagement by linking science, culture, and technology. Students not only understand concepts theoretically, but also see their concrete application in the context of Kasongan Pottery. A study by Ismail et al. (2023) states that ethnoscience-based science learning not only improves conceptual understanding and explanatory skills, but also fosters appreciation for local cultural values and environmental sustainability.

Conversely, the indicator with the smallest score difference between the experimental and control classes was analysis. The experimental class scored 66.41, while the control class scored 64.07, with a difference of 2.34 points. This relatively small difference was due to the application of the inquiry approach in the control class, which also encouraged students to think analytically. This is supported by the findings of Nugraheni et al. (2020), who stated that inquiry-based learning is proven to be effective in improving analytical thinking skills because students are directly involved in the scientific investigation process. Nevertheless, the experimental class still showed superiority, reflecting that the use of ethno-I-STEAM-based science modules was able to contribute positively to analytical skills, although not as clearly as in other indicators.

After obtaining the pretest and posttest data, data analysis was performed. The significance of the difference between the experimental class and the control class was determined through hypothesis testing using an independent sample t-test. After fulfilling the hypothesis prerequisite test with normal and homogeneous data results, an independent sample t-test could be performed on the posttest scores for critical thinking skills in the experimental and control classes with a Sig. (2-tailed) value of 0.000, indicating that the Sig. (2-tailed) value was < 0.05. This means that there was a difference in critical thinking skills between the experimental class and the control class after the treatment was given. This difference indicates that the use of the science module with an ethno-I-STEAM approach to making Kasongan pottery had an effect on students' critical thinking skills.

Based on the effect size test results in Table 17, the use of the science module-el with the ethno-I-STEAM approach shows a significant effect on critical thinking skills. The effect size value for critical thinking skills obtained is 0.919, which is in the very strong category. This shows that the science module-el is very effective in improving students' critical thinking skills.

The difference in critical thinking skills between the experimental and control classes was influenced by the learning method. The experimental class, which used the ethno-I-STEAM science module, was more student-centered, allowing them to learn independently with clear instructions and interactive features such as images, animations, and videos. In contrast, the control class used a science textbook with an inquiry approach, where the teacher dominated the learning process.

The e-modules utilize technology as an effective solution for exploring material compared to printed teaching materials. The ethno-I-STEAM approach in pottery making encourages students to be more active and focused in digital learning. The interactivity of the e-modules creates an engaging, flexible, and optimal learning experience, while also developing digital skills and scientific concept understanding in the context of local culture. This is also supported by research by Herawati & Muhtadi (2018) that electronic modules are more attractive to students because they are more interactive and can be embedded with media such as images, animations, and videos that can be easily accessed through electronic media anytime and anywhere. Thus, students can be more active in building their own knowledge independently.

The e-modules in this study fulfill five main aspects according to Vembriarto (1985). First, they are self-contained, containing complete material without relying on other sources. Second, they are sequential learning, designed with systematic learning stages. Third, they are instructional objectives-oriented, helping students understand the competencies that must be achieved. Fourth, they are self-instructional, allowing students to learn independently without complete dependence on educators. Fifth, they are individualized learning, adapting to each student's pace and learning style. With the etno-I-STEAM approach, e-modules not only increase learning effectiveness but also support a more personalized and contextual learning experience.

The inquiry model improves critical thinking skills by encouraging learners to investigate, analyze, evaluate evidence, and draw logical conclusions. This approach also strengthens understanding and motivation through independent exploration of concepts. By actively seeking solutions to problems, learners gain a more meaningful learning experience and critical thinking skills that can be applied in various contexts. This is in line with the theoretical basis that the inquiry learning model is a learning model that emphasizes students to be actively involved in teaching and learning activities so that they can try to find answers themselves, express opinions, respond, and solve problems either individually or in groups (Meo et al., 2021).

Furthermore, the application of the inquiry model integrated with the ethno-I-STEAM approach can further optimize students' critical thinking skills. The STEAM approach combines five main components, namely science, technology, engineering, art, and mathematics, which are directly related to the environment, thereby creating learning that presents real facts experienced by students in their daily lives (Izzani, 2019). In the context of ethno-I-STEAM, cultural integration is also an important aspect.

Positive research results are influenced by ethnoscience content, which makes science learning more meaningful (Suwandani *et al.*, 2022). This approach increases curiosity, investigation, and independent understanding of concepts (Palupi *et al*., 2018). Critical thinking skills develop when students analyze local culture in the context of science. In addition, the implementation of STEM in learning tools supports independent information seeking, which strengthens understanding and critical thinking skills (Mawaddah *et al.*, 2022; Rizkika *et al.*, 2022; Hasanah *et al.*, 2021).

The local culture-based ethno-I-STEAM approach, such as making Kasongan pottery, provides a contextual and relevant learning experience. Students not only understand scientific concepts theoretically but also apply them in real situations, which ultimately strengthens their critical thinking skills. This is in line with the theory that science learning with an Ethno-STEM approach, which utilizes the culture and native materials in the surrounding environment and integrates technology, science, engineering, and mathematics, can help students understand science material (Ahmad *et al.*, 2023).

Each indicator of critical thinking skills, such as interpretation, analysis, evaluation, inference, and explanation, is facilitated in the modules through experimental activities and problem solving. In contrast, the control class with inquiry-based textbooks experienced lower improvement due to more theoretical methods and minimal direct experience. This proves that the Ethno-I-STEAM-based science e-modules are more effective in improving critical thinking skills than science textbooks with an inquiry approach.

The Effect of Using Ethno-I-STEAM-based Science Modules on Kasongan Pottery Making on Collaboration Skills

Based on the results and data analysis, the use of the Ethno-I-STEAM-based science module for making Kasongan pottery produced a significant difference in the collaborative skills of students. Collaborative skills in this study were measured using non-test instruments in the form of initial self-assessment and final self-assessment. A comparison of the average scores of the initial and final self-assessments of the experimental and control classes is presented in Figure 3.

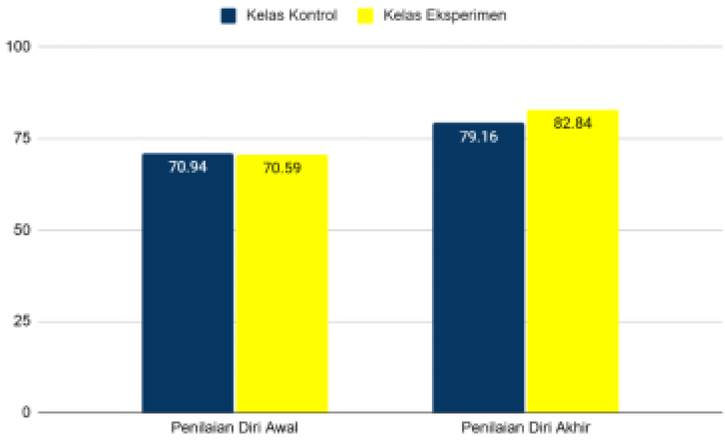

Figure 3. Comparison Diagram of Average Initial Self-Assessment and Final Self-Assessment Collaborative Skills in the Experimental Class and Control Class

Based on Figure 3, it can be seen that the experimental class and the control class have different average self-assessment scores. When viewed from the average initial self-assessment score, the experimental class had a score of 70.59 and the control class had a score of 70.94. It can be interpreted that the experimental class and the control class had the same initial abilities when viewed from the results of the descriptive statistical analysis of the average initial self-assessment given before the treatment. After both classes were given different treatments, the final self-assessment results of the experimental class had a higher average score of 82.84, while the control class only had an average score of 79.16. Based on the average final self-assessment scores, both classes experienced an increase from their initial self-assessment scores, but there was a significant difference in the average final self-assessment scores between the experimental class and the control class. The average final self-assessment score of the experimental class was higher than that of the control class by a difference of 3.68. Thus, the increase in the average initial and final self-assessment scores of the experimental class was higher, namely 12.25, while that of the control class was 8.22.

The indicators of collaboration skills taken in this study included active participation, productive work, responsibility, flexibility and compromise, and mutual respect among group members. In the self-assessment, there were 5 statements for each indicator. The percentage diagram of collaboration skill scores is presented in the following figure.

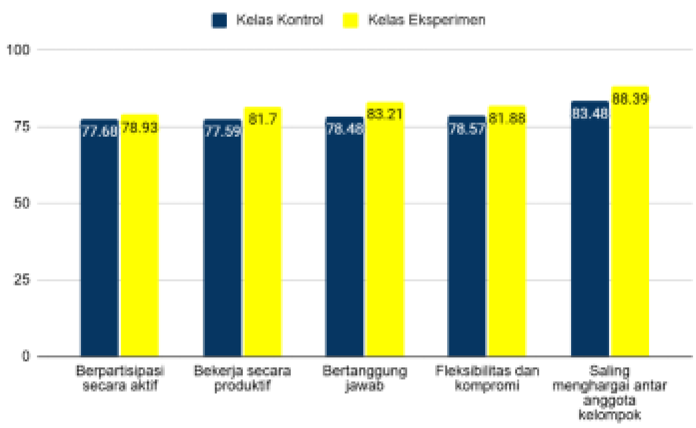

Figure 4. Comparison Diagram of Collaborative Thinking Skills for Each Indicator of Final Self-Assessment Scores

Based on Figure 4, the average final self-assessment scores for each collaboration skill indicator in the experimental class showed a higher increase than in the control class. This indicates that the science module with an ethno-I-STEAM approach is more effective in developing collaboration skills than textbooks with an inquiry approach.

The indicator with the highest score difference was mutual respect between individuals, with an average score difference of 4.91. The activities in the module were able to encourage deeper interaction and discussion within the group so that students became accustomed to listening to others' opinions, sharing ideas, and working together. Research by Pratiwi et al. (2021) shows that the application of a local wisdom-based STEAM approach not only increases student engagement in learning but also fosters mutual respect in group discussions because students learn to understand the cultural perspectives and ideas of their peers. Similar findings were reported by Fitriyani & Kurniawan (2022), who stated that the integration of ethnoscience in learning encourages the creation of a collaborative environment that fosters empathy and tolerance among students.

The indicator of collaboration skills in the form of mutual respect between individuals is facilitated through several phases in the Ethno-I-STEAM Science Module. Phase 1 (formulating problems) trains students to discuss and determine relevant issues, thereby encouraging them to listen to and respect their friends' opinions. Phase 4 (data collection and model development) and phase 5 (data processing) require intense cooperation, division of roles, and coordination, which strengthen mutual respect among individuals. Furthermore, phase 6 (drawing conclusions) encourages students to consider various views in order to formulate fair conclusions together. Phase 7 (communicating and reflecting) provides space for mutual appreciation and feedback in an open atmosphere.

Relevant research conducted by Ramadhani et al. (2023) shows that local culture-based activities in group learning encourage inclusive interactions and foster mutual respect. Similar findings were also presented by Putri & Sulastri (2022), who stated that discussions in the STEAM approach encourage tolerance and mutual respect in group dynamics. From the perspective of the inquiry approach, Ismail et al. (2023) emphasize that ethnoscience-based inquiry learning encourages students to engage in collaborative scientific thinking processes, which require listening skills, appreciating input, and accepting constructive criticism. In line with this, Yuliana & Hartono (2021) state that inquiry involving exploratory and reflective activities in groups plays a major role in fostering social values such as mutual respect and empathy towards teammates. Thus, the phases in the EtnoI-STEAM module not only develop cognitive aspects but also shape collaborative skills.

Meanwhile, the indicator with the lowest score difference was active participation. The factor influencing this was the inquiry approach in the control class, which also encouraged students to be more active in learning. However, the ethno-I-STEAM-based science module remained superior, especially in enriching the learning experience and strengthening student engagement through discussion and collaborative problem solving.

In addition to self-assessment, this study also used observation sheets to comprehensively and directly observe students' collaborative skills.

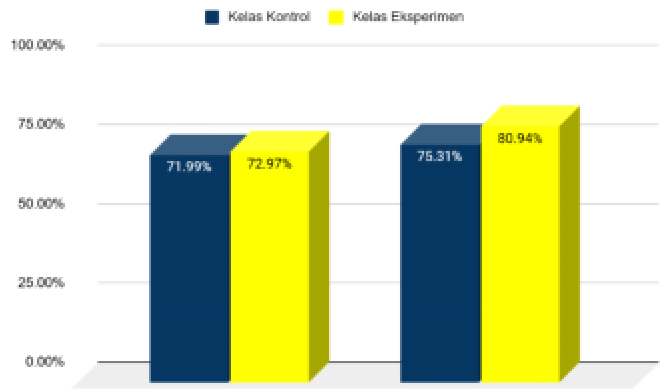

Figure 5. Diagram of the Percentage of Observation Results for Collaboration Skills

Overall, the average collaboration skills showed a greater increase in the experimental class than in the control class. The experimental class increased from 72.97% to 80.94%, while the control class increased from 71.99% to 75.31%. These data show that the learning methods applied in the experimental class were more effective in improving students' collaboration skills.

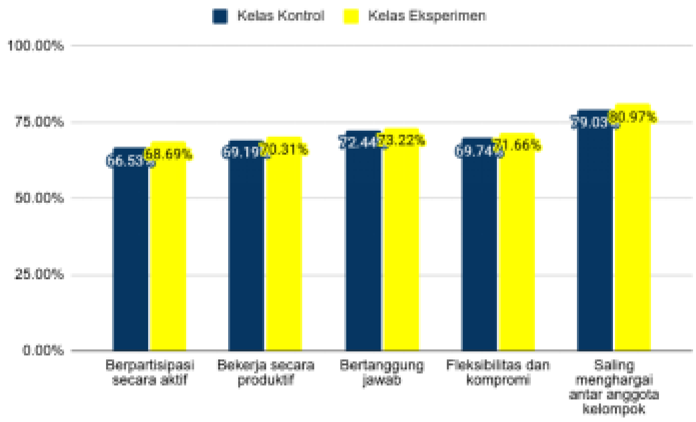

Figure 6. Diagram of Average Percentage of Observation Meeting II for Each Collaboration Skill Indicator

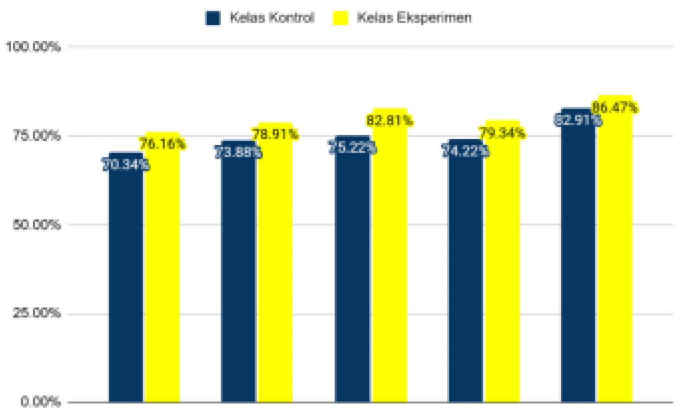

Diagram 7. Average Percentage of Observations in Meeting III for Each Collaboration Skill Indicator

In meeting II, the highest difference occurred in the indicator of active participation, with the experimental class reaching 68.69% and the control class 66.53% (a difference of 2.16%). This shows that the science module with an ethno-I-STEAM approach is more effective in encouraging student engagement than the approach in the control class. Meanwhile, the lowest difference occurred in the indicator of responsibility, with the experimental class at 73.22% and the control class at 72.44% (a difference of 0.78%), indicating that the inquiry approach also instills the value of responsibility in group work.

In meeting III, the indicator with the highest difference was responsibility, where the experimental class reached 82.81% and the control class 75.22% (a difference of 7.59%). This difference shows that the ethno-I-STEAM approach to science modules is more effective in increasing students' awareness of group responsibility, mainly because of the experiments that require the contribution of each member. The lowest difference occurred in the indicator of mutual respect among group members, with the experimental class at 86.47% and the control class at 82.91% (a difference of 3.56%). This shows that the inquiry approach still allows for cooperation and mutual respect, even though it does not explicitly emphasize cultural aspects as in the science module.

Overall, the difference in collaboration skills was greater in meeting III than in meeting II, indicating that as learning progressed, the use of the ethno-I-STEAM approach to science modules had an increasing impact on collaboration skills. Students became more accustomed to the concept of effective group work, mainly because the integration of local culture in learning reinforced collaborative values, such as active participation, productive work, responsibility, flexibility, and mutual respect. This proves that collaboration skills developed gradually, with culture-based learning providing a stronger stimulus than the inquiry approach in the control class.

After obtaining the initial self-assessment and final self-assessment data, data analysis was conducted. Significant differences between the experimental class and the control class were identified through hypothesis testing using an independent sample t-test. After fulfilling the hypothesis prerequisite test with normal and homogeneous results, an independent sample t-test could be performed on the final self-assessment results of the collaboration skills of the experimental class and the control class, which showed that the Sig. (2-tailed) value was < 0.05, meaning that there was a difference in the collaboration skills of students between the experimental class and the control class after being given treatment.

Based on the effect size test results in Table 17, the use of the science module with the ethno-I-STEAM approach showed a significant effect on collaboration skills. The effect size value for critical thinking skills obtained was 0.613, which is in the strong category. This shows that the science module is very effective in improving students' collaboration skills.

The ethno-I-STEAM-based science modules were proven to improve students' collaboration skills in making Kasongan pottery. The integration of local culture encouraged discussion and cooperation, while experiments and group discussions increased participation and communication, and interactive modules deepened understanding of science concepts. These results confirm that ethno-I-STEAM modules not only enrich learning but also significantly improve collaboration skills in science. Research by Mawaddah et al. (2022), Rizkika et al. (2022), and Hasanah et al. (2021) shows that STEM in learning tools improves collaboration skills through group experiments. Modules with student activity sheets encourage active participation, discussion, and interaction. Fatimah (2019) also emphasizes that STEM-based science learning in open spaces connects science with real-world contexts, increases student engagement, and prevents boredom, making learning more meaningful and relevant.

The Effect of Using the Ethno-I-STEAM Approach Module for Making Kasongan Pottery on Critical Thinking Skills and Collaboration Skills

The effect of using the Ethno-I-STEAM approach to science modules for making Kasongan pottery has a simultaneous effect on the critical thinking skills and collaboration skills of seventh-grade junior high school students. The third hypothesis was measured using the MANOVA test. Before conducting the MANOVA test, the data was tested using Box's M Test and showed a significance value of 0.230, where the Sig. value was < 0.05, which means that the dependent variables had the same variance (homogeneous).

After the prerequisite test was met, the MANOVA test was conducted and obtained Sig. values for Pillai's Trace, Wilk's Lambda, Hotelling's Trace, and Roy's Largest Root of 0.000, respectively. These results indicate that Sig. < 0.05, which means H0 is rejected and H1 is accepted. Based on these results, it can be seen that there is a significant effect of the use of the ethno-I-STEAM approach module in science for making Kasongan pottery on the critical thinking and collaboration skills of seventh-grade junior high school students simultaneously.

The ethno-I-STEAM approach science module facilitates the simultaneous improvement of students' critical thinking and collaboration skills through contextual experiments. In the learning process, students not only analyze, evaluate, and draw conclusions from various stimuli provided, but also work together in groups to complete tasks. Through this module, critical thinking skills develop because students must identify problems, find solutions, and connect science concepts with local wisdom, while their collaboration skills also improve because the process takes place in an intensive teamwork dynamic.

In addition, the application of ethno-I-STEAM in exploring the making of Kasongan pottery further strengthens critical thinking and collaboration skills simultaneously. As students discuss, share roles, and work together, they are also trained to think logically and systematically in solving problems that arise during the learning process. With structured interactions in these modules, students not only learn to understand science concepts in depth, but also develop attitudes of mutual respect, responsibility, and cooperation in order to achieve learning objectives.

This is in line with previous research that interaction between students in collaborative learning facilitates the development of higher-order thinking skills, including critical thinking. This study found that a collaborative inquiry-based learning approach is effective in increasing students' tendency to think critically (Chen & Hwang et al., 2017). Thus, the MANOVA test results show a significant effect of the science modules on critical thinking and collaboration skills simultaneously.

CONCLUSION

The results of the study indicate that the use of the ethno-I-STEAM approach science e-module in making Kasongan Pottery has a significant influence on students' critical thinking and collaboration skills. This is proven through an independent sample t-test, where critical thinking skills show a significance value of 0.000 with an effect size of 0.919 which is included in the very strong category. Meanwhile, collaboration skills have a significance value of 0.017 with an effect size of 0.613 which is included in the strong category. In addition, the results of the MANOVA test with a significance value of 0.000 confirm that the use of the ethno-I-STEAM approach science e-module has a significant effect on both skills simultaneously.

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AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Investigation; Project administration; Validation; Writing – review and editing; Data curation; Formal analysis; Methodology; Writing – original draft; Resources; Visualization.

Author 2: Validation; Formal analysis; Other contributions; Resources; Supervision.

Author 3: Validation; Formal analysis; Other contributions; Resources; Supervision.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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