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Meaningful Ethnoscience Integrated Problem-Based Learning for Analytical Thinking and Curiosity

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ABSTRACT

This study aimed to examine the effectiveness of Problem-Based Learning (PBL) integrated with meaningful learning and ethnoscience in enhancing analytical thinking and curiosity among junior high school students. The study was motivated by low student engagement and the dominance of conventional teacher-centered instruction that lacks contextualization and incorporation of local knowledge. A quantitative quasi-experimental design with a non-equivalent control group was employed, involving 60 eight-grade students divided into experimental and control classes. Analytical thinking was assessed through a validated essay test, while curiosity was measured using an observation checklist, both demonstrating adequate validity and reliability. Data analysis included normality and homogeneity tests, independent samples t-tests, and Pearson correlation. Results indicated a significant improvement in analytical thinking in the experimental class compared to the control ($t = –33.289$, $p < .001$), and curiosity was also significantly higher ($t = –20.079$, $p < .001$). Furthermore, a strong positive correlation was found between analytical thinking and curiosity ($r = 0.801$, $p < .001$), indicating that curiosity accounts for approximately 64.16% of the variance in analytical thinking. These findings confirm that integrating PBL, meaningful learning, and ethnoscience effectively improves students' analytical thinking, as indicated by a high N-Gain in the experimental class (0.703) compared to a low N-Gain in the control class (0.206), and increases students' curiosity, as shown by higher posttest mean scores in the experimental group than in the control group. The study implies that educators should adopt problem-based learning contextualized with local knowledge to improve science learning quality and 21st-century competencies.

Keywords: Problem-Based Learning, Meaningful Learning, Ethnoscience, Analytical Thinking, Curiosity

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INTRODUCTION

Science learning at the junior secondary level plays a crucial role in shaping students' fundamental scientific thinking, particularly in developing a deep and integrated understanding of biological concepts (Sukarma, 2023). However, national and international studies show that the quality of science instruction in Indonesia still encounters several challenges, especially low student engagement, the dominance of teacher-centered practices, and limited opportunities for students to develop higher order thinking skills. Various meta analyses and systematic reviews also highlight that conventional approaches are not effective in supporting conceptual analysis, problem solving, and scientific investigation (Wiratama et al., 2025)

These issues are clearly evident in the teaching of biology topics that are conceptual in nature and closely related to everyday life, including the digestive system. This topic requires a holistic understanding of structure, function, disorders, and common dietary habits that students encounter in their daily experiences. Previous studies indicate that students frequently experience misconceptions and difficulties in connecting digestive concepts with their empirical experiences. Therefore, contextual learning that integrates real world phenomena is essential for improving the quality of conceptual understanding (Ferreira et al., 2022). Hence, an instructional model is needed that enables students to analyze problems, relate concepts to their experiences, and construct understanding actively.

Problem Based Learning (PBL) is one of the instructional models that has consistently been shown to be effective in enhancing cognitive abilities, including analytical skills, conceptual understanding, and problem solving through engagement with authentic problems (Wiratama et al., 2025). The strength of PBL lies in its clearly structured learning steps that emphasize investigation, group discussion, and reflection, making it suitable for classroom experimental studies (Bayu Rachman & Setiawan Edi Wibowo, 2025). Nevertheless, the effectiveness of PBL strongly depends on students' ability to connect new information with their existing knowledge. This is where the principles of meaningful learning become relevant. Meaningful learning highlights the importance of activating prior knowledge, using advance organizers, and integrating concepts systematically to promote long term understanding (Bryce & Blown, 2024). Integrating meaningful learning principles into PBL can enrich the learning process so that it does not merely focus on problem solving procedures but also on the construction of meaning and a more comprehensive conceptual understanding (Ferreira et al., 2022).

In addition to requiring meaningful learning, science education also demands the presentation of contexts that are closely connected to students' daily lives. Ethnoscience or local knowledge serves as a potential learning resource because it bridges scientific concepts with cultural practices, traditional knowledge, and community experiences (Hamna & Muh. Khaerul Ummah Bk, 2024). Previous studies show that the integration of ethnoscience in science instruction can enhance the relevance of learning materials, foster appreciation for local culture, and strengthen students' ability to relate scientific theories to their sociocultural realities (Lidi et al., 2022). In the digestive system topic, ethnoscience contexts can be incorporated through local dietary habits, food processing techniques, and community health practices. Integrating such contexts aligns with the characteristics of PBL, which requires authentic problems that are relevant to students' lives.

The need for instructional innovation becomes increasingly evident when linked to the actual conditions at SMP Pandanaran Plupuh Sragen. Based on preliminary observations, science instruction is still dominated by teacher centered lectures, linear use of textbooks, and minimal opportunities for exploration and investigation. Limited laboratory facilities and the suboptimal use of contextual learning media result in students rarely engaging in activities that challenge their analytical abilities or curiosity. This situation reduces students' opportunities to develop cognitively and affectively in science learning. Therefore, a more participatory and contextual instructional model is needed, one that enables students to construct knowledge through problems that are closely related to their daily lives.

The two variables that form the focus of this study are analytical thinking and curiosity, which are essential competencies in twenty first century science education. Analytical thinking enables students to break down information, identify cause and effect relationships, and draw evidence based conclusions (Bayu Rachman & Setiawan Edi Wibowo, 2025). In science learning, analytical ability also serves as a key cognitive component that allows students to sort information, examine relationships among concepts, and evaluate evidence critically so they can build deeper scientific understanding (Bayani et al., 2025). Meanwhile, curiosity represents an affective drive that stimulates exploratory behavior, investigative actions, and persistence in learning (Hunaepi et al., 2024). Observational research recommends the use of observation sheets to measure curiosity because they are able to capture the dynamics of student behavior during inquiry activities (Jirout et al., 2022). Previous studies have shown that Problem-Based Learning (PBL) significantly improves students' analytical and higher-order thinking skills and also enhances affective aspects such as engagement and curiosity (Bayani et al., 2025; Wiratama et al., 2025; Hunaepi et al., 2024). Building on these findings, the present study integrates PBL with meaningful learning principles and ethnoscience contexts to simultaneously foster analytical thinking and curiosity through rich and meaningful contextual problems.

Although these three approaches have strong theoretical and empirical foundations, studies that examine their simultaneous integration in the junior secondary context, particularly in the digestive system topic and within schools that face facility limitations such as SMP Pandanaran Plupuh Sragen, remain very limited. This research gap underlies the need for the present study. The study aims to examine the effectiveness of the Problem Based Learning model integrated with meaningful learning and ethnoscience components on students' analytical thinking and curiosity. Specifically, the study investigates the differences between the experimental and control groups on both variables after the intervention. Therefore, this study is novel in that it simultaneously integrates Problem-Based Learning, meaningful learning, and ethnoscience within a single instructional design and examines their combined effects on both cognitive (analytical thinking) and affective (curiosity) outcomes. Moreover, this study provides empirical evidence from a junior high school context with limited learning facilities, highlighting the feasibility and added value of this integrated approach in resource-constrained settings. The findings are expected to provide empirical contributions as well as practical recommendations for science teachers in developing learning designs that are more contextual, meaningful, and oriented toward the development of twenty first century competencies.

METHOD

Research Type and Design

This study employed a quantitative approach using a quasi experimental method, specifically a non-equivalent control group design. The quasi experimental design was selected because the researcher could not randomize classes without disrupting the school's academic structure, making this approach the most realistic and ethical option in educational research. Methodologically, the non-equivalent control group design is one of the recommended quasi experimental designs when random assignment cannot be implemented (Gopalan et al., 2020). Although it does not involve class randomization, this design is still capable of producing strong causal estimates when accompanied by bias control mechanisms such as the administration of a pretest, the use of multiple raters, blind rating procedures, and monitoring of implementation fidelity. Therefore, the selection of this design is considered appropriate and valid in the context of a school with fixed class structures.

Research Location

The intervention was conducted at SMP Pandanaran Plupuh in Sragen. The school was selected because its characteristics align with the aims of the study, which are to examine the effectiveness of an innovative instructional model in a learning environment that remains dominated by teacher centered practices, provides limited exploratory activities, and has not yet integrated local cultural elements into science learning. These conditions are consistent with the requirements for implementing the Problem-Based Learning model combined with meaningful learning and ethnoscience, in which local contexts such as traditional dietary practices, local food processing methods, and community health beliefs related to digestion were integrated into problem scenarios and learning materials. The details of the research design are presented in the following table.

Table 1. Research Design

Group	n	Pretest	Treatment	Posttest
Experiment	30	O_1	X (Problem Based Learning integrated with meaningful learning and ethnoscience)	O_2
Control	30	O_3	— (Conventional instruction)	O_4

Research Subjects (Population, Sample, and Sampling)

Referring to (Capili, 2021), the population is distinguished into the target population, namely junior secondary students who share similar characteristics, and the accessible population, which consists of all seventh grade students in the school. Two intact classes were used as the sample: one class was assigned as the experimental group (n = 30), which received the Problem Based Learning intervention integrated with meaningful learning and ethnoscience, and one class served as the control group (n = 30), which received conventional instruction. Potential treatment contamination was minimized by scheduling learning sessions on different days and ensuring that intervention materials were not shared outside the experimental class. The use of a control group that received conventional instruction was chosen because it reflects common science teaching practices in the school, allowing the effectiveness of the intervention to be examined more realistically in relation to actual conditions. To maintain internal validity, several bias mitigation procedures were implemented, including the administration of a pretest, the use of multiple raters, blind rating procedures, and monitoring of implementation fidelity. Procedure and data analysis techniques should be emphasized to literature review article. The research stages should be clearly stated.

Instrument Validity and Reliability (Data Validity)

In assessing analytical ability, rater bias was minimized through a blind rating procedure using a standardized rubric and involving two independent raters. Both groups also received a pretest to ensure initial equivalence or to serve as the basis for calculating gain scores. The final score was obtained from the average of the two independent raters. Score differences between raters within a range of one to two points were considered acceptable and within a reasonable level of consistency. If a discrepancy of three points or more was found, a reassessment was conducted through a consensus discussion. This procedure ensured that the scoring process produced final scores that were stable, consistent, and objective.

For the curiosity observation instrument, assessments were conducted by two observers who first underwent a calibration process to align their understanding of the rubric and indicators. During the intervention, a fidelity checklist was used to monitor the extent to which the learning procedures were implemented as intended in the experimental class and to record the proportion of instructional time in both groups. This ensured that differences in outcomes were not attributable to variations in teaching methods or teacher attention. These procedures were applied to reduce potential selection bias, teacher effects, and inconsistencies in intervention implementation, allowing comparisons between the experimental and control groups to be interpreted more validly. Nevertheless, the possibility of diffusion of treatment is acknowledged as one of the limitations of the study.

The instruments used in this study consisted of two types. For analytical ability, an essay test comprising ten items was developed to measure students' capacity to perform cognitive operations at the analysis level (C4) in accordance with (Anderson et al., 2001) revision of Bloom's Taxonomy. The development of the test indicators adapted the analytical framework used by (Sirih et al., 2025), which emphasizes the ability to break down information, interpret cause and effect relationships, and draw data based conclusions. This framework was then adjusted to the context of the digestive system topic so that the stimuli, problems, and case scenarios reflected biological phenomena that are relevant to students' everyday experiences.

Based on this adaptation, the analytical ability indicators measured in the test included: (1) identifying the structures and functions of digestive organs accurately in relation to local food consumption practices, (2) analyzing the mechanisms of mechanical and chemical digestion across different stages of the process using cases derived from traditional food preparation and dietary habits, (3) connecting disorders or damage to digestive organs with potential clinical symptoms based on community health practices and commonly consumed local foods, (4) interpreting case data or information to determine the causes of digestive problems logically within ethnoscience-based scenarios, and (5) developing alternative solutions or preventive strategies for digestive disorders based on biological concepts and culturally relevant dietary practices. The content validity of the instrument was evaluated by two experts consisting of a biology education lecturer and an experienced science teacher. The experts assessed the appropriateness of the indicators, accuracy of the content, cognitive depth, and clarity of item construction. The evaluation yielded Aiken's V indices ranging from 0.82 to 0.92, indicating that all items possessed high content validity. The reliability of the instrument was analyzed using Cronbach's Alpha, given that it consisted of multiple essay items assessed with an analytical rubric. The calculation showed that the instrument demonstrated adequate internal consistency ($\alpha > 0.70$), allowing the conclusion that the items consistently measured students' analytical ability.

For the curiosity observation sheet, the content validity of the instrument was examined using a qualitative approach through expert judgment. The instrument, which consisted of 10 indicators of curiosity, was submitted to the validators. The validators were asked to assess the relevance of each indicator to the construct of curiosity, its alignment with the three theoretical dimensions adapted from (Gök & Doğan, 2025) namely Discovering Scientific Knowledge, Applying Science in Daily Life, and Experience-Based Scientific Curiosity as well as its suitability for eighth-grade students. The validators also evaluated the readability and clarity of the scoring rubric. Based on their review, the experts stated that all indicators were relevant, clear, and observable during the learning process. Several editorial improvements were made prior to finalizing the instrument. Therefore, the instrument was declared to have adequate content validity. The reliability of the instrument was tested using inter-rater reliability with Cohen's Kappa. Two observers simultaneously assessed students' curiosity behaviors using the same instrument. The calculation showed that the κ value fell within the substantial agreement category, indicating that the instrument was reliable.

The data analysis in this study comprised three main stages. First, differences in analytical ability between the experimental and control groups were examined using an Independent Samples t-test, or a Mann–Whitney U test if the normality assumption was not met. Second, differences in students' levels of curiosity were analyzed using the same comparative tests, selected according to the characteristics of the observational data. Third, the relationship between analytical ability and curiosity was assessed using either Pearson or Spearman correlation tests, depending on the results of the prerequisite assumption checks.

RESULTS & DISCUSSION

Result

Students' Analytical Thinking Ability

To obtain an initial overview of students' analytical thinking ability in both the control and experimental classes, descriptive statistical analyses were conducted. The parameters examined included the minimum score, maximum score, mean, and standard deviation, as presented in Table 2 below.

Table 2. Descriptive Statistics of Students' Analytical Thinking Ability

	Analytical Thinking Ability			
Class	**Min**	**Max**	**Mean**	**Std. Dev**
Control	0.11	0.32	0.2060	0.05697
Experiment	0.60	0.82	0.7033	0.05874

The descriptive analysis indicates that the analytical thinking ability of students in the experimental class is substantially higher than that of the control class. The mean score of the experimental class reached 0.7033, whereas the control class obtained only 0.2060, meaning that the achievement of students in the experimental class was nearly three times greater. The minimum and maximum score ranges in the experimental class (0.60–0.82) were also higher and more consistent than those of the control class (0.11–0.32), indicating that students in the experimental class demonstrated uniformly better analytical performance. Meanwhile, the standard deviations of both classes were relatively similar, suggesting comparable levels of variance within each class despite their differing achievement levels. Overall, these results confirm that the instructional treatment implemented in the experimental class contributed positively to enhancing students' analytical thinking ability.

After obtaining the descriptive overview of students' analytical thinking ability, the next step was to conduct inferential analysis to examine differences in improvement between groups using N-Gain scores. Prior to the mean difference test, a series of prerequisite tests was carried out. The Kolmogorov–Smirnov and Shapiro–Wilk normality tests indicated that the score distributions for both groups were normal ($p > 0.05$), and the Levene's test for homogeneity of variance confirmed that the variances of the two groups were equal ($p > 0.05$). These results indicate that the data met the assumptions for parametric testing, allowing the analysis to proceed using an independent samples t-test. With these assumptions satisfied, the subsequent analysis focused on the differences in N-Gain scores between the experimental and control classes to determine whether the instructional intervention produced a statistically higher improvement in analytical thinking ability compared to conventional instruction. The results of this test are presented in Table 3 below.

Table 3. Independent Samples t-Test Results for Students' Analytical Thinking

Statistic	Value
t-value	-33.289
Df	58
Sig. (2-tailed)	< .001
Mean Difference	-0.49733
95% CI	[-0.527, -0.467]

The results of the t-test indicate a highly significant difference between the N-Gain scores of the experimental and control groups ($t = –33.289$, $p < .001$). The mean N-Gain score of the experimental group (0.703) was substantially higher than that of the control group (0.206), with a mean difference of 0.497. The 95% confidence interval for the mean difference ranged from –0.527 to –0.467, which does not include zero, confirming that the difference is statistically significant. These findings demonstrate that the instructional intervention implemented in the experimental class had a considerably greater effect on improving students' analytical thinking skills compared to the conventional instruction provided in the control class.

Students' Analytical Thinking Ability

To obtain an initial overview of students' curiosity levels in both the control and experimental classes, a descriptive statistical analysis was conducted. The parameters examined included minimum, maximum, mean, and standard deviation values, which served as the basis for identifying general trends and data variability prior to inferential testing. The descriptive results of students' curiosity scores are presented in the following table:

Table 4. Descriptive Statistics of Students' Curiosity

	Students' Curiosity			
Class	**Min**	**Max**	**Mean**	**Std. Dev**
Control	60.73	50	68	5.38
Experiment	86.23	78	95	4.42

The descriptive results show a substantial difference in students' curiosity levels between the two groups. The control class obtained a mean score of 60.73, whereas the experimental class reached 86.23, indicating that students in the group receiving the PBL–ethnoscience–based instruction demonstrated a much higher level of curiosity. The distribution of scores was relatively stable in both groups, as reflected by the modest standard deviations (5.38 in the control group and 4.42 in the experimental group), suggesting that students' scores were relatively homogeneous within each class. The higher score range in the experimental class (78–95) compared to the control class (50–68) confirms that the instructional intervention contributed positively to enhancing students' curiosity.

After obtaining the descriptive overview of students' curiosity in both groups, the next step was to conduct assumption testing prior to inferential analysis. The normality tests indicated that the data in both the control and experimental classes were normally distributed, as shown by Kolmogorov–Smirnov and Shapiro–Wilk significance values greater than 0.05. The homogeneity of variance test using

Levene's test also produced significance values above 0.05, indicating that the variances of the two groups were homogeneous. With the assumptions of normality and homogeneity fulfilled, the analysis proceeded with an independent samples t test to examine the difference in curiosity levels between the control and experimental classes. The results of the independent samples t test are presented in the following table:

Table 5. Independent Samples t-Test Results for Students' Curiosity

Statistic	Value
t-value	–20.079
Df	58
Sig. (2-tailed)	< .001
Mean Difference	–25.500
95% CI	[–28.042, –22.958]

The t-test revealed a highly significant difference in curiosity scores between the experimental and control groups ($p < .001$). The experimental group achieved a much higher mean score (86.23) than the control group (60.73), with a mean gap of –25.50. The 95% confidence interval is [–28.042, –22.958], confirming the statistical significance of this difference. These results show that the instructional intervention in the experimental group had a substantially stronger effect on students' curiosity than the conventional teaching applied.

Table 6. Result of Pearson bivariate correlation test applying SPSS

	Analytical Thinking [X]	Curiosity [Y]
Analytical Thinking [X]	Pearson Correlation	1
	Sig. (2-tailed)	—
	N	60
Curiosity [Y]	Pearson Correlation	0.801***
	Sig. (2-tailed)	0.000
	N	60

Correlation Between Analytical Thinking Skills and Curiosity

After confirming that both analytical thinking skills and curiosity differed significantly between the control and experimental groups, the analysis was further extended to explore how these two variables relate to one another. Pearson's correlation test was selected because the dataset met the required parametric assumptions, particularly the normal distribution of each variable. This procedure was conducted to determine not only the strength but also the direction of the association between students' analytical thinking skills and their curiosity, thereby revealing whether improvements in one construct tend to coincide with increases in the other. The resulting correlation values are presented in the following table and serve as the basis for interpreting the nature of the relationship between the two variables.

The Pearson correlation analysis revealed that analytical thinking skills and curiosity exhibited a very strong positive relationship ($r = 0.801$, $p < .001$), indicating a large effect size. This result shows that students with higher levels of curiosity consistently demonstrated higher analytical thinking abilities. The magnitude of the correlation reflects a substantial association between the two variables in this study.

Discussion

This study demonstrates that the application of a Problem-Based Learning (PBL) model integrated with meaningful learning and local cultural content (ethnoscience) produces a substantial improvement in junior high school students' analytical thinking skills and curiosity. The experimental group showed markedly higher analytical thinking scores than the control group, and their curiosity levels also differed significantly. These findings confirm the hypothesis that the combination of PBL and meaningful ethnoscience-based learning effectively addresses the limitations of conventional instruction, which often fails to stimulate students' exploration and reflective thinking.

These findings are consistent with research at the elementary school level conducted by (Yulianto et al., 2023), which demonstrated that ethnoscience-based PBL significantly improves students' science learning outcomes. Likewise, literature reviews on the integration of ethnoscience in science education indicate that embedding local knowledge into modern scientific concepts enhances the relevance of the material and strengthens students' motivation and comprehension (Tatia Endah Puspita Sari & Tias Ernawati, 2025). Problem-Based Learning has also been shown to bridge the gap between theory and practice through active learning, engagement with real-world problems, and continuous assessment, thereby substantially improving students' learning outcomes and critical thinking skills (Ajid et al., 2025). Therefore, the findings of this study offer strong empirical support for the notion that ethnoscience is not merely a cultural complement, but a pedagogical element that helps students internalize scientific concepts in a more contextual and meaningful way.

This finding is also consistent with recent meta-analyses showing that the implementation of Problem-Based Learning (PBL) in science education consistently enhances students' critical and analytical thinking skills compared to conventional methods. Research by (Wiratama et al., 2025) reported moderate to large effect sizes across most studies, strengthening the argument that PBL is an effective pedagogical strategy for developing higher-order thinking skills in school settings. More specifically, studies conducted in school contexts have demonstrated that the combination of PBL and curiosity significantly improves students' higher-order thinking skills (HOTS) (Hanifah et al., 2025). These results are relevant to the present study, as they indicate that PBL not only fosters students' analytical thinking abilities but also reinforces the curiosity that naturally emerges during the learning process.

Explicitly, the mechanism underlying the effectiveness of PBL in enhancing analytical thinking and curiosity can be explained through two pathways, namely the cognitive and the affective. On the cognitive side, PBL requires students to solve problems that are relevant to their daily lives, such as topics related to the digestive system and local dietary practices. Throughout this process, students must identify relevant information, analyze structures and functions, evaluate data, and develop solutions or recommendations. These activities collectively represent analytical thinking and higher order cognitive processes.

Theoretically, Problem Based Learning employs authentic and contextual problems as the starting point of instruction. In this study, the digestive system content was connected to students' dietary habits and local cultural practices (ethnoscience). Such an approach enables more meaningful activation of prior knowledge, allowing new concepts to be integrated not through mechanical memorization but through connections to students' real experiences. This study also emphasizes that contextual learning aligned with students' daily lives can enhance motivation and deepen understanding. In this regard, students demonstrated better conceptual comprehension, accompanied by a significant improvement in their analytical thinking skills.

The affective dimension, particularly curiosity, is strengthened through the integration of ethnoscience content in the learning process. When students are introduced to problems that are closely connected to their cultural environment, dietary practices, and social realities, the material becomes more meaningful and engaging for them. This relevance fosters intrinsic curiosity that encourages students to actively explore and seek information. These findings are also consistent with the study conducted by (Widhy Hastuti et al., 2018), which reported that the implementation of Problem Based Learning demonstrates that curiosity and problem solving develop in parallel, as students showed improvements in both aspects following the intervention.

PBL further facilitates reflective and analytical thinking through its systematic stages, which include problem orientation, investigation, data collection, analysis, and the presentation of solutions. Problem Based Learning is considered superior to traditional methods because it enhances student engagement, improves learning outcomes, and develops problem solving skills through active involvement with real issues that are relevant to the curriculum (Gumartifa et al., 2023). In the context of the digestive system and ethnoscience, students do not merely memorize the structure and function of organs but also relate them to cultural practices such as local dietary habits and potential health problems. This process stimulates complex cognitive activities, including problem identification, causal reasoning, case data analysis, and the formulation of conclusions based on logic and evidence. These activities align with the indicators of analytical thinking in the revised Bloom taxonomy.

The integration of ethnoscience in this learning intervention was implemented by embedding local cultural practices into the Problem Based Learning activities, consistent with recent studies showing that ethnoscience-based PBL enhances contextual understanding and higher-order thinking skills (Damayanti et al., 2024). Through this approach, students did not merely study digestive system concepts at a theoretical level, but also connected them with familiar cultural experiences such as the preparation of papeda in Maluku, the consumption of herbal drinks in Java, the tradition of eating lawar in Bali, and the practice of chewing areca nut in several regions of Indonesia, which reflects previous findings that integrating traditional food and cultural practices strengthens conceptual relevance and meaningful learning (Aprilia et al., 2025). When these cultural contexts were incorporated into PBL scenarios, students were confronted with real-world problems that required them to analyze how food ingredients, preparation techniques, and dietary habits influence digestive mechanisms, thereby promoting active, reflective, and structured learning, in line with recent evidence that ethnoscience-integrated PBL supports critical thinking and problem-solving through culturally grounded contexts (Sarkingobir & Bello, 2024).

A substantial body of previous research consistently demonstrates that the combination of PBL and ethnoscience enhances cognitive abilities and various higher order thinking skills, which aligns with the findings of the present study. A literature review by (Wirama et al., 2023) emphasizes that ethnoscience-based instruction strengthens students' creative and critical thinking because they are actively involved in identifying scientific phenomena rooted in local cultural practices. Similarly, (Sarkingobir & Bello, 2024) report that integrating ethnoscience into PBL produces significant improvements in critical thinking compared to expository teaching, as cultural contexts make learning more meaningful and relevant for students. This consistency is further supported by (Amini et al., 2021), who found that ethnoscience-based PBL substantially improved critical thinking skills in colloid topics, and by (Wahyuni et al., 2023), who showed that similar models significantly enhanced students' learning independence. Integrating ethnoscience into instruction enables local knowledge and cultural practices to be incorporated into the learning process, thereby increasing relevance, deepening understanding, and strengthening students' twenty-first century skills (Fatihatussa'adah et al., 2024).

The integration of ethnoscience within Problem Based Learning not only enhances learning outcomes but also strengthens students' energy literacy through culturally familiar contexts (Devia et al., 2025). These findings are fully aligned with the results of the present study, which demonstrate that Problem Based Learning grounded in meaningful learning and enriched with ethnoscience is highly effective for classroom implementation. It is not only successful in improving analytical thinking skills but also in fostering students' curiosity, as the culturally relevant problem solving tasks encourage learners to explore, reason, and connect digestive system concepts with traditional dietary practices they encounter in daily life.

A very strong positive correlation between analytical thinking ability and curiosity indicates that these two constructs develop concurrently and reinforce one another. In other words, when instruction is able to stimulate curiosity through relevant and meaningful contexts, students' analytical abilities are encouraged to grow. This finding is consistent with the conceptual view that curiosity functions as a driver of information exploration, which subsequently facilitates analytical processing. Practically, this result suggests that interventions that enhance students' disposition toward curiosity may contribute to the improvement of higher-order cognitive skills.

Theoretically, the mechanism linking analytical ability and curiosity can be explained through the PACE framework (Prediction, Appraisal, Curiosity, Exploration), which posits that curiosity drives a series of cognitive and motivational processes such as attentional focus, enhanced information encoding, and deeper semantic processing (Gruber & Ranganath, 2019). This framework clarifies why learners who experience an information gap tend to seek evidence, formulate provisional hypotheses, and consider multiple possibilities, all of which are fundamental characteristics of analytical thinking. These insights align with the findings of the present study, in which the very strong positive correlation between analytical ability and curiosity indicates that both aspects increase simultaneously as a logical consequence of a meaningful problem-based learning design grounded in ethnoscience.

In culturally enriched PBL environments, students are presented with authentic problems that are closely connected to their everyday experiences, which stimulates curiosity early in the learning process and encourages deeper cognitive engagement. When this context is combined with the principles of meaningful learning, students do not merely search for answers but construct mechanistic understanding through exploration, analysis, and the integration of digestive system concepts with familiar traditional dietary practices. This process explains why the empirical relationship between curiosity and analytical ability in the present study is not only statistically significant but also theoretically grounded in neurocognitive frameworks.

However, the effectiveness of PBL depends greatly on its design and implementation. PBL must be accompanied by the development of authentic problems, appropriate scaffolding, clear guidance, and teacher support so that students do not become confused or lose direction (Pinar et al., 2025). In this regard, the integration of ethnoscience and meaningful learning in the PBL design of this study can function as a form of cultural and cognitive scaffolding that enables students to understand scientific concepts within real and familiar cultural contexts. This approach simultaneously strengthens student engagement, as they learn through experiences that are closely connected to their everyday lives and their cultural identity.

Although this study demonstrates the strong influence of meaningful-learning-based PBL integrated with ethnoscience on improving students' analytical abilities and curiosity, several limitations must be acknowledged. The study was conducted within a single school context and at one educational level; therefore, generalizing the findings to broader learning settings should be done cautiously. The implementation of ethnoscience is also shaped by the extent to which students are connected to their local cultural traditions, meaning that its effectiveness may vary across populations with different cultural backgrounds. In addition, the relatively short intervention period may not fully capture long-term developments in both analytical ability and curiosity. Future studies are therefore encouraged to expand the sample scope, extend the intervention duration, and explore more diverse cultural contexts so that the learning model can become more robust, adaptable, and applicable across a wider range of settings.

Overall, this study confirms that the integration of Problem-Based Learning (PBL) with meaningful learning and ethnoscience constitutes an effective pedagogical approach for enhancing students' analytical thinking while simultaneously fostering their curiosity. This approach creates learning experiences that are relevant, contextual, and rooted in local culture, enabling conceptual understanding to be both constructive and reflective rather than purely procedural. The strong positive correlation observed between analytical thinking and curiosity indicates that these two dimensions are intrinsically linked within active learning processes that encourage the exploration of authentic problems. Consequently, this research provides a significant contribution to the design of science education that is more human-centered, contextually grounded, and responsive to students' cognitive needs and cultural characteristics, while also opening avenues for the development of problem-based learning innovations across diverse content areas and educational levels.

CONCLUSION

This study shows that implementing a Problem-Based Learning (PBL) model integrated with meaningful learning and an ethnoscience approach can simultaneously enhance students' analytical thinking and curiosity. Learning that is grounded in cultural contexts and real-life experiences creates meaningful informational gaps, which stimulate curiosity and encourage active engagement in exploring scientific problems. The experimental group demonstrated a significant improvement in analytical thinking, as reflected by high N-Gain scores, while a very strong positive correlation between analytical thinking and curiosity indicates that both skills develop in parallel within a relevant, contextual, and challenging learning environment. These findings suggest that science teachers, particularly at the junior high school level, can increase student engagement and higher-order thinking by integrating culturally relevant examples, local knowledge, and authentic problem scenarios into PBL activities. Future research is recommended to examine the long-term effects of this integrated approach, involve larger and more diverse student samples, and explore its impact on additional twenty-first century skills, including scientific reasoning, creativity, and scientific literacy.

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