

## How Ethnoscience-Integrated Problem-Based Learning Shapes Students' Critical Thinking: A Mixed-Methods Study

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### Article Info

#### Article History

Received: January 2026

Revised: February 2026

Published: March 2026

#### Keywords

Ethnoscience;

Problem-based learning;

Critical thinking;

Mixed methods;

Physics education

 [10.33394/ijete.v3i1.19617](https://doi.org/10.33394/ijete.v3i1.19617)

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### Abstract

The study aimed to examine how ethnoscience-integrated Problem Based Learning (PBL) shapes secondary students' critical thinking in the physics topic of work and energy and to explore the factors that support improvement. The study employed a mixed-methods design with a dominant quantitative phase followed by a qualitative explanatory phase. In the quantitative phase, a quasi-experimental nonequivalent control group pretest posttest design was implemented with an experimental class receiving ethnoscience-integrated PBL and a control class receiving expository instruction. Critical thinking was assessed through a validated test, and qualitative data were collected through observations, student artifacts, and brief reflections to explain learning processes. The experimental class achieved a moderate total n-gain of 0.70, whereas the control class showed a low n-gain of 0.27. ANCOVA results indicated a significant class effect on posttest scores after controlling for pretest,  $F(1, 63) = 293.27$ ,  $p = 0.001$ ,  $\eta_p^2 = 0.823$ . Qualitative findings suggested that culturally grounded problems supported problem interpretation, structured collaboration strengthened justification and analysis, teacher questioning promoted inference and revision, and comparing ethnoscience and scientific explanations fostered evaluative reasoning. The findings imply that ethnoscience-integrated PBL can strengthen critical thinking when local knowledge is used as an epistemic resource for exploration and evidence-based reasoning, supported by facilitation that makes justification and evaluation explicit during learning.

**How to Cite:** Gummah, S., Fitri, M., & Verawati, N. N. S. P. (2026). How Ethnoscience-Integrated Problem-Based Learning Shapes Students' Critical Thinking: A Mixed-Methods Study. *International Journal of Ethnoscience and Technology in Education*, 3(1), 13–36. <https://doi.org/10.33394/ijete.v3i1.19617>

## INTRODUCTION

Education is increasingly evaluated not only by students' mastery of subject content but also by the extent to which schooling develops the cognitive and social capacities needed to face complex challenges. Recent scholarship emphasizes that learning should cultivate cognitive skills alongside social competencies that help learners respond to real-world problems (Salveti et al., 2023; Haryanti, 2017). Within this broader agenda, critical thinking is

consistently positioned as a key competency for the demands of the twenty-first century (Defiyanti & Sumarni, 2020). In Indonesia, this emphasis is reinforced by curriculum expectations that require students to demonstrate critical thinking, making it a practical and measurable indicator of what should be trained and achieved through classroom instruction (Falah & Windyariani, 2018). These policy and curriculum signals imply a clear instructional obligation. If critical thinking is a target competency, then it requires deliberate teaching strategies rather than being treated as an automatic byproduct of content delivery.

Critical thinking is commonly associated with students' capacity to interpret information, analyze relationships, draw warranted inferences, and evaluate claims. It functions as an intellectual resource that enables students to reconsider incoming information in light of prior knowledge, select credible information, and justify decisions about what to accept or reject. For students, these skills are relevant not only for academic achievement but also for future career readiness, where individuals must navigate uncertain information environments and make reasoned judgments. However, critical thinking does not develop instantly, and it is not reliably produced through exposure to content alone. Several recent studies highlight that fostering critical thinking requires didactic mechanisms that explicitly train reasoning processes rather than assuming that thinking skills will transfer automatically from content learning (Aliyu et al., 2023; Bilad, Doyan, et al., 2022; Ekayanti et al., 2022). This point is important because it shifts the focus from whether students receive correct explanations to whether they repeatedly practice the reasoning processes that define critical thinking.

Empirical evidence in science education increasingly indicates that students' critical thinking remains troublingly low, even when curricular goals prioritize higher-order outcomes. Gencer and Doğan (2020) reported that fifth-grade students' science critical thinking skills were substantially lacking, suggesting that many learners engage with scientific material without sustained critical analysis (Gencer & Doğan, 2020). Hidayah et al. (2020) similarly found that, despite attempts to incorporate problem-focused coping strategies, students did not show the expected advancement in critical thinking, indicating broader systemic deficiencies in educational practice (Hidayah et al., 2020). These findings point to a persistent gap between intended learning outcomes and observed competencies, and they support the argument that improving critical thinking requires changes in the structure of learning activities rather than minor adjustments in assessment formats.

Domain-specific studies strengthen this concern by showing that critical thinking is connected to students' disciplinary knowledge and their ability to solve non-routine scientific problems. Abeden and Siew (2022) found a relationship between students' physics knowledge and critical thinking skills, implying that weak critical thinking performance often reflects limited subject understanding and insufficient analytical habits for solving problem-based questions (Abeden & Siew, 2022). Fitriani et al. (2022) argue that the need for learning models that foster critical thinking is urgent because prevailing instructional routines have not adequately prepared students for complex scientific inquiry (Fitriani et al., 2022). Taken

together, these studies suggest that critical thinking development is not simply a matter of adding higher-level questions to conventional lessons. Instead, it requires learning environments in which reasoning is central, visible, and consistently practiced.

Structural characteristics of classroom instruction also help explain why critical thinking development remains limited in many science learning environments. Traditional instructional approaches often emphasize lower-order cognition, including memorization and procedural repetition, which reduces opportunities for students to practice analysis, inference, and evaluation. Thomas and Hayes (2021) argue that many educational frameworks do not effectively cultivate the cognitive skills required for rigorous analytical reasoning (Thomas & Hayes, 2021). At the same time, research indicates that inquiry-based and problem-solving approaches can support higher-order thinking development, although their implementation is inconsistent across educational settings (Sadhu & Laksono, 2018; Dakabesi & Luoise, 2019). This inconsistency matters because the success of innovative models is strongly influenced by how teachers design tasks, scaffold reasoning, and facilitate collaborative learning. Without systematic attention to these implementation factors, students may continue to show low competencies in critical thinking despite curriculum mandates and instructional reform efforts.

In addition to instructional structure, sociocultural relevance has been identified as an important factor in science education quality. A recurring critique is that science learning frequently neglects students' social and cultural environments, contributing to instruction that is disconnected from learners' lived experiences. When students cannot apply science concepts in everyday contexts, learning may remain abstract and fragmented, and instruction may fail to emphasize the principle that conceptual understanding should be linked to daily life (Zidny et al., 2020). This disconnection has consequences for critical thinking because reasoning is strengthened when students analyze authentic situations, compare explanations, and evaluate evidence that is meaningful and observable in their environments. Local wisdom and community values can therefore be used as learning resources that increase meaningfulness and strengthen students' engagement with scientific ideas (Prayogi et al., 2022). In recent Indonesian science education trends, the integration of local wisdom in science learning is commonly conceptualized through ethnoscience (Verawati, Harjono, et al., 2022).

Ethnoscience integration in education refers to the use of local knowledge, cultural practices, and community interpretations of natural phenomena as contexts for learning scientific concepts and practices. Its potential benefit is not limited to increasing interest. The more substantial contribution is epistemic and cognitive. When students examine local explanations and practices, they can be guided to analyze why practices are effective, what assumptions underlie them, and what evidence supports or challenges them. These activities align with key operations of critical thinking, including evaluating claims, identifying assumptions, drawing inferences, and revising conclusions based on evidence. However, ethnoscience integration does not automatically lead to stronger reasoning. If local contexts are presented only as examples without requiring analysis and evaluation, they may enrich

classroom narratives without changing students' thinking practices. For ethnoscience to support critical thinking, it needs to be aligned with a pedagogical model that consistently demands inquiry, problem solving, justification, and reflection.

Critical thinking itself requires students to engage actively in analyzing and solving problems encountered in their surroundings, including problems embedded in learning activities (Bilad, Anwar, et al., 2022). It can be understood as a skill for comparing information received from external sources with existing knowledge, recognizing similarities and differences, and responding by asking for clarification or offering reasoned comments aimed at understanding and justification. As a cognitive resource, critical thinking is often described as an essential form of intellectual capital for learners and citizens (Indrašienė et al., 2021). Yet because critical thinking does not emerge instantly, it requires appropriate stimulation and pedagogical intervention that directs students toward sustained analytical reasoning. In science education, such intervention is ideally oriented toward learning processes that allow students to explore authentic contexts, interpret evidence, construct explanations, and evaluate conclusions.

Problem-Based Learning is frequently proposed as a model that can meet these requirements because it positions students as active problem solvers in meaningful contexts. It is often characterized as an active, student-centered approach that enables learners to participate directly in learning processes through engagement with problems that require investigation and resolution (Gultom & Adam, 2018). Prior studies suggest that PBL can increase students' activity levels in classrooms by encouraging them to search for information independently and to learn collaboratively, making learning more meaningful and cognitively demanding (Sari et al., 2019). Nofziarni et al. (2019) describe PBL as learning based on practical problems with real-world contexts designed to develop thinking, problem solving, and students' intellectual abilities. This alignment with the processes of interpretation, analysis, inference, and evaluation provides a theoretical rationale for expecting improvements in critical thinking through PBL.

However, it is important to avoid overstating the automatic effectiveness of PBL. Its impact depends on the design of problems, the quality of facilitation, the structure of group discussion, and the extent to which students are required to justify claims and evaluate evidence. This is where ethnoscience integration may strengthen PBL by providing contexts that are both meaningful and rich in observable phenomena. When PBL problems are grounded in local practices and culturally familiar situations, students may find them more accessible and worth investigating, increasing persistence and depth of inquiry. More importantly, ethnoscience contexts can make assumptions and evidence more visible because students can draw on observations and community experiences while also being guided to evaluate explanations using scientific reasoning. Within Indonesian science education research, ethnoscience-integrated PBL is frequently positioned as a dynamic pedagogical approach to train how students think, particularly in developing critical thinking skills, and prior studies have suggested that PBL is promising for critical thinking development (Fitriani

et al., 2022; Suhirman & Prayogi, 2023; Suhirman & Ghazali, 2022). The key issue is whether these anticipated benefits are realized in actual classroom implementation and what features of instruction explain observed learning gains.

Mixed-methods research is particularly suitable for addressing this issue because critical thinking development is both measurable and process-dependent. Quantitative approaches can identify patterns of change across time and differences across instructional conditions, including which indicators of critical thinking improve most. Yet quantitative gains alone cannot explain mechanisms. Qualitative evidence can provide insight into how classroom interactions, task design, teacher scaffolding, and the integration of local knowledge contribute to students' reasoning development. This integration of quantitative and qualitative evidence is also valuable because ethnoscience involves epistemic dynamics that are difficult to capture with test scores alone. Students may accept local knowledge uncritically, reject it without understanding, or engage in reflective evaluation that respects cultural knowledge while applying criteria for evidence and justification. The educational value lies in reflective evaluation, and qualitative analysis can clarify how learning environments support or constrain this form of reasoning.

This study is situated in a secondary school context in Mataram - Indonesia, where an ethnoscience-integrated PBL model was implemented and compared with conventional instruction. The context reflects realistic classroom constraints, including intact classes and curriculum expectations that emphasize critical thinking (Falah & Windyariani, 2018). Rather than treating critical thinking as a single outcome, the study considers critical thinking through indicator-based competencies, including interpretation, analysis, inference, and evaluation. This is important because different indicators may respond differently to instructional interventions, and identifying these patterns can support more precise instructional design. At the same time, given ongoing evidence of low critical thinking outcomes in science education (Gencer & Doğan, 2020; Hidayah et al., 2020) and the need for explicit didactic mechanisms to train reasoning (Aliyu et al., 2023; Bilad, Doyan, et al., 2022; Ekayanti et al., 2022), classroom research that integrates outcome evidence with process explanation can contribute to both pedagogical knowledge and practical teaching improvement.

Critical thinking remains a central yet difficult outcome in science education, as many students still show limited ability to interpret information, analyze evidence, draw justified inferences, and evaluate claims. This problem is strengthened when instruction is dominated by lower-order activities and when science learning is disconnected from students' sociocultural contexts (Thomas & Hayes, 2021). In response, this study addresses the need for learning designs that are both cognitively demanding and culturally meaningful. The study aims to explore the effect of an ethnoscience-integrated Problem Based Learning model on students' critical thinking skills and to examine the instructional and contextual factors that enhance critical thinking during its implementation.

## Objectives and Research Questions

Critical thinking remains a central yet challenging outcome in science education, as many students still show limited ability to interpret information, analyze evidence, draw justified inferences, and evaluate claims. This issue becomes more persistent when instruction relies on lower-order activities and when science learning is weakly connected to students' sociocultural contexts. In response, this study addresses the need for learning designs that are both cognitively demanding and culturally meaningful. The study has two objectives: (a) to explore the effect of an ethnoscience-integrated Problem-Based Learning model on students' critical thinking skills, and (b) to explore the factors that enhance students' critical thinking skills within the implementation of ethnoscience-integrated Problem-Based Learning. Based on these objectives, the research questions are as follows:

- (1) To what extent does ethnoscience-integrated Problem-Based Learning influence students' critical thinking skills?
- (2) What instructional and contextual factors contribute to the improvement of students' critical thinking skills in ethnoscience-integrated Problem-Based Learning?

## METHODS

### Design

This study used a mixed-methods approach with a dominant quantitative component supported by qualitative inquiry to explain the learning processes behind observed outcomes. The quantitative strand adopted a quasi-experimental nonequivalent control group design, in which two intact classes served as an experimental group and a control group. The design followed the structure shown in Table 1, where  $O_1$  represents the pretest and  $O_2$  represents the posttest.

Table 1. Research design

Group	Pretest	Treatment	Posttest
Experimental	$O_1$	X	$O_2$
Control	$O_1$	Y	$O_2$

The experimental class received ethnoscience-integrated Problem Based Learning (PBL) as the treatment X, while the control class received conventional expository instruction as the treatment Y. Because classes were not randomly assigned, the groups were considered nonequivalent. The qualitative strand was designed to explore factors that enhanced critical thinking during implementation of ethnoscience-integrated PBL, supporting the second objective of the study by examining classroom processes and student learning experiences.

### Participants

The study was conducted in a secondary school in Mataram, Indonesia. The sample comprised 66 students distributed across two classes, consisting of 31 students in the experimental class and 35 students in the control class. Classes were selected using purposive sampling, a non-probability technique in which participants are chosen based on

predetermined considerations relevant to the research purpose and known characteristics of the population. In this case, the two classes were selected within the constraints of the school schedule and instructional organization, then assigned as experimental and control groups at the class level. Demographic variables such as age and gender were not included in the analysis because they were not specified as study variables and were not treated as explanatory factors in the research objectives.

### **Procedure**

The study proceeded through three phases. First, both groups completed a pretest to measure baseline critical thinking. The pretest was administered before instruction under standardized classroom testing conditions using the same instructions and time allocation across groups. Second, both classes learned the same physics topic, work and energy, but received different learning treatments. The experimental class received ethnoscience-integrated Problem Based Learning. Instruction began with contextual problems connected to local practices and community-relevant phenomena to link scientific concepts of work and energy with students' sociocultural environment. Students worked in groups to interpret the problem situation, identify what they needed to learn, collect and evaluate relevant information, construct explanations or solutions, and justify reasoning through discussion and reporting. The teacher facilitated inquiry by scaffolding questions, guiding evidence use, and supporting argument-based discussion rather than providing direct solutions.

In contrast, the control class received conventional expository instruction emphasizing teacher explanation, guided examples, and routine exercises consistent with typical classroom practice. The duration of instruction and content coverage were aligned across groups to reduce differences in learning exposure. Third, after the instructional period, both groups took the posttest using the same assessment framework as the pretest.

Qualitative data collection occurred primarily during the intervention phase and focused on the experimental class to document factors that shaped the development of critical thinking under ethnoscience-integrated PBL. Data sources included observation notes and student learning artifacts, and where feasible, brief student reflections were used to capture students' perceptions of learning experiences that supported their reasoning.

### **Instruments**

Students' critical thinking skills were assessed using a validated critical thinking test administered as both pretest and posttest. The instrument included indicators aligned with key operations of critical thinking, including analysis, inference, evaluation, and decision making. Scoring procedures were adapted from the Ennis Weir Critical Thinking Essay Test using a modified scoring scale (Prayogi et al., 2018). The scoring categories ranged from not critical to very critical, enabling interpretation of students' critical thinking levels as well as changes across pretest and posttest.

For the qualitative strand, data were gathered from classroom observations and student artifacts such as worksheets and group reports to capture evidence of reasoning practices, including how students justified claims, selected evidence, and revised explanations during

problem solving. Brief reflective responses were also collected to provide insight into what students perceived as helpful for improving their critical thinking during the intervention.

### **Data Analysis**

Quantitative analysis was conducted in SPSS 23.0 with a significance level of 0.05. Descriptive statistics were calculated for pretest and posttest scores in both groups, including minimum, maximum, mean, and standard deviation. Improvement from pretest to posttest was examined using gain analysis. Normalized gain scores were computed using the formulation proposed by Hake (1999) to describe improvement relative to baseline performance and to categorize levels of improvement.

Inferential analysis was preceded by prerequisite tests of normality and homogeneity. Within-group differences between pretest and posttest were tested using paired-samples t-tests. To evaluate the effect of ethnoscience-integrated PBL compared with conventional instruction while controlling for initial differences, an ANCOVA was conducted with posttest score as the dependent variable, pretest score as the covariate, and class condition as the fixed factor. The hypothesis framework was defined as  $H_a$  indicating a significant instructional effect and  $H_o$  indicating no significant effect.

Qualitative data were analyzed thematically. Observation notes, artifacts, and reflective data were coded to identify patterns related to critical thinking development and the instructional factors that supported it, such as the authenticity and cultural relevance of problems, the structure of collaborative discussion, teacher scaffolding strategies, and the use of evidence in explanation and decision making. Codes were organized into broader themes representing factors that enhanced or constrained critical thinking. Integration of quantitative and qualitative findings was conducted by linking qualitative themes to quantitative patterns of critical thinking improvement to explain how ethnoscience-integrated PBL shaped students' reasoning.

### **Ethical Consideration**

Permission to conduct the study was obtained from the school. Students participated in curriculum-aligned learning activities on work and energy, and assessment procedures were designed to minimize disruption to routine instruction. Students were informed that learning data would be used for research purposes and that participation would not affect official grades. Data were anonymized using codes rather than student names, and results were reported in aggregate to reduce the risk of individual identification. Access to raw data was restricted to the research team to ensure confidentiality and responsible data handling.

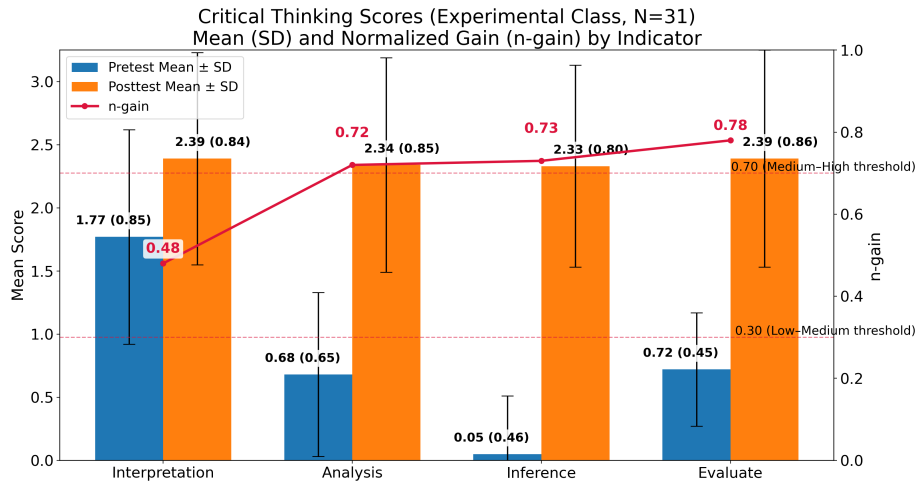
## **RESULTS AND DISCUSSION**

### **Results**

This study examined the influence of ethnoscience integrated Problem Based Learning on students critical thinking skills using a nonequivalent control group pretest posttest design. Quantitative findings are reported through indicator level descriptive statistics for each

group, total score summaries, assumption testing, within group significance testing, and an ANCOVA model to compare groups while controlling for baseline differences.

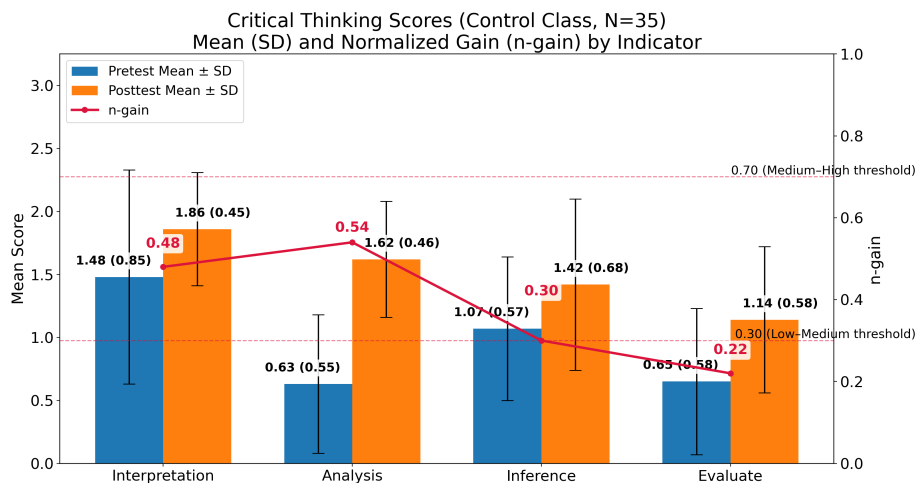
Figure 1 summarize the experimental class performance across interpretation, analysis, inference, and evaluation.



**Figure 1.** Visualization of the descriptive analysis of the experimental class critical thinking skills based on indicator mean scores and normalized gain (n-gain)

The experimental class showed increased mean scores from pretest to posttest on all indicators. Interpretation increased from  $1.77 \pm 0.85$  to  $2.39 \pm 0.84$  with a medium n gain of 0.48. Analysis increased from  $0.68 \pm 0.65$  to  $2.34 \pm 0.85$  with a high n gain of 0.72. Inference increased from  $0.05 \pm 0.46$  to  $2.33 \pm 0.80$  with a high n gain of 0.73. Evaluation increased from  $0.72 \pm 0.45$  to  $2.39 \pm 0.86$  with a high n gain of 0.78. These patterns indicate broad improvement across indicators, with the strongest gains appearing in analysis, inference, and evaluation.

Furthermore, the descriptive analysis results for the control class, based on the mean critical thinking scores and n-gain for each indicator, are presented in Figure 2.



**Figure 2.** Visualization of the descriptive analysis of the control class critical thinking skills based on indicator mean scores and normalized gain (n-gain)

Figure 2 report the same indicator level summaries for the control class. The control class also improved from pretest to posttest on all indicators, but gains were generally smaller. Interpretation increased from  $1.48 \pm 0.85$  to  $1.86 \pm 0.45$  with a medium n gain of 0.48. Analysis increased from  $0.63 \pm 0.55$  to  $1.62 \pm 0.46$  with a medium n gain of 0.54. Inference increased from  $1.07 \pm 0.57$  to  $1.42 \pm 0.68$  with a medium n gain of 0.30. Evaluation increased from  $0.65 \pm 0.58$  to  $1.14 \pm 0.58$  with a low n gain of 0.22. The lowest improvement in the control class occurred for evaluation, suggesting that expository instruction was less supportive of evaluative reasoning.

Furthermore, the descriptive analysis results based on the mean total critical thinking scores at the class level for the experimental and control groups are presented in Figure 3.

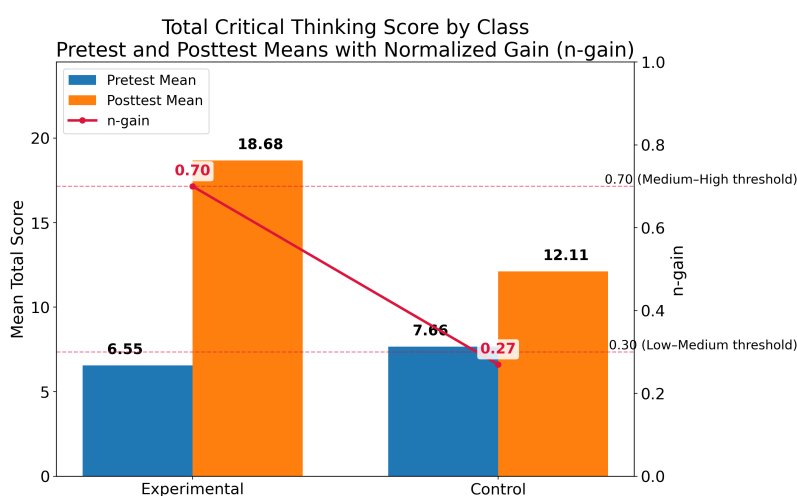


Figure 3. Visualization of the descriptive analysis results based on the mean total critical thinking scores at the class level for the experimental and control groups

Figure 3 summarize total critical thinking scores. The experimental class increased from a pretest mean of 6.55 to a posttest mean of 18.68, with an n gain of 0.70 categorized as moderate. The control class increased from a pretest mean of 7.66 to a posttest mean of 12.11, with an n gain of 0.27 categorized as low. These totals indicate that both groups improved, while the experimental class improved substantially more.

Differences in students’ critical thinking scores between the two classes were examined statistically, preceded by normality and homogeneity tests. The results of the normality and homogeneity tests are presented in Table 2.

Table 2. The results of normality and homogeneity tests

Class	Score	N	Normality			Homogeneity	
			Mean	SD	Sig.	Levine test	Sig.
Experimental	Pre-test	31	6.65	2.027	0.217	8.196	0.06
	Post-test	31	18.68				
Control	Pre-test	35	7.66	1.272	0.311		
	Post-test	35	12.11				

Table 2 reports that pretest scores were normally distributed in both groups, with Sig. 0.217 for the experimental class and 0.311 for the control class. Homogeneity testing using Levene statistics yielded Sig. 0.06, which supports the homogeneity assumption at the 0.05 level. Furthermore, paired-samples t-tests were conducted within each class. The results are presented in Table 3.

**Table 3.** Paired samples t test results within each class

Pair	Group	N	Mean Difference	SD	t	df	p
Pair 1	Experimental, Pretest vs Posttest	31	-12.129	2.125	-31.778	30	0.000
Pair 2	Control, Pretest vs Posttest	35	-4.343	1.679	-15.299	33	0.000

For the experimental class, the mean difference between pretest and posttest is reported as -12.129 with SD 2.125 and  $t(30) = -31.778$ ,  $p = 0.000$ . Using the common SPSS convention where the difference is computed as pretest minus posttest, the negative mean difference indicates that posttest scores were higher than pretest scores by about 12.129 points on average. For the control class, the mean difference is -4.343 with SD 1.679 and  $t(33) = -15.299$ ,  $p = 0.000$ , indicating posttest scores were higher than pretest scores by about 4.343 points on average. These results show statistically significant improvement in both groups, with a larger average improvement in the experimental group.

Paired-samples t-tests confirm that each group improved significantly from pretest to posttest, but these tests do not directly determine whether the experimental class outperformed the control class after controlling for baseline differences. To address the primary between-group inference aligned with the first objective of the study, an ANCOVA was conducted with posttest scores as the dependent variable, pretest scores as the covariate, and class as the fixed factor. This analysis allows comparison of posttest performance between groups while statistically adjusting for initial pretest differences, thereby providing a more appropriate test of the instructional effect than within-group comparisons alone.

**Table 4.** The results of ANCOVA

Source	Type III SS	df	MS	F	p	$\eta_p^2$
Covariate	20.23	1	20.23	8.33	0.005	0.117
Fixed factor	711.79	1	711.79	293.27	0.001	0.823
Error	152.90	63	2.43			

Table 4 provides the key inferential evidence for the first objective of the study, which was to examine the effect of ethnoscience-integrated PBL on students' critical thinking skills. The ANCOVA results show that pretest scores significantly predicted posttest performance,  $F(1, 63) = 8.33$ ,  $p = 0.005$ , partial eta squared = 0.117, indicating that baseline critical thinking contributed meaningfully to students' final scores. More importantly for the study purpose, after controlling for pretest differences, the class factor remained significant,  $F(1, 63) = 293.27$ ,  $p = 0.001$ , partial eta squared = 0.823, indicating a substantial difference in adjusted posttest critical thinking outcomes between the experimental and control groups. This result supports

the conclusion that the ethnoscience-integrated PBL condition was associated with stronger critical thinking performance than expository instruction when baseline performance was held constant.

Qualitative findings were drawn from classroom observations during ethnoscience integrated Problem Based Learning sessions, student learning artifacts such as worksheets and group reports, and brief student reflective responses collected during or immediately after the intervention. The analysis focused on identifying instructional and contextual factors that enhanced students critical thinking, consistent with the second study objective. The results are organized into themes that describe how ethnoscience integrated PBL supported interpretation, analysis, inference, evaluation, and decision making in the topic of work and energy.

*Theme 1. Contextual problems grounded in local practices supported problem interpretation and relevance*

Observation notes indicated that lessons began with problems derived from local practices and community relevant phenomena, which helped students interpret problem situations and clarify what was being asked. In early sessions, students were more willing to restate problem conditions in their own words and to identify known and unknown information when the problem referenced familiar settings. Student worksheets showed that groups frequently described the context before attempting solution steps, suggesting that contextual familiarity supported initial problem framing. Reflections also indicated that students perceived these contexts as easier to understand and more meaningful than abstract textbook problems, which appeared to reduce hesitation at the start of inquiry and encouraged students to engage with the task requirements.

*Theme 2. Structured collaborative inquiry increased analytical reasoning through information seeking and justification*

Across observed sessions, group work was not limited to dividing tasks but involved discussion about what information was needed and how it should be used. Students commonly generated lists of learning issues, searched for relevant concepts related to work and energy, and compared alternative explanations. Artifacts showed progression from short answers to more elaborated reasoning, including identification of variables, comparison of energy forms, and interpretation of relationships between force, displacement, and work. In many groups, analysis improved when students were prompted to explain why a certain principle applied, rather than only calculating numerical results. This pattern suggests that collaborative inquiry, when structured around evidence and justification, contributed to analytical development.

*Theme 3. Teacher scaffolding through questioning supported inference making and explanation building*

Observation notes consistently recorded the teacher using probing questions to prompt students to move beyond recall and toward inference, such as asking students to predict outcomes, explain causal mechanisms, or connect observed phenomena to scientific

principles. This facilitative role helped students construct explanations by linking evidence from the problem context to concepts of work and energy. In student reports, inferences were often expressed as conditional statements that connected changes in conditions to expected changes in outcomes, indicating that students were learning to reason from premises to conclusions. Students also appeared more able to revise their initial claims when teachers asked for reasons and evidence rather than confirming answers immediately.

*Theme 4. Comparing ethnoscience explanations with scientific concepts strengthened evaluation of claims*

A recurring classroom pattern involved students discussing local explanations of phenomena and then examining how those explanations aligned or conflicted with scientific ideas. In these moments, evaluation became visible as students judged which explanation was more consistent with evidence or with the constraints of scientific concepts. Artifacts showed that some groups explicitly stated reasons for accepting or rejecting an explanation, for example by referencing observable effects or principles learned during inquiry. Reflective responses suggested that students became more cautious about accepting explanations without reasons, especially when they were encouraged to articulate why an explanation should be considered valid. This theme indicates that ethnoscience integration created opportunities for evaluative reasoning that were tied to real claims rather than abstract statements.

*Theme 5. Decision making improved when students used explicit criteria for selecting solutions*

The instrument included decision making as part of critical thinking, and qualitative evidence showed that decision making occurred when students selected a final solution among alternatives. In several observed discussions, groups initially proposed multiple approaches and then converged on one after debating assumptions or comparing evidence. Worksheets indicated that decisions were more defensible when groups used explicit criteria, such as consistency with physical laws, fit with available information, and plausibility in the local context. When these criteria were absent, groups tended to choose solutions based on convenience or dominant voices. This suggests that decision quality depended on whether the learning process made evaluation criteria explicit.

*Theme 6. Constraints that limited critical thinking development*

Although the intervention supported multiple aspects of critical thinking, qualitative data also identified constraints. First, some groups experienced uneven participation, where one or two students dominated reasoning while others followed procedurally. Second, time constraints sometimes led groups to focus on producing an answer rather than evaluating alternative explanations. Third, students occasionally treated ethnoscience content as narrative information rather than as a claim to be examined, which reduced opportunities for critical evaluation unless the teacher explicitly prompted comparison and justification. These constraints help explain why critical thinking growth may vary across indicators and why evaluation and decision making require consistent scaffolding.

To clarify how themes relate to the second objective, Table 5 summarizes the qualitative factors that enhanced critical thinking and the associated critical thinking processes observed in classroom activity and artifacts.

**Table 5.** Summary of qualitative themes and their contribution to critical thinking

<b>Theme</b>	<b>Key qualitative evidence sources</b>	<b>Contribution to critical thinking processes</b>
1. Contextual problems grounded in local practices	• Observations, worksheets, reflections	• Supported interpretation, problem framing, and relevance
2. Collaborative inquiry and information seeking	• Observations, group reports	• Strengthened analysis through justification and variable reasoning
3. Teacher scaffolding through probing questions	• Observations, artifacts	• Supported inference making, explanation building, and revision
4. Comparison of ethnoscience and scientific explanations	• Observations, reports, reflections	• Strengthened evaluation of claims and evidence based judgment
5. Explicit criteria for selecting solutions	• Worksheets, reports	• Improved decision making and defensible conclusions
6. Constraints in participation and time	• Observations, reflections	• Limited depth of evaluation and consistency of critical engagement

Overall, qualitative findings indicate that ethnoscience integrated PBL supported critical thinking by making problems meaningful, structuring collaborative inquiry around justification, and using teacher questioning to promote inference and evaluation. At the same time, the findings show that critical thinking development was sensitive to group participation patterns, time allocation, and the extent to which evaluation criteria were made explicit during problem solving.

## **Discussion**

This mixed-methods study examined the influence of ethnoscience-integrated Problem Based Learning on students' critical thinking and explored the instructional and contextual factors that enhanced critical thinking during implementation. Quantitative results indicate that the experimental group achieved substantially higher posttest critical thinking performance than the control group after controlling for baseline differences, while qualitative results clarify the mechanisms through which ethnoscience-integrated PBL shaped students' reasoning. When considered together, the findings suggest that ethnoscience integration can strengthen PBL not merely by increasing student interest, but by creating culturally meaningful contexts that invite justification, comparison of explanations, and criteria-based evaluation.

The quantitative findings speak directly to the first objective and the first research question concerning the extent to which ethnoscience-integrated PBL influences students' critical thinking. At the indicator level, the experimental class improved across interpretation, analysis, inference, and evaluation, with the strongest normalized gains appearing in analysis,

inference, and evaluation. Interpretation improved at a medium level, while the other indicators improved at a high level. This pattern is consistent with how the instructional model was enacted. Interpretation involves framing a problem, recognizing relevant information, and clarifying task demands, which can improve with exposure and practice even in conventional instruction. In contrast, analysis, inference, and evaluation require students to articulate relationships, generate and justify conclusions, and judge claims using evidence and criteria. These cognitive operations are less likely to emerge through expository teaching, which often emphasizes teacher explanation and routine exercise completion. The control class, although improving over time, showed smaller gains, especially for evaluation, which remained the weakest indicator. This aligns with the idea that traditional instruction tends to provide fewer opportunities for students to evaluate competing claims, revise explanations, or defend decisions with explicit criteria.

The class-level results further reinforce this interpretation. The experimental class achieved a moderate total normalized gain, while the control class showed a low gain. Importantly, the ANCOVA results provide the strongest test of the instructional effect in a nonequivalent design. Pretest scores significantly predicted posttest performance, confirming that baseline differences matter. Yet, after adjusting for pretest, the class factor remained statistically significant with a very large effect size. This finding supports the claim that the ethnoscience-integrated PBL condition was associated with superior critical thinking outcomes compared with conventional instruction. In the context of the wider literature, this result is aligned with research emphasizing that critical thinking does not develop automatically and requires instructional mechanisms that repeatedly engage students in reasoning and evaluation (Aliyu et al., 2023; Bilad, Doyan, et al., 2022; Ekayanti et al., 2022). It is also consistent with empirical evidence showing critical thinking levels remain low in science education under conventional approaches (Gencer & Doğan, 2020; Hidayah et al., 2020), suggesting that stronger learning gains require more cognitively demanding designs.

The qualitative findings help explain why the experimental class achieved stronger gains by identifying classroom processes that plausibly produced improvements in critical thinking. The first theme, contextual problems grounded in local practices, supports a key argument in the ethnoscience literature. Ethnoscience connects scientific concepts to local cultural knowledge, and the relatability of local contexts can facilitate deeper understanding and more active participation, enabling students to engage more critically with learning content (Hidayanti & Wulandari, 2023). In this study, observation notes and student artifacts showed that students were more willing to restate the problem in their own words, identify known and unknown information, and begin inquiry when the problem scenario reflected familiar community contexts. This matters because problem interpretation is the gateway to higher-order reasoning. If students can frame the problem meaningfully, they are more likely to proceed to analyzing variables, generating explanations, and evaluating claims. The findings also align with the argument that science education becomes less effective when it is detached from students' sociocultural environments, limiting meaningful application of

concepts (Zidny et al., 2020). Ethnoscience-based contexts appear to reduce that detachment and support more sustained engagement, which is a plausible precursor to critical thinking development.

The second theme, structured collaborative inquiry and information seeking, offers an explanation for the strong gains in analysis. Students in the experimental class did not merely split tasks but discussed what information was needed, compared alternative explanations, and produced more elaborated reasoning in worksheets and reports. This is consistent with prior work describing PBL as a student-centered approach that increases student participation and encourages independent and collaborative learning (Gultom & Adam, 2018; Sari et al., 2019). However, the present qualitative evidence suggests that collaboration supports critical thinking only when it is structured around justification and reasoning rather than around answer production. This interpretation fits with research showing that ethnoscience-based learning can shift students from rote memorization toward deeper analytical thought (Wibowo, 2022). When students must explain why a scientific principle applies to a culturally grounded problem, they cannot rely solely on memorized formulas. Instead, they must analyze conditions, interpret relationships among variables, and link evidence to claims.

The third theme, teacher scaffolding through questioning, helps explain improvements in inference. The teacher's facilitation encouraged students to predict outcomes, explain causal mechanisms, and connect observed phenomena to scientific concepts of work and energy. This supports the view that PBL is not automatically effective without instructional guidance and didactic structure. Recent scholarship emphasizes that critical thinking requires targeted mechanisms that train reasoning processes (Aliyu et al., 2023; Bilad, Doyan, et al., 2022; Ekayanti et al., 2022). In this study, teacher questioning appeared to function as a cognitive scaffold that prompted students to move from recalling information to drawing inferences and building explanations. The result is consistent with the claim that ethnoscience integration supports students not only in solving problems but also in developing critical thinking capacities when problem solving is paired with reasoning demands (Wahyuningtyas et al., 2023). Moreover, research on ethnoscience-based PBL suggests that cultural-context problem solving can meet students' cognitive needs and encourage practice of thinking skills through inquiry (Haulia et al., 2022), which fits the observation that inference making became more visible when students were required to justify conclusions with evidence from the problem context.

The fourth theme, comparing ethnoscience explanations with scientific concepts, provides a plausible mechanism for the high gains in evaluation. Evaluation requires students to judge the quality of claims and evidence and to apply criteria. Ethnoscience integration can provide multiple plausible explanations, including culturally grounded interpretations and scientific accounts, creating a natural need for comparison and judgment. This is consistent with findings that ethnoscience enhances contextual understanding and supports more engaged and analytical learning processes (Suciayati et al., 2021). In this study, evaluation was visible when students examined whether a local explanation aligned with scientific

constraints and observable evidence. This is also aligned with the argument that reflection on cultural values during learning can enhance critical thinking while strengthening scientific literacy and appreciation for local knowledge (Prayogi et al., 2023). Importantly, this theme illustrates that ethnoscience is not simply a motivational add-on. Its instructional value emerges when local knowledge is treated as a set of claims that can be examined through evidence-based reasoning, prompting students to justify acceptance, revision, or rejection of explanations.

The fifth theme, decision making through explicit criteria, further clarifies how the model supported higher-order thinking beyond solving problems. Decision making becomes cognitively meaningful when students use explicit criteria, such as consistency with scientific laws, adequacy of evidence, and plausibility within the context. This finding resonates with research showing that ethnoscience-integrated learning can foster cognitive shifts toward critical thinking when students are actively involved in relevant problem-solving scenarios (Kusuma & Sumarni, 2025). In practical terms, this suggests that ethnoscience-integrated PBL should be supported by curriculum materials and learning tools that make reasoning criteria explicit. The development of ethnoscience-based worksheets, for instance, has been shown to facilitate critical thinking by structuring students' engagement with culturally relevant problems and requiring justification rather than recall (Kusuma & Sumarni, 2025). This also aligns with the idea that contextual relevance supports engagement and, when combined with structured reasoning tasks, can foster deeper critical thinking (Hidayanti & Wulandari, 2023).

Beyond explaining mechanisms, the findings also align with a broader pattern of evidence supporting ethnoscience-integrated models for critical thinking improvement. Empirical studies report statistically significant enhancements in critical thinking for students engaging in ethnoscience-based PBL compared to traditional learning methods (Gummah et al., 2023). Similar positive effects have been reported for ethnoscience-based project-oriented models that encourage critical thinking through contextualized inquiry (Rahman et al., 2023). At the level of synthesis evidence, a meta-analysis has supported the effectiveness of ethnoscience-based educational models in enhancing students' critical thinking (Idul & Fajardo, 2023). The current study contributes to this body of evidence by showing not only that gains occurred, but also by providing qualitative explanations for how gains were produced in classroom activity, especially through scaffolding, collaborative justification, and evaluative comparison of explanations.

At the same time, the constraints identified in the qualitative results temper overly simple interpretations of effectiveness. Uneven participation patterns, limited time, and occasional treatment of ethnoscience as narrative rather than examinable claims reduced opportunities for evaluation and deeper reasoning. These constraints indicate that ethnoscience-integrated PBL is sensitive to implementation quality. Students may still prioritize answer completion over evaluation, particularly when classroom time is limited. Group dynamics can also restrict the distribution of reasoning opportunities, allowing a small number of students to dominate discussion. These constraints reinforce a critical point:

ethnoscience integration does not automatically produce critical thinking. Its impact depends on whether teachers and curriculum materials create sustained opportunities for evidence-based argumentation, criteria articulation, and reflective evaluation.

Methodologically, the nonequivalent control group design reflects authentic classroom constraints but introduces limits to causal inference. ANCOVA improves the validity of between-group comparisons by controlling baseline differences, yet it cannot account for all unmeasured differences between classes. The focus on one school and one topic, work and energy, limits generalizability. Replication across topics and schools would strengthen claims about broader applicability. The qualitative findings were derived primarily from the experimental class, which supports explanatory depth about the intervention but does not offer direct process comparison with the control class. Future work could strengthen inference by collecting parallel observational and artifact data in both classes to determine which discourse and reasoning patterns are distinctive to ethnoscience-integrated PBL.

Despite these limitations, the findings yield clear implications for practice. First, ethnoscience should be integrated as an epistemic resource, where local knowledge is examined through scientific reasoning rather than presented as contextual background. Second, PBL effectiveness depends on facilitation strategies that prompt students to justify claims, explain mechanisms, and revise reasoning based on evidence. Third, collaborative learning should be structured to promote equitable participation and explicit reasoning criteria, which can be supported through well-designed worksheets and reporting formats that require justification and evaluation (Kusuma & Sumarni, 2025). Finally, reflection on cultural values and community practices should be included as a deliberate learning step, as such reflection has been linked to improvements in critical thinking and scientific literacy while also strengthening appreciation for local knowledge (Prayogi et al., 2023).

In summary, the quantitative findings support the conclusion that ethnoscience-integrated PBL is associated with stronger critical thinking outcomes than expository instruction when baseline differences are controlled, fulfilling the first objective of the study. The qualitative findings explain that improvement occurred through culturally grounded problem interpretation, structured collaborative inquiry, teacher scaffolding that promoted inference, and evaluative comparison of explanations supported by explicit criteria, fulfilling the second objective. These results strengthen the argument that culturally meaningful problem contexts, when paired with inquiry structures and evaluative norms, can provide a robust pathway for improving critical thinking in science education.

## **CONCLUSION**

This mixed-methods study examined how ethnoscience-integrated Problem Based Learning influenced secondary school students' critical thinking in the physics topic of work and energy, while also identifying the instructional and contextual factors that supported improvement. The quantitative results indicate that students in the experimental class demonstrated stronger gains than those in the control class across critical thinking indicators and in total scores. After controlling for baseline differences through ANCOVA, the class

effect remained statistically significant, supporting the conclusion that ethnoscience-integrated PBL was associated with higher adjusted posttest performance compared with expository instruction.

The qualitative findings clarify why the experimental class improved more. Culturally grounded problems helped students interpret tasks and frame problems more meaningfully, while structured collaborative inquiry encouraged students to search for information, justify reasoning, and refine explanations. Teacher scaffolding through probing questions supported inference making and explanation building, and the comparison of ethnoscience explanations with scientific concepts strengthened evaluative reasoning and criteria-based decision making. At the same time, the findings show that the model's effectiveness depended on implementation quality, including equitable participation in groups, sufficient time for evaluation, and the consistent treatment of ethnoscience content as claims to be examined rather than as narrative information.

These conclusions imply that ethnoscience-integrated PBL can be a promising approach for strengthening critical thinking when local knowledge is positioned as an epistemic resource for inquiry and evaluation, and when facilitation ensures that justification and criteria-based judgment are explicit classroom norms. Future research should replicate the intervention across topics, include parallel qualitative process data from both experimental and control classes, and examine how variations in scaffolding and group structures influence particular critical thinking indicators, especially evaluation and decision making.

## **LIMITATIONS**

This mixed-methods study used a quasi-experimental nonequivalent control group design with purposive sampling in one secondary school and one physics topic, work and energy, so the findings should not be generalized without caution to other schools, grades, or content areas. Because intact classes were compared, unmeasured class-level differences such as teacher routines, peer dynamics, or prior exposure to student-centered learning may still influence outcomes even though ANCOVA adjusted for baseline pretest scores. The qualitative strand primarily documented the experimental class to explain how ethnoscience-integrated PBL worked in practice, but it did not provide parallel process evidence from the control class, which limits direct comparison of classroom mechanisms across conditions. In addition, the study relied on pretest and posttest measures within a single intervention window, so it cannot determine whether the critical thinking gains persist over time or transfer to other scientific topics and problem contexts.

## **RECOMMENDATIONS**

Future research should replicate the intervention across multiple schools, teachers, and science topics to test robustness and improve external validity, while also adding delayed posttests to examine retention and transfer of critical thinking. To strengthen causal claims in quasi-experimental settings, researchers can include additional covariates that plausibly affect outcomes, such as prior achievement or learning motivation, and document fidelity of

implementation to clarify which components of ethnoscience integration and PBL drive effects. Qualitative data should be collected in both experimental and control classes using the same observation protocols and artifact analysis so that differences in discourse, scaffolding, and student participation can be compared directly. For practice, teachers implementing ethnoscience-integrated PBL should be supported with structured lesson plans and worksheets that require justification and evaluation, and with facilitation strategies that reduce unequal participation in groups and protect time for deeper evaluation rather than answer completion.

#### **Author Contributions**

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

#### **Funding**

This research received no external funding.

#### **Acknowledgment**

The authors express gratitude to the school leadership, the physics teacher, and the participating students in Mataram for cooperation and support throughout this study. Appreciation is also extended to colleagues and reviewers for constructive feedback that helped improve the clarity and quality of this manuscript.

#### **Conflict of Interests**

The authors declare no conflict of interest.

## **REFERENCES**

- Abeden, N., & Siew, N. (2022). Assessing students' critical thinking and physics problem-solving skills in secondary schools. *Malaysian Journal of Social Sciences and Humanities (MJSSH)*, 7(6), e001584. <https://doi.org/10.47405/mjssh.v7i6.1584>
- Aliyu, H., Ebikabowei, M., & Kola, A. J. (2023). Problem-based learning in remote learning scenario utilizing climate change virtual reality video in mobile application to train critical thinking. *International Journal of Essential Competencies in Education*, 2(2), 144–159. <https://doi.org/10.36312/ijece.v2i2.1612>
- Bilad, M. R., Anwar, K., & Hayati, S. (2022). Nurturing prospective STEM teachers' critical thinking skill through virtual simulation-assisted remote inquiry in Fourier transform courses. *International Journal of Essential Competencies in Education*, 1(1), 1–10. <https://doi.org/10.36312/ijece.v1i1.728>
- Bilad, M. R., Doyan, A., & Susilawati, S. (2022). Analyzing STEM students' critical thinking performance: Literacy study on the polymer film fabrication process irradiated with gamma rays. *International Journal of Essential Competencies in Education*, 1(2), 49–60. <https://doi.org/10.36312/ijece.v1i2.782>

- Dakabesi, D., & Luoise, I. (2019). The effect of problem based learning model on critical thinking skills in the context of chemical reaction rate. *Journal of Education and Learning (EduLearn)*, 13(3), 395–401. <https://doi.org/10.11591/edulearn.v13i3.13887>
- Defiyanti, & Sumarni, W. (2020). Analisis kemampuan berpikir kritis setelah penerapan problem based learning berbantuan lembar kerja peserta didik bermuatan etnosains. *Phenomenon: Jurnal Pendidikan MIPA*, 9(2), 206–218. <https://doi.org/10.21580/phen.2019.9.2.4200>
- Ekayanti, B. H., Prayogi, S., & Gummah, S. (2022). Efforts to drill the critical thinking skills on momentum and impulse phenomena using discovery learning model. *International Journal of Essential Competencies in Education*, 1(2), 84–94. <https://doi.org/10.36312/ijece.v1i2.1250>
- Falah, C. M. N., & Windyariani, S. (2018, March 2). Peningkatan kemampuan berpikir kritis peserta didik melalui model pembelajaran Search, Solve, Create, and Share (SSCS) berbasis etnosains. <https://garuda.kemdikbud.go.id/documents/detail/701353>
- Fitriani, H., Samsuri, T., Rachmadiarti, F., Raharjo, R., & Mantlana, C. D. (2022). Development of evaluative-process learning tools integrated with conceptual-problem-based learning models: Study of its validity and effectiveness to train critical thinking. *International Journal of Essential Competencies in Education*, 1(1), 27–37. <https://doi.org/10.36312/ijece.v1i1.736>
- Gencer, A., & Doğan, H. (2020). The assessment of the fifth-grade students' science critical thinking skills through design-based STEM education. *International Journal of Assessment Tools in Education*, 7(4), 690–714. <https://doi.org/10.21449/ijate.744640>
- Gultom, M., & Adam, D. H. (2018). Pengaruh pendekatan pembelajaran problem based learning terhadap kemampuan berpikir kritis di MTs Negeri Rantauprapat. *Jurnal Pembelajaran Dan Biologi Nukleus*, 4(2), 1-5. <https://doi.org/10.36987/jpbn.v4i2.1595>
- Gummah, S., Fitri, M., Prayogi, S., & Asy'ari, M. (2023). The effects of ethnoscience integrated problem-based learning models on students' critical thinking skills. *Lensa: Jurnal Kependidikan Fisika*, 11(2), 54–62. <https://doi.org/10.33394/j-lkf.v11i2.10447>
- Haulia, L., Hartati, S., & Mas'ud, A. (2022). Learning biology through the ethnoscience-PBL model: Efforts to improve students' scientific thinking skills. *Scientiae Educatia*, 11(2), 119–129. <https://doi.org/10.24235/sc.educatia.v11i2.11229>
- Hake, R. R. (1999). *Analyzing change/gain scores*. Indiana University.
- Haryanti, Y. D. (2017). Model problem based learning membangun kemampuan berpikir kritis siswa sekolah dasar. *Jurnal Cakrawala Pendas*, 3(2), 57–63. <https://doi.org/10.31949/jcp.v3i2.596>

- Hidayah, N., Yuliana, A., & Hanafi, H. (2020). Theoretical validity of problem focused-coping skill guideline to develop students' critical thinking skills. *Jurnal Kajian Bimbingan Dan Konseling*, 5(4), 183–191. <https://doi.org/10.17977/um001v5i42020p183>
- Hidayanti, I., & Wulandari, F. (2023). The effect of problem-based learning based ethnoscience on science literacy ability of elementary school. *Edunesia: Jurnal Ilmiah Pendidikan*, 4(3), 967–982. <https://doi.org/10.51276/edu.v4i3.475>
- Idul, J., & Fajardo, M. (2023). Ethnoscience-based physical science learning and its effects on students' critical thinking skills: A meta-analysis study. *Journal of Mathematics and Science Teacher*, 3(2), em048. <https://doi.org/10.29333/mathsciteacher/13700>
- Indrašienė, V., Jegelevičienė, V., Merfeldaitė, O., Penkauskienė, D., Pivorienė, J., Railienė, A., Sadauskas, J., & Valavičienė, N. (2021). Linking critical thinking and knowledge management: A conceptual analysis. *Sustainability*, 13(3), 1476. <https://doi.org/10.3390/su13031476>
- Kusuma, I., & Sumarni, W. (2025). Development of ethnoscience integrated e-worksheet in acid base materials to improve critical thinking skill. *Edusains*, 16(2), 97–109. <https://doi.org/10.15408/es.v16i2.34136>
- Nofziarni, A., Hadiyanto, H., Fitria, Y., & Bentri, A. (2019). Pengaruh penggunaan model problem based learning (PBL) terhadap hasil belajar siswa di sekolah dasar. *Jurnal Basicedu*, 3(4), 2016–2024. <https://doi.org/10.31004/basicedu.v3i4.244>
- Prayogi, S., Ahzan, S., Indriaturrahmi, I., & Rokhmat, J. (2022). Opportunities to stimulate the critical thinking performance of preservice science teachers through the ethno-inquiry model in an e-learning platform. *International Journal of Learning, Teaching and Educational Research*, 21(9), 134–153. <https://doi.org/10.26803/ijlter.21.9.8>
- Prayogi, S., Ahzan, S., & Rokhmat, J. (2023). The validity and effectiveness of the ethnoscience-loaded inquiry learning model to improve students' critical thinking skills. In *Proceedings of* (pp. 1877–1885). [https://doi.org/10.2991/978-2-38476-152-4\\_189](https://doi.org/10.2991/978-2-38476-152-4_189)
- Prayogi, S., Ardi, R. F. P., Yazidi, R. E., Tseng, K.-C., & Mustofa, H. A. (2023). The analysis of students' design thinking in inquiry-based learning in routine university science courses. *International Journal of Essential Competencies in Education*, 2(1), 1–14. <https://doi.org/10.36312/ijece.v2i1.1338>
- Prayogi, S., Yuanita, L., & Wasis. (2018). Critical inquiry based learning: A model of learning to promote critical thinking among of prospective teacher of physic. *Journal of Turkish Science Education*, 15(1), 43-56. <https://doi.org/10.36681>
- Rahman, A., Santosa, T., Nurtamam, M., Widoyo, H., & Rahman, A. (2023). Meta-analysis: The effect of ethnoscience-based project based learning model on students' critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, 9(9), 611–620. <https://doi.org/10.29303/jppipa.v9i9.4871>

- Sadhu, S., & Laksono, E. (2018). Development and validation of an integrated assessment for measuring critical thinking and chemical literacy in chemical equilibrium. *International Journal of Instruction*, 11(3), 557–572. <https://doi.org/10.12973/iji.2018.11338a>
- Salvetti, F., Rijal, K., Owusu-Darko, I., & Prayogi, S. (2023). Surmounting obstacles in STEM education: An in-depth analysis of literature paving the way for proficient pedagogy in STEM learning. *International Journal of Essential Competencies in Education*, 2(2), 177–196. <https://doi.org/10.36312/ijece.v2i2.1614>
- Sari, R. N., Ahda, Y., & Yanti, F. (2019). Effectiveness of guided inquiry learning model and problem based learning learning model on thematic integrated learning competency. *International Journal of Educational Dynamics*, 1(2), Article 2. <https://doi.org/10.24036/ijeds.v1i2.188>
- Suciyati, A., Suryadarma, I., & Paidi, P. (2021). Integration of ethnoscience in problem-based learning to improve contextuality and meaning of biology learning. *Biosfer: Jurnal Pendidikan Biologi*, 14(2), 201–215. <https://doi.org/10.21009/biosferjpb.18424>
- Suhirman, & Prayogi, S. (2023). Problem-based learning utilizing assistive virtual simulation in mobile application to improve students' critical thinking skills. *International Journal of Education and Practice*, 11(3), 351–364. <https://doi.org/10.18488/61.v11i3.3380>
- Suhirman, S., & Ghazali, I. (2022). Exploring students' critical thinking and curiosity: A study on problem-based learning with character development and naturalist intelligence. *International Journal of Essential Competencies in Education*, 1(2), 95–107. <https://doi.org/10.36312/ijece.v1i2.1317>
- Thomas, C., & Hayes, A. (2021). Using exploratory structural equation modeling to investigate the construct validity of the critical thinking disposition scale. *Journal of Psychoeducational Assessment*, 39(5), 640–648. <https://doi.org/10.1177/0734282921990564>
- Verawati, N. N. S. P., Harjono, A., Wahyudi, W., & Gummah, S. (2022). Inquiry-creative learning integrated with ethnoscience: Efforts to encourage prospective science teachers' critical thinking in Indonesia. *International Journal of Learning, Teaching and Educational Research*, 21(9), 232–248. <https://doi.org/10.26803/ijlter.21.9.13>
- Wahyuningtyas, D., Rohmanurmeta, F., & Widyastuti, S. (2023). Improving the critical thinking ability science through problem-based learning model assisted student worksheet ethnoscience. *Jurnal PTK Dan Pendidikan*, 9(1), 27–36. <https://doi.org/10.18592/ptk.v9i1.9002>
- Wibowo, A. (2022). Changing the concept of prospective primary education teachers through ethnoscience-based critical thinking. *Al Ibtida: Jurnal Pendidikan Guru MI*, 9(2), 382–391. <https://doi.org/10.24235/al.ibtida.snj.v9i2.10273>

Zidny, R., Sjöström, J., & Eilks, I. (2020). A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability. *Science & Education*, 29(1), 145–185. <https://doi.org/10.1007/s11191-019-00100-x>