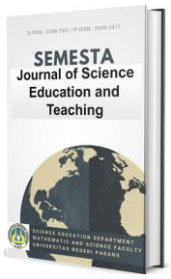

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Empowering 21st-Century Skills through Ethno-PjBL: The Case of 'Geplak' in Science Education

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ABSTRACT

Developing 21st-century skills—such as critical thinking and communication—is essential to prepare students for real-world challenges, yet these skills remain underdeveloped in many science classrooms. This study investigates the effect of the Project-Based Learning (PjBL) model integrated with ethnoscience content based on the traditional food "Geplak" on students' critical thinking and communication skills in the context of science education. It also examines whether significant differences exist between students taught using ethnoscience-based PjBL and those taught using the Discovery Learning model on the topic of food additives. A quasi-experimental design was employed with eighth-grade students, divided into an experimental group and a control group. The experimental group received learning through the PjBL model with ethnoscientific integration, while the control group followed the Discovery Learning model. Data were collected through pretest-posttest assessments on critical thinking, communication skill questionnaires, and observation sheets. MANOVA and effect size analyses revealed that the PjBL model significantly enhanced students' critical thinking and communication abilities. The findings suggest that integrating local cultural content such as traditional food into science learning can meaningfully contribute to the development of essential 21st-century skills.

Keywords: Critical thinking skills, Communication, Project-based learning, Ethnoscience, Traditional food "Geplak"

Introduction

Education plays a strategic role in shaping individuals who can adapt to future challenges and needs. In facing the wave of globalization and rapid technological advancement, 21st-century learning demands mastery of technology as well as life skills that are relevant to the current era. In line with this, the curriculum at the elementary, junior high, senior high, and vocational school levels has been adjusted to support the achievement of these goals (van Laar et al., 2019).

Technological advancements and globalization have brought significant changes to the types of skills students must acquire. Mastery of learning content alone is no longer sufficient, as 21st-century students are expected to possess four essential skills: Critical Thinking, Creativity, Collaboration, and Communication—collectively known as the 4Cs (Griffin & McGraw, 2012; Trilling & Fadel, 2009). These skills are crucial for navigating the challenges of modern life and for shaping individuals who are adaptive, creative, and competitive in the global era (Greenstein, 2012).

Critical thinking, as one of the 21st-century skills, is a logical and reflective thinking process that focuses on making decisions about what to believe and what actions to take (Ennis, 2011). This skill is highly important in the context of 21st-century education, where students are not only taught to recall information but also to analyze, evaluate, and make sound decisions based on evidence (Thornhill-Miller et al., 2023). However, Indonesian students' critical thinking abilities remain relatively low. Despite growing awareness of the importance of this skill in modern education, many students still struggle to apply logical and reflective thinking when faced with complex problems. This is evident in their tendency to rely more on memorization or repetition of information rather than engaging in deep analytical processes (Arda et al., 2024).

The results of PISA (Programme for International Student Assessment) 2022, which indicate low literacy levels in Indonesia, reflect significant challenges in preparing students to meet the demands of the 4c era (Organisation for Economic Co-operation and Development, 2023). According to the 2022 PISA data in the field of science, Indonesian students' critical thinking skills remain relatively low. This is evident from the extremely small percentage of students who reached Level 5 and Level 6, only 0.03% and 0.00%, respectively. These levels represent higher order thinking skills, including deep analysis, critical evaluation, and complex problem-solving. In contrast, most students were still at Level 1a (41.12%) and Level 2 (26.29%), indicating that students' critical thinking abilities are generally still at a low to moderate level.

A preliminary study conducted by (Zebua, 2024) revealed that students' critical thinking skills remain low, with an average score of 42.95. This indicates a lack of skill development in analyzing information and solving problems. These findings are consistent with (Hasanah et al., 2023), who reported that 64% of students demonstrated low levels of critical thinking, suggesting that most students are still unable to effectively evaluate information, solve problems efficiently, or make sound decisions. This is further supported by (Gustianingrum et al., 2023) who found that students' critical thinking abilities are still in the low category. Students continue to face difficulties in analyzing problems, constructing logical arguments, and connecting learning concepts to real-life situations.

In addition to critical thinking, communication skills are also a crucial aspect of 21st-century skill development. (Alpusari et al., 2019) stated that students' communication abilities remain relatively low. This condition is largely due to teacher-centered learning, which limits student involvement in the thinking process and collaboration. As a result, students struggle to develop effective communication skills. This finding is supported by (Duncan, 2020) who reported that students' communication skills are still lacking, as seen in the limited exchange of ideas during group learning activities. This obstacle stems from students' limited participation in expressing opinions and listening to others, causing some students to become overly reliant on their peers. Similarly, (Syahdani & Tyas, 2025) found that the average level of students' communication skills remains low or inadequate. This low level is attributed to students' lack of understanding of the material, which leads to passivity and reluctance to express their opinions actively.

Based on these conditions and supported by interviews with the 8th-grade science teacher at SMP Muhammadiyah 2 Depok, it was revealed that students' critical thinking and communication skills still need to be developed. Students tend to rely on memorization without truly understanding the concepts, and communication is only practiced during presentations, without being fully integrated throughout the learning process.

The low levels of students' critical thinking and communication skills can be improved through learning models that encourage students to explore and solve problems independently in science classes. One effective and innovative model for this purpose is Project-Based Learning. According to (Khairani Astri et al., 2022a), the Project-Based Learning model has proven effective in enhancing the quality of students' project outcomes in science learning. Through this model, students are actively involved in designing, developing, and presenting projects that are relevant to the learning topics, leading to more meaningful final products aligned with instructional goals. This is also supported by (Gabuardi & María, 2021), who stated that Project-Based Learning allows students the freedom to think creatively and express their ideas, providing a platform for them to share opinions, ask questions, respond, debate, and collaborate to produce the expected project outcomes.

Learning through the Project-Based Learning model allows students to engage more actively with one another, rather than passively listening to the teacher without meaningful feedback (Ngereja et al., 2020). In addition, through the testing of completed projects, students can express their arguments and demonstrate the outcomes of their self-regulation processes in learning (Maros et al., 2023). Project-Based Learning places students at the center of the learning process while also preparing them for real-life challenges through engagement in contextual and relevant problem-solving activities (Kartini et al., 2021). To optimize the implementation of Project-Based Learning, the learning process should be connected to problems or activities commonly encountered in students' everyday environments (Wilujeng et al., 2024).

The flexible integration of local content into other subjects—through theme selection or the development of specialized courses, can serve as part of an ethnoscience-based learning approach (Sarkingobir & Bello, 2024). Ethnoscience refers to the body of knowledge possessed by particular social groups, ethnic communities, or local societies (Anwar & Sumarna, 2022). In the learning process, students are encouraged to connect local phenomena with scientific concepts, making learning

more meaningful and positively influencing students' learning outcomes (Hanum et al., 2023).

Ethnoscience is not only an approach rooted in local wisdom but also serves as a bridge between formal scientific knowledge and students' cultural contexts (Yazidi & Rijal, 2024). The application of ethnoscience in science education allows students to develop critical thinking and communication skills through contextual experiences that are closely related to their daily lives (Rahman et al., 2023). By connecting science learning with local culture, students can better understand the material meaningfully while also fostering an appreciation for their own cultural heritage. This aligns with the findings of (Anggreini et al., 2024) who stated that ethnoscience-based learning can enhance students' critical thinking skills, as it exposes them to knowledge embedded in their local culture, enabling them to observe real-life facts more closely and improve their thinking processes. Similarly, (Puspasari et al., 2019) emphasized that integrating ethnoscience into learning serves as an effort to optimize contextual, integrated instruction and strengthen the use of the environment as a learning resource.

One example of the application of ethnoscience that is closely related to students' daily lives is research on traditional local foods, such as geplak. Geplak is a traditional snack that has great potential to contain food additives. Geplak was chosen because of its close connection to local culture and its suitability to the topic of food additives, as dyes and sweeteners are often used in its production, which students can study further. In addition, geplak is easily found in the surrounding environment, making it easy for students to make direct observations and understand the application of food additive concepts in a real context. Therefore, ethnoscience research on geplak can be effectively integrated with the Project-Based Learning model in teaching the topic of food additives. This topic is included in the "Merdeka Curriculum," which emphasizes project-based learning as one of its main principles. Through this approach, students acquire knowledge, skills, and character development through investigations driven by meaningful questions (Chin & Brown, 2002; Chu et al., 2017).

Based on the identified issues, a project-based learning approach integrated with ethnoscience is needed in classroom instruction. This type of learning is expected to enhance students' critical thinking and communication skills through meaningful learning experiences. This is supported by (Sholihah & Lastariwati, 2020) who stated that critical thinking and effective communication are closely interconnected in the learning process, critical thinking enables students to analyze, evaluate, and construct logical arguments, while communication helps them clearly and convincingly express their ideas (Nurohman et al., 2025). Without strong communication, critical thinking outcomes may be difficult to convey, and without critical thinking, communication may lack depth (Thornhill-Miller et al., 2023). However, previous studies have not yet integrated ethnoscience into the Project-Based Learning model. This forms the basis for examining whether the implementation of a PjBL model incorporating ethnoscientific elements also has a significant impact on students' communication and critical thinking skills.

Previous research conducted by Mirnawati et al. (2021), entitled "The Effect of Project-Based Learning Model Based on Ethnoscience on Colloid Material and Its Relation to Students' Creative Thinking Ability at SMA Negeri 2 Kota Jambi," concluded that the Project-Based Learning (PjBL) model is suitable to be integrated with the ethnoscience approach. This is because PjBL allows students to actively engage in projects that are relevant to real-life contexts, while ethnoscience provides

local cultural perspectives that enrich the learning experience. However, the study was conducted at the senior high school level, so the influence of the ethnoscience-based PjBL model has not yet been explored at the junior high school level in science learning. Moreover, the study focused on students' creative thinking skills, leaving a research gap regarding its impact on critical thinking and communication skills.

This study aims to determine the significant differences in students' critical thinking and communication skills between those taught using the Project-Based Learning model integrated with the ethnoscience of the traditional food geplak and those taught using the Discovery Learning model on the topic of food additives. Additionally, the study seeks to examine the effect of the ethnoscience-integrated Project-Based Learning model based on geplak on students' critical thinking and communication skills in learning about food additives. The selection of the Project-Based Learning (PjBL) model over Discovery Learning is based on fundamental differences in their approaches to the learning process. While Discovery Learning emphasizes individual exploration, it provides limited opportunities for students to engage in collaborative work that demands active communication and real-world problem-solving. In contrast, PjBL integrated with ethnoscience not only encourages students to think critically in addressing challenges rooted in local culture but also fosters communication skills through meaningful discussions, collaboration, and project presentations.

Methods

A. Research Design

The study was conducted using a quasi-experimental design. The specific design employed was the Nonequivalent Control Group Design, as both the experimental and control groups were not selected randomly. This design is presented in Table 1. The sample selection was based on the science teacher's recommendations, considering students' academic performance and individual characteristics. Prior to the intervention, both classes were given a pretest to assess their initial abilities. The experimental class received instruction through the Project-Based Learning model integrated with the ethnoscience of the traditional food Geplak, while the control class was taught using the Discovery Learning model. After the intervention, both groups were given a posttest to determine the effects and differences in outcomes between the two instructional models.

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

B. Participant

The participants of this study consisted of 48 eighth-grade students, with 24 students in the experimental class and 24 in the control class. The participants were selected from a population of 96 eighth-grade students at Junior High School in Yogyakarta, using purposive sampling. The sample selection was based on specific criteria and requirements determined by the researcher, considering input from the science teacher regarding student engagement during lessons, academic performance

in each class, and the number of students in both classes. The sample included Class VIII A as the control group and Class VIII B as the experimental group.

C. Data Collection

The data collection techniques used to examine the effect of implementing ethnoscience-integrated Project-Based Learning using traditional food *Geplak* on students' critical thinking and communication skills consisted of tests and observations. The instruments used in this study included:

D. Pretest and postest

This study employed both pretests and posttests. A written test was used to assess students' critical thinking skills. The pretest and posttest consisted of 25 multiple-choice questions designed to measure students' critical thinking abilities. The pretest was administered to both the experimental and control groups prior to the start of instruction to assess their initial skill levels. The posttest, on the other hand, was conducted after the instructional intervention to evaluate students' critical thinking skills following the implementation of the ethnoscience-integrated Project-Based Learning model using the traditional food *Geplak*.

E. Self-Assessment Questionnaire on Communication Skills

A student self-assessment questionnaire was used to evaluate students' perceptions of their own communication abilities. This questionnaire employed a Likert scale using a bipolar format to capture both positive and negative responses to each statement. In this format, positive items were used to measure positive scales, while negative items assessed negative tendencies. The Likert scale consisted of the following response options: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD).

F. Observation of Communication Skills

This study utilized an observation sheet to assess students' communication skills during the learning process. The observation instrument was designed to observe and evaluate students' communication abilities based on specific indicators of communication competence. The observation was conducted by trained observers who assessed students throughout the lesson activities.

G. Observation Sheet on Learning Implementation

An observation sheet was also used to evaluate the implementation of the learning process, specifically focusing on teacher activities during instruction. This sheet took the form of a checklist (✓), listing various instructional activities carried out by the teacher. Observers were responsible for completing the checklist during the lesson to monitor and document the extent to which the planned learning steps were implemented.

H. Content Validity

Content validity refers to the extent to which the test items accurately measure what they are intended to measure and are truly relevant and representative of the construct in line with the assessment objectives. Content validity in this study was established by seeking expert judgment from science education lecturers and teachers,

who were asked to complete validation sheets prepared by the researcher. After receiving feedback from expert validators, the instruments were revised based on their suggestions. The instruments evaluated by the validators included the teaching module, student worksheets, handouts, critical thinking assessment questions, and the communication skills questionnaire. The overall validation scores of the science learning tools evaluated by the experts are presented in Table 2.

Table 2. Content Validity Results

Product	Score Result		Average	Category
	1	2		
Lesson Plan	4	3.76	3.61	Very Good
Student Worksheet	4	3.76	3.81	Very Good
Handout	4	4	3.87	Very Good

Based on Table 2, the evaluation results for each component of the science learning device based on Project-Based Learning with the ethnoscience content of traditional food *Geplak* indicate that it is feasible, as the average scores obtained fall within the "very good" category. Therefore, the science learning device based on Project-Based Learning with the ethnoscience content of traditional food *Geplak* is considered suitable for use in learning to examine its effect on students' critical thinking and communication skills.

I. Empirical Validity

Empirical validation was carried out by testing the items on ninth-grade students who had previously received the topic of additives. The purpose of the empirical validation was to determine whether an item is considered valid in terms of language, concept, content, and other aspects based on the results of item analysis. In this study, validity and reliability tests were conducted using the QUEST program. Several criteria are applied to determine the validity of the instrument using QUEST. According to (Tyas et al., 2023) the fit of each item with the model in the QUEST program is determined by the values of Infit MNSQ, Outfit T, and the item difficulty index (threshold). A good item must meet the requirements of the item response theory. The quality of an item is determined by its fit with the Rasch model and its threshold. The criteria for item quality based on the item response theory approach are presented in Table 3.

Table 3. Criteria for Item Quality Based on Item Response Theory

Fit Item with Rasch Model		Item Difficulty Index (b)	Criteria
Infit MNSQ	Outfit T		
$0.77 \leq x \leq 1.33$	$T \leq 2.00$	$-2 \leq b \leq 2$	Good
$0.77 \leq x \leq 1.33$	$T \leq 2.00$	$b > 2$ atau $b < -2$	Fairly Good
$x < 0.77$ atau $x > 1.33$	$T > 2.00$	$b > 2$ atau $b < -2$	Poor

Based on the analysis of the quality of 40 test items, it was found that 4 items were categorized as fairly good. The item analysis using the QUEST application was conducted to examine the validity of each test item. The results showed that 13 items

were invalid and therefore needed to be revised or removed. Meanwhile, 27 items were found to be valid and could accurately measure critical thinking skills. The number of test items was then reduced to 25, considering the threshold values that represent item difficulty levels. Items that were too difficult or too easy were eliminated. After determining item quality and validity, the reliability values of the items were interpreted.

The empirical test was not only conducted on test-based assessments but also on non-test instruments, namely the communication skills questionnaire. Based on the quality analysis of 22 questionnaire items, it was found that 5 items were categorized as misfitting. The analysis using the QUEST application was conducted to examine the validity of each questionnaire item. The results showed that 5 items were invalid and therefore needed to be revised or deleted. Meanwhile, 17 items were found to be valid and could accurately measure communication skills.

J. Reliability

The test used was Cronbach's Alpha or the alpha coefficient. The range of alpha coefficient values extends from 0 (no reliability) to 1 (perfect reliability), presented in Table 4.

Table 4. Reliability Coefficient Correlation Values

Reliability Index	Criteria
$r < 0.20$	Very Low
$0.20 < r < 0.40$	Low
$0.40 < r < 0.70$	Moderate
$0.70 < r < 0.90$	High
$0.90 < r < 1.00$	Very High

The results of the reliability test for the critical thinking test items and the student communication skills questionnaire are presented in Table 5.

Table 5. Results of the Instrument Reliability Test

Instrument	Reliability of Estimate	Category
Test Items Critical Thinking Skills	0.95	Very High
Questionnaire Communication Skills	0.81	Very High

Based on the results of the reliability analysis of the instruments used, the Reliability of Estimate value was 0.95 for the critical thinking skills test and 0.81 for the communication skills questionnaire. According to the reliability category, both instruments fall into a very high category, indicating that they have excellent internal consistency in measuring the intended aspects. In other words, the critical thinking test and communication questionnaire provide stable and dependable results when administered under similar conditions, making them reliable measurement tools for this study.

The data analysis methods employed in this study included descriptive statistical analysis and inferential statistical analysis, comprising assumption tests, MANOVA, and effect size analysis. The analysis of the implementation of the teaching module during learning activities was carried out by calculating the total score obtained from

the observation sheets filled out by observers during the learning process. Descriptive statistical analysis was used to determine the improvement in students' critical thinking and communication skills by employing gain scores. Inferential statistical analysis was used to examine the effectiveness of the ethnoscience-based Project-Based Learning model developed in this research.

Before conducting the MANOVA test, the data obtained were first converted into interval data, followed by assumption testing. The assumption tests included the Shapiro–Wilk normality test and Levene's Test of homogeneity, both performed using SPSS 26.0. The data was considered normally distributed and homogeneous if the Asymp. Sig. (2-tailed) value was greater than half of α, with $\alpha = 0.05$. Once the data met the assumptions of normality and homogeneity, the MANOVA test was conducted to determine the difference in improvement between the two paired data samples. The effect size in this study was measured using Partial Eta Squared (η^2). According to (Cohen et al., 2017) the interpretation of effect size in behavioral sciences is as follows: a value of 0.01 indicates a small effect, 0.06 indicates a medium effect, and 0.14 or higher indicates a large effect.

Results and Discussion

The influence of the ethnoscience-based Project-Based Learning (PBL) model in science education on traditional food *Geplak* was examined in terms of improving students' critical thinking and communication skills. The data were obtained from learning activities conducted in two classes: an experimental class that implemented the ethnoscience-based PBL model using *Geplak* as the learning context, and a control class that applied the Discovery Learning model. In the experimental class, students were divided into six groups, and each group was assigned to make *Geplak*, a traditional food from Yogyakarta. The following activities were carried out by the groups during the *Geplak*-making process.

Each stage of the Project-Based Learning model contributed directly to the development of students' abilities. In the initial stage, students were given trigger questions related to the nutritional content and local wisdom associated with *Geplak* to stimulate curiosity and initiate critical thinking processes. In the investigation stage, students searched for information, explored natural ingredients, and observed the *Geplak*-making process collaboratively, which encouraged them to develop critical thinking skills through problem-solving and decision-making. During the reflection stage, students discussed their learning experiences and the challenges encountered during the project, helping them to deepen their understanding and evaluate their thinking processes. Finally, in the project publication stage, students presented their *Geplak* creations to teachers and peers, an activity that enhanced their oral and written communication skills.

The use of traditional food such as *Geplak* in science learning made the classroom atmosphere more engaging and less monotonous. Since the content originated from students' own cultural background, the learning experience became more authentic, relatable, and meaningful. This approach fostered enthusiasm, active participation, and a sense of responsibility among students in completing their tasks. Moreover, it helped them realize that science is closely connected to everyday life and local culture. When students learn through familiar and personally relevant contexts, they tend to be more focused and perceive the learning as valuable. Consequently, they develop greater care and ownership of their learning process and outcomes.

Figure 1. Preparation of the Traditional Food *Geplak*

The main ingredients for making *Geplak*—a traditional delicacy from Yogyakarta, particularly from the Bantul region—are grated coconut mixed with sugar, which is roasted and shaped into colorful round pieces. These ingredients were selected because they are easily accessible in the students' local environment. After each group completed the process of making *Geplak*, the next activity involved testing for the presence of food additives, specifically focusing on coloring agents and sweeteners used in the *Geplak* samples.

A. The Influence of Ethnoscience-Based Project-Based Learning Using Traditional Food Geplak on Students' Critical Thinking Skills

After conducting the learning activities in both the experimental and control classes using different models, the Project-Based Learning (PBL) model was found to have a significant effect on students' critical thinking skills. This finding is supported by the study of (Cahyani et al., 2024) which states that Project-Based Learning helps students develop critical thinking skills by guiding them in designing processes and frameworks to find solutions to problems encountered during project implementation.

Based on the analysis results, students' critical thinking skills in the experimental class showed an increase in the average pretest and posttest scores. The average pretest score in the experimental class was 64.67, while the posttest score increased to 83.17, with an average gain of 73.92. This indicates that the ethnoscience-based Project-Based Learning model using traditional food *Geplak* effectively enhances students' critical thinking skills. The next step was to conduct assumption tests, which included tests of normality and homogeneity, before proceeding to the hypothesis testing stage. The univariate normality test aimed to determine whether the data for each dependent variable were normally distributed. This test used the Shapiro–Wilk test, referring to the Asymp. Sig (2-tailed) value. If the value was greater than the significance level of 0.05, the data were considered normally distributed. The results of the normality test were obtained using SPSS version 26.0 and are presented in Table 6.

Table 6. Results of the Univariate Normality Test and Homogeneity

	Normality Test		**Homogeneity**	
	Experiment	**Control**	**Sig.**	
Critical Thinking Skill	0.114 normal	0.300 normal	0.104	homogeneous
Communication Skill	0.203 normal	0.159 normal	0.083	homogeneous

Based on the results of the univariate normality test of the gain scores for each variable presented in the table above, the Asymp. Sig. (2-tailed) values for both the critical thinking and communication skills variables exceeded the significance level of 0.05. This indicates that both variables were normally distributed. After the normality

test, the next assumption test conducted was the homogeneity of variance test. This test aimed to determine whether the dependent variables had equal variances. The test was performed using Levene's Test, by referring to the significance (Sig.) value. If the Sig. value was greater than the significance level of 0.05, it could be concluded that the data variances for each dependent variable were homogeneous.

Based on the results of the homogeneity of variance test for the gain scores of each variable presented in Table 6, the significance (Sig.) values were greater than 0.05 for all variables. This indicates that the data for each variable had homogeneous or equal variances. After fulfilling the assumption tests, the next step was to conduct the MANOVA test to examine the research hypothesis. The purpose of the MANOVA test was to determine whether the ethnoscience-based Project-Based Learning (PBL) model had a significant effect on improving students' critical thinking and communication skills, compared to the Discovery Learning model. The analysis was performed using SPSS software with a significance level of $\alpha = 0.05$. The decision rule for the MANOVA test was: if Sig < 0.05, then H_0 is rejected and H_1 is accepted.

Table 7. Results of the MANOVA Test

Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Etta Square
Pillai's Trace	0.925	276.247	2.000	45.000	0.000	0.925
Wilk's Lambda	0.075	276.247	2.000	45.000	0.000	0.925
Hotelling's Trace	12.278	276.247	2.000	45.000	0.000	0.925
Roy's Largest Root	12.278	276.247	2.000	45.000	0.000	0.925

Based on the results of the four analyses, it was found that the influence of the independent variable on the dependent variables was very strong. All analyses showed a significance value of 0.000, which is lower than the significance threshold of 0.05. This indicates that there was a significant difference in students' critical thinking and communication skills through learning with the ethnoscience-based Project-Based Learning (PBL) model using traditional food *Geplak* in the topic of food additives. The Partial Eta Squared value of 0.925 on the intercept, which is close to 1, indicates a large effect size, showing that the ethnoscience-based PBL model using *Geplak* had a strong influence on students' critical thinking and communication skills. The MANOVA test also produced a Test of Between-Subjects Effects, which aimed to confirm that the science learning model based on ethnoscience-integrated Project-Based Learning that was developed truly enhanced both dependent variables being measured. The results of the Test of Between-Subjects Effects are presented in Table 8.

Table 8. Test of Between – Subject's Effects Result

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Critical	8.772	1	8.772	381.949	0.000
	Thinking Communication	8.093	1	8.093	418.227	0.000

Based on the results of the Test of Between-Subjects Effects presented above, it can be seen that the Sig. values for the gain scores of critical thinking skills and communication skills in the intercept statistics were both 0.000. With a significance level set at 0.05, these results (being smaller than 0.05) indicate that H_1 is accepted. This means that there was a significant effect on students' critical thinking and communication skills among the group that participated in learning using the ethnoscience-based Project-Based Learning (PBL) model on the topic of food additives, compared to the group that did not use this learning model. The Test of Between-Subjects Effects also produced Partial Eta Squared values to determine the magnitude of the effect. The size of the effect for each dependent variable was observed from the Partial Eta Squared values in the intercept statistics of the test results. The Partial Eta Squared results from the Test of Between-Subjects Effects are presented in Table 9.

Table 9. Partial Eta Squared Values from the Test of Between-Subjects Effects

Source	Dependent Variable	Partial Etta Square	Category
Intercept	Critical Thinking	0.893	Strong
	Communication	0.901	Strong

Based on Table 10, the Partial Eta Squared values indicate that both critical thinking skills and communication skills fall into the large effect category. This classification refers to the theory proposed by (Cohen et al., 2017), which states that the effect size, represented by η^2 (eta squared) or ω^2 (omega squared) in behavioral sciences, can be interpreted as follows: a value of 0.01 indicates a small effect, 0.06 indicates a medium effect, and 0.14 or higher indicates a large effect.

Table 10. Results of Critical Thinking Skills in the Experimental and Control Classes

Aspect	Experiment		N Gain	Control		N Gain
	Pretest	Posttest		Pretest	Posttest	
Interpretation	71	83	0.41	77	86	0.39
Analysis	68	84	0.50	76	76	0.35
Evaluation	47	86	0.74	53	77	0.51
Inference	74	82	0.31	82	84	0.11
Explanation	65	78	0.37	50	58	0.16

Based on the results of the gain score analysis for the critical thinking skills aspect, it was found that the increase in the experimental class was higher than that in the control class. The experimental class achieved higher gain scores across all aspects of critical thinking skills compared to the control class. Based on the results of the study, the ethnoscience-based Project-Based Learning (PBL) materials developed proved to be effective in enhancing students' critical thinking skills compared to the group of students who did not use these science learning materials. This effectiveness can be attributed to the nature of Project-Based Learning, which helps students develop critical thinking skills by guiding them to design processes and frameworks to find solutions to problems encountered during project implementation. According to (Hanum et al., 2023), the application of the Project-Based Learning model has been proven effective in improving students' critical thinking skills. Through various projects that require interpretation, analysis, inference, evaluation, explanation, and

self-regulation, students demonstrate significant development in critical thinking. Moreover, the Project-Based Learning model plays an important role in fostering critical thinking skills because it encourages students to exchange ideas, collaborate, and reach consensus in completing projects collaboratively.

B. The Influence of Ethnoscience-Based Project-Based Learning Using Traditional Food Geplak on Students' Communication Skills

Based on the analysis results, the communication skills of students in the experimental class were found to be higher, falling into the moderate category, compared to the control class, which was in the low category. Communication skills were measured using a communication skills questionnaire administered to students at the beginning (pretest) and end (post test) of the learning process.

Table 11. Results of Communication Skills in the Experimental and Control Classes

Aspect	Experiment		N Gain	Control		N Gain
	Pretest	Posttest		Pretest	Posttest	
Verbal Communication	62.25	81.41	0.51	64.5	74.55	0.28
Listening	67.47	75.47	0.25	78.86	77.67	-0.06
Non-Verbal Communication	50	80.79	0.64	46.5	74.28	0.52

Based on the gain score calculations for the various aspects of students' communication skills, it was found that all aspects showed a higher increase in the experimental class compared to the control class. In the experimental class, the highest aspect was non-verbal communication, with a score of 0.62, while the control class scored 0.52, showing a difference of 0.10 points. The second-highest aspect was verbal communication, with the experimental class scoring 0.51, which was higher than the control class score of 0.28, resulting in a difference of 0.23 points. The listening aspect had the lowest score in the experimental class, with a value of 0.25, compared to -0.06 in the control class, showing a difference of 0.34 points in favor of the experimental class.

Table 12. Observation Results of Students' Communication Skills

Aspect	Observation Result (%)					
	1	2	3	4	Average	Category
Verbal Communication	0.58	0.64	0.78	0.85	0.58	Moderate
Listening	0.53	0.61	0.71	0.81	0.67	Good
Non-Verbal Communication	0.60	0.67	0.77	0.84	0.72	Good

Based on the table above, the average achievement of communication skills for each meeting shows that the experimental class consistently obtained higher mean scores than the control class. Data obtained from both questionnaires and observation sheets indicate that students in the experimental class demonstrated better communication skills compared to those in the control class. The results of this study reveal that the developed project-based learning tools integrated with ethnoscience effectively enhanced students' communication skills. This finding is consistent with (Syahdani & Tyas, 2025; Yanti et al., 2019), who reported that the Project Based

Learning (PjBL) model can improve students' communication abilities. The PjBL model encourages students to express their opinions clearly, understand others' perspectives, and exchange ideas effectively. Moreover, PjBL activities require students to present their project results, thereby fostering their public speaking abilities and their capacity to deliver structured information. This result is also supported by (Yanti et al., 2019), who stated that students actively engaged in learning activities focused on solving real-life problems tend to develop stronger communication skills. Therefore, implementing ethnoscience-based project learning can serve as an effective approach to promote students' communication skills in a contextual and meaningful way.

C. The Effect of the Project-Based Learning Model Integrated with Ethnoscience of Traditional Food Geplak on Students' Critical Thinking and Communication Skills

Students' critical thinking and communication skills are closely interrelated in the educational context. These two aspects complement each other to build a holistic and sustainable learning environment. According to (Arda et al., 2024), students with strong critical thinking skills demonstrate their ability to express ideas clearly, organize thoughts systematically, and use communication as a foundation for problem-solving. Critical thinking is essential in finding solutions, as it helps guide thinking and working processes more accurately and logically while identifying relevant connections among concepts. Communication skills also play an equally important role, as they support idea formulation and serve as the core of learning that must be implemented in every classroom activity.

The Project-Based Learning (PjBL) model plays a vital role in developing both critical thinking and communication skills, as it encourages students to engage in discussions, communicate within groups, and express their ideas throughout the project completion process. The ethnoscience-integrated Project-Based Learning approach is designed to enhance students' critical thinking and communication skills. Through project implementation, these two aspects can be simultaneously nurtured, as students are encouraged to analyze, discuss, and collaborate in solving challenges. For example, conducting a project on producing natural additives derived from the traditional food *Geplak* trains students to think critically and communicate effectively in understanding the concept of food additives.

Sudarmin et al. (2023) stated that the Project-Based Learning model significantly improves students' collaboration during the learning process. Moreover, applying ethnoscience-based Project-Based Learning trains students to be more critical in analyzing subject matter while enhancing their communication skills in expressing and discussing ideas rooted in local wisdom values. The stages of Project-Based Learning cultivate students' communication and teamwork abilities while developing critical thinking skills through discussions and project completion.

This finding aligns with (Khairani Astri et al., 2022b), who explained that Project-Based Learning follows systematic stages aligned with the indicators of critical thinking skills. The process begins with material presentation, group formation, project selection, schedule planning, project implementation, and testing stages. During the material presentation stage, students acquire fundamental understanding as the basis for project execution. Subsequently, project selection is carried out collaboratively within groups, allowing students to discuss, express opinions, and

consider multiple ideas before deciding on the project to be implemented. This is consistent with the study by (Hanum et al., 2023; Rahman et al., 2023), which found that project activities provide students with opportunities to sharpen critical thinking through investigation, decision-making, and group discussions. In these discussions, effective communication supports idea sharing, solution evaluation, and collaboration, resulting in the continuous development of both critical thinking and communication skills.

Conclusion

Based on the results of the analysis and discussion, it can be concluded that there is a significant difference in students' critical thinking and communication skills between those who used the science learning materials based on ethnoscience-integrated Project-Based Learning (PjBL) and those who did not. This finding is supported by the results of the Partial Eta Square analysis, which indicate that the ethnoscience-based Project-Based Learning science materials developed in this study have a large effect on both critical thinking and communication skill variables. The application of the ethnoscience-integrated Project-Based Learning model using the traditional food Geplak in teaching the topic of food additives to Grade VIII junior high school students proved effective in enhancing students' critical thinking and communication skills. The findings of this study provide valuable insights for teachers and pre-service teachers to reflect on and improve their instructional practices by considering the use of appropriate learning models that can enhance students' critical thinking and communication abilities. These two skills are interrelated, as communication plays an essential role in group discussions during project activities. Through communication, students can exchange ideas, express their thoughts critically, and collaboratively develop solutions to problems. Learning activities that focus on fostering critical thinking also have a positive impact on students' communication skills, as both are mutually reinforced within the context of collaborative, inquiry-driven learning environments.

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