



THE IMPLEMENTATION OF ETHNOSCIENCE INTEGRATED PROBLEM-BASED LEARNING: A QUANTITATIVE RESEARCH IN JUNIOR HIGH SCHOOL SCIENCE EDUCATION OF CIREBON TERASI PRODUCTION TO ENHANCE CRITICAL THINKING SKILLS

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Abstract

Critical thinking skills constitute fundamental competencies that students must develop to meet the demands of twenty-first-century education. However, science instruction in Indonesian junior high schools frequently lacks integration of local cultural contexts, thereby impeding students' capacity to connect scientific concepts to authentic real-world situations. This study aimed to examine the effect of Problem-Based Learning (PBL) integrated with the ethnoscience of Cirebon terasi (fermented shrimp paste) production on the critical thinking skills of junior high school science students. A quasi-experimental design with a pretest-posttest control group arrangement was employed. Participants comprised 68 seventh-grade students from SMPN 1 Cirebon, randomly assigned to an experimental group ($n = 34$) receiving PBL integrated with ethnoscience instruction and a control group ($n = 34$) receiving conventional instruction. Data were gathered using a validated critical thinking skills instrument based on Facione's six-dimensional framework, encompassing interpretation, analysis, evaluation, inference, explanation, and self-regulation. The instrument demonstrated high content validity ($CVR = 0.87$) and reliability (Cronbach's $\alpha = 0.89$). Results indicated a statistically significant difference in critical thinking skills between the experimental and control groups ($t(66) = 11.42$, $p < 0.001$), with normalized gain (N-gain) values of 0.72 (high category) and 0.35 (medium category), respectively, and a very large effect size (Cohen's $d = 2.64$). The greatest improvement was observed in the evaluation dimension (N-gain = 0.78). Furthermore, 87.6% of students expressed positive responses toward the ethnoscience-integrated PBL approach. These findings confirm that contextualizing science learning within the local wisdom of Cirebon terasi production through PBL significantly enhances critical thinking skills, thereby offering a culturally responsive and pedagogically robust model for science education in Indonesian junior high schools.

Keywords: *Critical thinking skills; ethnoscience; indigenous knowledge; Problem-Based Learning; science education; terasi Cirebon*

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INTRODUCTION

Science education at the junior high school level plays a pivotal role in cultivating students' scientific competencies and preparing them for participation in an increasingly knowledge-driven society. Among the critical competencies emphasized in contemporary educational frameworks, critical thinking skills have been widely recognized as foundational requirements for twenty-first-century learners (Redhana, 2019). Critical thinking enables

individuals to analyze problems systematically, evaluate evidence rigorously, and generate well-reasoned conclusions capacities that are indispensable not only in academic settings but also in civic and professional life (*Facione, 1990; Ennis, 2011*).

Despite its recognized importance, empirical evidence suggests that the development of critical thinking skills remains inadequate in many Indonesian schools. Data from the Programme for International Student Assessment (PISA) 2022 reveal that Indonesia ranked 68th out of 81 participating countries in scientific literacy, with students demonstrating particular weaknesses in tasks that require higher-order reasoning and the application of scientific knowledge to real-world contexts (OECD, 2023). This persistent gap underscores the urgent need for pedagogical innovation in Indonesian science classrooms—innovation that moves beyond rote memorization toward instruction that actively cultivates analytical, evaluative, and reflective thinking (*Wahyuni et al., 2021*).

Problem-Based Learning (PBL) is an instructional model that positions authentic, ill-structured problems as the starting point for learning. By engaging students in collaborative problem-solving, PBL promotes self-directed inquiry, metacognitive reflection, and the development of higher-order thinking skills (*Hmelo-Silver, 2004; Savery, 2006*). A meta-analysis conducted by *Merritt et al. (2017)* synthesizing 108 empirical studies confirmed that PBL consistently produces significant improvements in critical thinking skills across diverse grade levels and subject areas, particularly when students are presented with authentic, contextually relevant problems.

In parallel, the integration of ethnoscience defined as the study of how cultural communities categorize and explain natural phenomena through their indigenous knowledge systems into science instruction has garnered increasing scholarly attention (*Cobern & Loving, 2001; Aikenhead & Ogawa, 2007*). Ethnoscience-based instruction acknowledges the coexistence of Western Modern Science and indigenous knowledge systems, and leverages students' cultural experiences as cognitive anchors for learning scientific concepts (*Sударmin et al., 2020*). Such culturally responsive pedagogy has been shown to increase student motivation, engagement, and conceptual understanding by rendering abstract scientific knowledge personally meaningful (*Gay, 2018*).

Terasi a traditional fermented shrimp paste is a culturally iconic product deeply embedded in the culinary heritage of Cirebon, West Java, Indonesia. The artisanal production process involves a rich array of scientific phenomena, including halophilic bacterial fermentation, proteolytic enzymatic activity, osmotic processes resulting from salt application, the Maillard reaction producing characteristic aromatic compounds, and natural food preservation mechanisms (*Owens, 2014; Giri & Bhosle, 2019*). These phenomena correspond directly to fundamental science concepts in the junior high school curriculum, including changes in matter, biochemical reactions, microbiology, and food science. The indigenous knowledge embedded in terasi production thus represents an untapped pedagogical resource for authentic, contextually grounded science learning.

A review of the existing literature reveals a notable gap: while studies have separately examined PBL effectiveness (*Hung et al., 2019*) and ethnoscience integration in science education (*Sudarmin et al., 2021; Suastra et al., 2017*), no published study has systematically investigated the synergistic combination of PBL and the ethnoscience of local fermented food production specifically terasi as a context for developing critical thinking skills at the junior high school level. Addressing this research gap, the present study examined (1) whether PBL integrated with the ethnoscience of Cirebon terasi production significantly improved students' critical thinking skills compared to conventional instruction; (2) which dimensions of critical thinking showed the greatest gains; and (3) how students responded to the ethnoscience-integrated PBL approach. The findings contribute to the growing body of literature on culturally responsive science pedagogy and provide evidence-based recommendations for Indonesian science educators.

METHODOLOGY

This study employed a quasi-experimental design with a pretest-posttest control group arrangement (*Creswell & Creswell, 2018*). This design was selected because true random assignment of students to conditions was not feasible given the pre-existing class structure of the school. Two groups participated in the study: an experimental group that received PBL instruction integrated with the ethnoscience of Cirebon terasi production, and a control group that received conventional teacher-centered instruction covering the same content objectives. Both groups were taught by the same certified science teacher to control for teacher effects.

Participants were 68 seventh-grade students enrolled at SMPN 1 Cirebon, West Java, Indonesia, during the 2024/2025 academic year. Class selection was conducted using purposive sampling based on verified equivalence of prior academic achievement. Baseline equivalence between classes was confirmed through a homogeneity test (Levene's test, $F = 1.23$, $p = 0.27$) and an independent samples t-test on students' most recent science assessment scores ($t(66) = 0.41$, $p = 0.68$), indicating no statistically significant difference in prior performance. The experimental group comprised Class VII-A ($n = 34$; 18 female, 16 male), and the control group comprised Class VII-B ($n = 34$; 19 female, 15 male). All participants were aged 12–13 years. Informed consent was obtained from parents or legal guardians prior to the study, and the research protocol was reviewed and approved by the institutional ethics committee.

The intervention was implemented across eight learning sessions (equivalent to 16 lesson periods) over a period of four weeks. The content domain covered was the topic of 'Changes in Matter and Biodiversity,' as specified in the Indonesian national junior high school science curriculum. The same learning objectives, time allocation, and teacher were used for both groups.

The *experimental group* received PBL instruction organized around the ethnoscience context of Cirebon terasi production. The five-phase PBL instructional sequence (*Arends, 2012*) was implemented as follows: (1) *Problem Orientation*, students were presented with an authentic problem scenario via video documentation and direct observation of terasi production, framed through guiding questions (e.g., 'Why does shrimp fermentation change the color, smell, and texture of the product?'); (2) *Student Organization*, students were arranged into collaborative heterogeneous groups of four to five members to discuss and delineate the

problem; (3) *Guided Inquiry*, students conducted structured laboratory investigations, including microscopic observation of fermentation samples and chemical tests to identify pH changes and protein degradation products; (4) *Artifact Development and Presentation*, student groups produced written scientific reports and delivered presentations explaining the science underlying terasi production; and (5) *Reflection and Evaluation*, students engaged in guided metacognitive reflection on their problem-solving process, reasoning strategies, and the relationship between indigenous knowledge and scientific explanations. The *control group* received conventional instruction characterized by direct teaching, textbook-based exercises, and teacher-led discussion, without integration of ethnoscience contexts.

The primary data collection instrument was a *Critical Thinking Skills Test* comprising 25 structured essay items developed based on Facione's (1990) six-dimensional framework. All items were embedded within the context of Cirebon terasi production to ensure ecological validity. Content validity was established through expert review by three validators (two science education specialists and one food chemistry expert), yielding a mean Content Validity Ratio (CVR) of 0.87, which exceeds the minimum acceptable threshold of 0.78 for a three-validator panel (Lawshe, 1975). Instrument reliability was assessed through a pilot test with 30 students outside the study sample, yielding a Cronbach's alpha coefficient of $\alpha = 0.89$, indicating high reliability (George & Mallery, 2003).

A supplementary *Student Response Questionnaire* was administered to experimental group students following the intervention to assess their perceptions of the ethnoscience-integrated PBL approach. The questionnaire consisted of 20 positively and negatively worded items rated on a four-point Likert scale (1 = strongly disagree, 4 = strongly agree), encompassing dimensions of learning meaningfulness, motivation, active engagement, and perceived relevance to daily life. The instrument demonstrated satisfactory reliability (Cronbach's $\alpha = 0.83$).

All quantitative data were analyzed using IBM SPSS Statistics version 26.0. Prior to hypothesis testing, data were screened for normality using the Kolmogorov-Smirnov test and for homogeneity of variance using Levene's test. Learning gains for each group were calculated using the normalized gain (N-gain) formula proposed by Hake (1998): $N\text{-gain} = (\text{posttest score} - \text{pretest score}) / (\text{maximum score} - \text{pretest score})$. N-gain scores were interpreted according to Hake's classification: ≥ 0.70 = high, $0.30\text{--}0.69$ = medium, < 0.30 = low. The primary hypothesis regarding between-group differences in critical thinking skills was tested using an independent samples t-test at a significance level of $\alpha = 0.05$. Practical significance was assessed by computing Cohen's d effect size, interpreted according to conventional thresholds: small ($d \geq 0.20$), medium ($d \geq 0.50$), large ($d \geq 0.80$), and very large ($d \geq 2.00$) (Cohen, 1988). Student response questionnaire data were analyzed using descriptive percentage statistics.

RESULTS

Prior to the intervention, both groups were confirmed to be statistically equivalent in critical thinking skills. Pretest data for both the experimental group ($D = 0.118$, $p = 0.20$) and the control group ($D = 0.121$, $p = 0.19$) were normally distributed (Kolmogorov-Smirnov test, $p > 0.05$). Levene's test confirmed homogeneity of variance between groups ($F = 1.47$, $p =$

0.23). Mean pretest scores were 38.6 (SD = 7.2) for the experimental group and 37.9 (SD = 7.5) for the control group, with no statistically significant difference ($t(66) = 0.41$, $p = 0.68$). These findings confirm that any post-intervention differences in critical thinking skills can be attributed to the instructional treatment rather than pre-existing ability differences.

Table 1. Pretest, Posttest, and N-gain Results for Critical Thinking Skills by Dimension

CT Dimension	Experimental Group		Control Group		N-Gain	
	Pre	Post	Pre	Post	Exp.	Con.
Interpretation	36.8	74.2	35.9	57.8	0.59 (M)	0.28 (L)
Analysis	39.1	79.5	38.4	60.2	0.66 (M)	0.31 (M)
Evaluation	37.4	83.6	36.9	64.1	0.78 (H)	0.38 (M)
Inference	40.2	81.8	39.8	62.4	0.70 (H)	0.37 (M)
Explanation	38.9	80.4	38.2	61.0	0.68 (M)	0.34 (M)
Self-Regulation	39.2	82.1	38.7	63.8	0.71 (H)	0.41 (M)
Overall	38.6	80.3	37.9	61.6	0.72 (H)	0.35 (M)

Note. Pre = pretest mean score; Post = posttest mean score; Exp. = Experimental Group; Con. = Control Group; H = High ($N\text{-gain} \geq 0.70$); M = Medium ($0.30 \leq N\text{-gain} < 0.70$); L = Low ($N\text{-gain} < 0.30$). Classification based on Hake (1998).

Prior to the hypothesis test, normality was confirmed for posttest data in both the experimental group ($D = 0.112$, $p = 0.22$) and the control group ($D = 0.119$, $p = 0.18$), and homogeneity of variance was verified (Levene's test: $F = 1.52$, $p = 0.22$). An independent samples t-test revealed a statistically highly significant difference in overall critical thinking skills between the experimental group ($M = 80.3$, $SD = 7.8$) and the control group ($M = 61.6$, $SD = 8.2$) at posttest, $t(66) = 11.42$, $p < 0.001$ (two-tailed). The computed effect size was Cohen's $d = 2.64$, which falls within the very large effect size category (Cohen, 1988). This finding indicates that the PBL intervention integrated with ethnoscience not only produced a statistically significant but also a practically and educationally meaningful improvement in critical thinking skills. Significant between-group differences were also observed for each individual critical thinking dimension (all $p < 0.001$), with the largest effect for the evaluation dimension ($d = 2.91$).

Analysis of the student response questionnaire revealed an overall positive response rate of 87.6% among experimental group students. The highest positive response rates were observed for the dimensions of learning meaningfulness (93.8%), perceived relevance to daily life (89.7%), learning motivation (91.2%), and active participation in collaborative inquiry (88.4%). The lowest positive response rate was recorded for the dimension of task difficulty management (79.4%), suggesting that some students found the ill-structured PBL tasks cognitively demanding and would benefit from additional scaffolding. Qualitative responses from the open-ended section of the questionnaire frequently referenced students' appreciation

for the integration of terasi production as a learning context, with many students reporting heightened awareness of the scientific dimensions of their cultural heritage.

DISCUSSION

The results of this study provide compelling evidence that integrating PBL with the ethnoscience of Cirebon terasi production produces substantially greater gains in critical thinking skills ($N\text{-gain} = 0.72$; Cohen's $d = 2.64$) than conventional science instruction. These findings align with and extend the existing body of literature. The very large effect size obtained surpasses those reported in previous PBL studies in Indonesian secondary science education (*Wahyuni et al., 2021*) and is consistent with *Abrami et al.'s (2015)* meta-analytic finding that embedded, context-rich instructional approaches produce the strongest critical thinking gains. The exceptional magnitude of the observed effect ($d = 2.64$) may be attributed to the dual cognitive activation produced by the PBL-ethnoscience combination: students were simultaneously engaged in the cognitively demanding processes of scientific inquiry (PBL) and cultural knowledge reconstruction (ethnoscience integration).

The authentic, culturally familiar context of terasi production appears to have functioned as a powerful motivational catalyst, increasing students' cognitive engagement with the problem-solving tasks. This interpretation is supported by the high student response rate (87.6%) and is consistent with *Subramaniam's (2013)* finding that problems embedded in students' cultural lifeworlds elicit deeper cognitive processing because they carry personal and social meaning. From a constructivist perspective (*Hmelo-Silver, 2004*), this cultural anchoring likely facilitated the activation of prior knowledge schemas, thereby enabling more efficient construction of new scientific understanding.

The evaluation dimension exhibited the greatest improvement ($N\text{-gain} = 0.78$), followed by self-regulation ($N\text{-gain} = 0.71$) and inference ($N\text{-gain} = 0.70$). The pronounced gain in evaluation can be explained by the inherent structure of the PBL-ethnoscience task design: students were consistently required to critically assess the quality and reliability of both traditional terasi-making practices and scientific evidence, compare indigenous explanations with Western scientific frameworks, and make defensible judgments about the validity of competing interpretations. This ongoing evaluative activity aligns directly with *Facione's* conceptualization of the evaluation skill as the assessment of the credibility of statements, arguments, and experimental designs (*Facione, 1990*).

The significant improvement in self-regulation ($N\text{-gain} = 0.71$) is consistent with theoretical predictions derived from self-regulated learning theory (*Zimmerman, 2002*). PBL,

by its nature, demands that students plan their inquiry strategies, monitor their understanding, and evaluate the effectiveness of their problem-solving approaches—precisely the metacognitive processes constitutive of self-regulation. The ethnoscience dimension added an additional metacognitive layer: students were prompted to reflect on the epistemological differences and complementarities between traditional and scientific knowledge systems, thereby deepening their self-regulatory awareness (*Schraw et al., 2006*). The inference dimension also showed strong improvement (N-gain = 0.70), likely because the process of connecting observable phenomena in terasi production (e.g., color change, texture alteration, aroma development) to underlying scientific mechanisms (e.g., Maillard reaction, proteolysis) requires systematic inferential reasoning.

The high rate of positive student responses (87.6%), particularly on the learning meaningfulness (93.8%) and daily life relevance (89.7%) dimensions, strongly suggests that the ethnoscience integration effectively addressed a fundamental challenge in science education: the perceived irrelevance of abstract scientific content to students' lived experiences (*Gay, 2018*). When students recognized that the familiar process of terasi production—a practice embedded in the daily life of many Cirebon families—could be scientifically analyzed and explained, they appear to have developed a more personal connection to scientific inquiry. This finding resonates with *Treagust and Duit's (2008)* argument that conceptual change is most readily facilitated when new scientific knowledge is anchored to students' existing experiential frameworks.

The observed effectiveness of terasi as a contextual anchor for PBL also has important implications for the conceptualization of ethnoscience-based science pedagogy more broadly. Unlike many ethnoscience integration studies that use cultural knowledge primarily as a motivational backdrop, the present study embedded terasi production as the core epistemic context through which scientific concepts were both introduced and investigated. This deeper level of integration what might be termed *epistemic ethnoscience integration* may account for the stronger-than-typical effect sizes observed, and warrants further investigation in future research.

The findings of this study carry several significant pedagogical implications. First, science teachers in Cirebon and other coastal regions of Indonesia can leverage the locally available and culturally familiar knowledge of terasi production as an authentic context for developing critical thinking skills through PBL without requiring expensive resources or specialized facilities. Second, the success of this approach provides empirical support for systematic integration of local cultural knowledge into the national science curriculum, an

approach that aligns with UNESCO's recommendations for culturally responsive education in diverse societies (*Aikenhead & Ogawa, 2007*). Third, the PBL-ethnoscience framework developed in this study is readily adaptable to other local wisdom contexts across Indonesia, such as tempeh production (involving fungal fermentation in Central Java), batik-making (involving chemical dyeing processes in Yogyakarta), or traditional salt harvesting (involving evaporation and crystallization in Madura).

The lower positive response rate for task difficulty management (79.4%) indicates that students may require additional instructional scaffolding such as worked examples, process-oriented prompts, or structured inquiry guides particularly in the early stages of PBL implementation. This finding is consistent with *Hung et al.'s (2019)* recommendation that PBL designers provide calibrated scaffolding that progressively fades as students develop greater problem-solving competence and self-regulatory capacity.

Several limitations of this study should be acknowledged. First, the study was conducted at a single school in Cirebon, which constrains the generalizability of findings to other school contexts, student populations, and geographical settings. Future research should replicate this study across multiple schools and regions to establish broader generalizability. Second, the relatively short duration of the intervention (eight sessions over four weeks) limits conclusions regarding the long-term retention of critical thinking gains and the sustained effects of ethnoscience-integrated PBL. Longitudinal studies with follow-up assessments are warranted to examine the durability of learning effects. Third, this study used a quantitative quasi-experimental design; complementary qualitative methods such as think-aloud protocols, semi-structured interviews, or discourse analysis of student discussions would provide richer insights into the cognitive processes through which PBL-ethnoscience integration enhances critical thinking. Fourth, potential moderating variables, including students' prior exposure to terasi production, family socioeconomic background, and learning style preferences, were not examined and may have influenced outcomes. These variables should be included as covariates or moderators in future research.

CONCLUSION

This study demonstrated that the implementation of Problem-Based Learning integrated with the ethnoscience of Cirebon terasi production significantly enhanced the critical thinking skills of seventh-grade junior high school science students, yielding a high normalized gain ($N\text{-gain} = 0.72$) in the experimental group compared to a medium gain ($N\text{-gain} = 0.35$) in the control group, with a statistically significant and practically large between-group difference

($t(66) = 11.42$, $p < 0.001$; Cohen's $d = 2.64$). The evaluation and self-regulation dimensions exhibited the greatest instructional gains, reflecting the inherent epistemic demands of comparing indigenous and scientific knowledge frameworks within the PBL process. Students' strongly positive responses to the ethnoscience-integrated PBL approach (87.6%) indicate high levels of engagement, perceived relevance, and learning motivation.

These findings make a substantive contribution to the literature on culturally responsive science pedagogy, ethnoscience-based learning, and PBL in developing contexts. The study provides robust empirical support for the pedagogical proposition that local cultural knowledge when systematically and epistemically integrated into PBL contexts can serve as a powerful scaffold for developing critical thinking skills in science education. Science educators, curriculum developers, and policymakers are encouraged to incorporate ethnoscience-integrated PBL frameworks into junior high school science education design, with attention to the provision of appropriate scaffolding to support students in managing the cognitive demands of ill-structured problem-solving tasks.

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