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Development of Problem-Based Learning (PBL) Ethnoscience Based Teaching Materials Food and Beverage Additives Material to Improve Students' Science Literacy

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Abstract

This study aims to develop Problem-Based Learning (PBL) teaching materials integrated with an ethnoscience approach on the topic of food and beverage additives to enhance students' scientific literacy. The research was motivated by the low level of scientific literacy among Indonesian students, as indicated by the 2022 PISA results, which suggest that science learning remains largely theoretical and insufficiently connected to local cultural contexts. The ethnoscience approach integrates scientific concepts with indigenous cultural knowledge, while the PBL model promotes active learning, critical thinking, and problem-solving skills. This study employed a Research and Development (R&D) method using the 4D model, consisting of Define, Design, Develop, and Disseminate stages. The research subjects were eighth-grade students at SMP Islam Sunan Giri Salatiga. Research instruments included expert validation sheets for materials and media, student response questionnaires, and scientific literacy tests. Data were analyzed using descriptive quantitative and qualitative techniques to determine the feasibility, practicality, and effectiveness of the developed teaching materials. The results indicate that the PBL–ethnoscience-based teaching materials are highly valid, with average validation scores of 89.38% from material experts and 87.68% from media experts. Student responses were categorized as very good, with scores of 80.61% on a small scale and 81.45% on a large scale. The N-gain analysis showed improvements in scientific literacy at high (41.94%), moderate (38.71%), and low (9.68%) levels. These findings demonstrate that PBL–ethnoscience-based teaching materials effectively improve junior high school students' scientific literacy and can serve as a reference for culturally integrated science learning.

How to Cite

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INTRODUCTION

Research in the modern era plays a crucial role in producing high-quality human resources who are not only knowledgeable but also capable of thinking critically, creatively, and independently. Learning today is no longer focused merely on transferring knowledge but also on developing students' competencies in problem solving, critical reasoning, and making decisions based on valid scientific evidence (Yusmar & Fadilah, 2023). In this context, scientific literacy becomes a fundamental competence that must be developed in science education. Scientific literacy does not only relate to students' understanding of scientific concepts but also to their ability to apply these concepts in real-life situations (Marwah & Pertiwi, 2024). Through scientific literacy, students are expected to understand, evaluate, and communicate scientific information effectively so they can participate responsibly in a society that is increasingly influenced by science and technology (Hidayah et al., 2024). Graham (2024) also emphasizes that scientific literacy includes the ability to understand scientific ideas, evaluate scientific claims critically, and communicate them logically.

A review conducted by Sanjiartha et al. (2024) indicates that scientific literacy is not merely about mastering scientific knowledge, but also about developing critical thinking, innovation, evidence evaluation, and informed decision-making. Therefore, the main objective of science education is to develop critical thinking skills, foster lifelong learning, and prepare students to face complex global challenges (Rudolph, 2023). For this reason, efforts to improve students' scientific literacy must be supported by appropriate learning strategies that integrate real-life contexts, cultural relevance, and meaningful learning experiences (Rizalia et al., 2025).

However, science education in Indonesia still faces serious challenges. The 2022 PISA results show that Indonesia has not yet reached the expected international standards, especially in scientific literacy. Several studies note that the low level of students' scientific literacy is closely related to learning that is still theoretical, the absence of teaching materials that encourage scientific literacy, the lack of contextual learning, and students' low reading ability (Suparya et al., 2022). Indonesia ranked 67th out of 81 participating countries with an average science score of 383 (OECD, 2022). PISA measures students' abilities in reading, mathematics, and science, including their ability to reason scientifically, solve problems, and engage with scientific issues in daily life. These unsatisfactory results show that students still have limited ability to understand concepts, identify problems, interpret data, and draw logical conclusions from environmental phenomena.

In fact, science education provides material that is closely related to students' daily lives, such as food and beverage additives. This topic can be used as an effective learning resource when linked to students' cultural and social environments. Observations at Sunan Giri Islamic Junior High School in Salatiga show that learning still tends to be theoretical and has not been optimally integrated with local cultural contexts. Indonesia's rich cultural heritage offers the opportunity to apply an ethnoscience approach. Ethnoscience integrates modern science with local wisdom and traditional knowledge (Rahman et al., 2023). Nadiyah et al. (2022) state that ethnoscience makes learning more meaningful because it connects science with students' cultural experiences. However, learning in schools is still considered to lack real-life problem orientation and has not maximally integrated local cultural values (Patricia et al., 2022).

Problem-Based Learning (PBL) is one of learning models that supports the development of scientific literacy (Suhirman & Khotimah, 2020). PBL has long been recognized as an effective approach to improving understanding through authentic problem solving. This model encourages students to engage actively, think critically, collaborate, communicate, and construct knowledge through inquiry (Rahman et al., 2023). Although PBL is not new, many studies show that it has strong potential to make learning more contextual, interactive, and socially relevant.

However, teaching materials that integrate PBL and ethnoscience, especially in the topic of food and beverage additives, are still limited. Therefore, there is a strong need to develop PBL–ethnoscience-based teaching materials that are able to build scientific concepts while strengthening local cultural understanding. Through such development, students are expected not only to understand additive concepts but also to make wise and informed consumption decisions.

When linked to scientific literacy, ethnoscience provides a meaningful and contextual learning framework, helping students understand science through their cultural environment and everyday life. This makes learning more interesting, relevant, and engaging. Scientific literacy is a fundamental competence that must be developed in science-based subjects because modern society faces many issues related to science, technology, health, environment, and consumption behavior (Mujahidin et al., 2023; Sanova et al., 2023; Rubini et al., 2018). Scientific literacy generally includes four aspects: context, process skills, cognitive competence, and attitudes toward science (Spitzer & Fraser, 2020). In the context of additives, good scientific literacy is very important so that students become critical and aware consumers.

Previous research supports the integration of PBL and ethnoscience to improve scientific literacy. Dewi et al. (2019) reported that ethnoscience-based learning improves students' understanding and literacy. Sanova et al. (2023) found that the integration of ethnoscience in PBL significantly enhances scientific literacy. Nisa et al. (2015) also demonstrated that ethnoscience-based problem learning modules improve scientific literacy and provide meaningful learning experiences. Fahrudin et al. (2023) and Khoiri et al. (2019) emphasized that ethnoscience strengthens cultural context so students can relate scientific concepts to real-life phenomena, which is the core of modern scientific literacy. Anazifa and Djukri (2017) confirmed that PBL effectively improves scientific thinking skills as an essential component of scientific literacy. Therefore, the development of PBL–ethnoscience-based teaching materials is both a necessity and a challenge for educators and researchers to meet 21st century learning demands that emphasize critical thinking, collaboration, cultural relevance, and scientific literacy.

METHOD

This study utilises a Research and Development (R&D) approach to development first used by Sivasailam Thiagrajan, Dorothi S. Semmel and Melvyn l. Semmel by applying the 4D development model (Define, Design, Develop, Disseminate) (Aimmah & Amin. 2025). This model can support problem-based learning (PBL). The product of this research is PBL-Ethnoscience-Based Teaching Materials on Food and Beverage Additives to Improve Students' Science Literacy. The learning outcomes by Ramandanti & Supardi (2020) show that Problem-Based Learning integrated with ethnoscience has an effect on students' understanding of the concept of redox, making them more active in learning and able to solve problems. The results of research conducted by Rosmita (2023) to determine the effectiveness of the PBL-based ethnoscience learning model in improving students' science literacy in acid-base titration material showed that the high results of students' science literacy abilities after the implementation of learning became effective after using the PBL-based ethnoscience model.

The subjects of this study were 31 eighth-grade students at Sunan Giri Islamic Junior High School in Salatiga. The research sample was selected using cooperative learning, adjusted to the class conditions and research needs. Data was obtained through teacher interviews, validation sheets, tests (pre-test and post-test), and student responses after using the teaching materials. The independent variable was PBL-Ethnoscience Teaching Materials, while the dependent variable was improving students' science literacy.

Definition Stage

The initial stage of this study involved analysing the needs of students. Interviews conducted with two science teachers at Sunan Giri Islamic Junior High School in Salatiga revealed that students had limitations in understanding the material on additives. The analysis of students aimed to identify their initial conditions in terms of their characteristics and learning needs. The analysis of tasks and final concepts determines the basic competencies and indicators of learning achievement. This stage serves as a starting point in accordance with the syntax of Problem-Based Learning (PBL).

Design Stage

The instructional material design stage, as shown in Figure 1, involves the preparation of learning tools. The format of the learning material facilitates the Problem Based Learning (PBL) process based on Ethnoscience.

Figure 1. Design learning material facilitates PBL process based on ethnoscience

Development Stage

The product development stage follows the design of initial problem-based teaching materials supplemented with ethnoscience. Once developed, the teaching materials are validated by subject matter experts and media experts to determine their suitability, with the validators providing assessments, suggestions and input to refine the materials. The instruments are evaluated using validity tests to determine the validity level of the questions tested in Grade XI, reliability tests to determine the extent of variability due to measurement errors and the actual question scores, then a difficulty measurement test to find out how easy or difficult several questions are, and a question discrimination test to measure the ability of questions to distinguish between pretest results before using teaching materials and posttest results after using teaching materials.

Data Collection and Analysis

This study utilised qualitative research methods, employing descriptive techniques through interviews, expert validation sheets, and student response questionnaires. Descriptive quantitative data was obtained through research results in numerical form, obtained from expert validation, feasibility tests, effectiveness tests, and student response sheets. The teaching materials were validated by two validators, a media expert and a subject matter expert, using Aiken's V scale.

Table 1. Aiken's Assessment Scale

Aiken's V Scale	Validity
≤ 0.4	Invalid
0.4 < V ≤ 0.8	Valid
0.8 < V	Highly Valid

Validity testing using SPSS with Pearson's correlation coefficient the following formula.

$$r = \frac{n\sum XY-(\sum X)(\sum Y)}{\sqrt{\{n\sum X^2-(\sum X)^2)(n\sum Y^2-(\sum Y)^2)\}}}$$

R : is the product moment correlation value
N : is the number of respondents
x : is the item score
Y : is the total item score

Interpreting the validity level, with correlation coefficient categorized according to criteria.

Table 2. Test Instrument Validity Criteria

r value	Interpretation
0.00 – 0.20	Very low
0.21 - 0.40	Low
0.41 - 0.60	Fairly
0.61 - 0.80	High
0.81 - 1.00	Very High

Reliability testing using SPSS with the Cronbach's Alpha formula as follows.

$$r_{kk} = \left[\frac{k}{k-1}\right][1-\frac{\sum S_h^2}{S_t^2}]$$

Description:
r_{kk} : instrument reliability
k : number of questions
$\sum S_b^2$: item variance
S_t^2 : varians total

Table 3. Reliability Level Criteria

Test Validity Coefficient	Criteria
0.00 ≤ VR < 0.40	Very Low
0.40 ≤ VR < 0.60	Low
0.60 ≤ VR < 0.80	High
0.80 ≤ VR < 1.00	Very High

The level of difficulty of a question is the opportunity for students to answer questions correctly at a level of ability that can be classified as easy or difficult (Purba et al., 2021). According to Du Bois (2019), the index number in determining the level of difficulty of an item using SPSS.

$$P = \frac{Np}{N}$$

Description:
P : item difficulty index proportion or figure
N_p : the number of test takers who answered the item correctly
N : number of test takers who took the learning outcome test

Table 4. Question Difficulty Criteria

Question Difficulty Index	Interpretation
Less than 0.30	Too difficult
0.30 ≤ P ≤ 0.70	Just right (Moderate)
More than 0.70	Too easy

(Thorndike & Hagen, 2019)

Knowing the size of the item discrimination index and its formula.

$D=P_A- P_B$

Table 5. Discrimination Power

The magnitude of the Item Discrimination Index (D)	Classification	Interpretation
Less than 0.20	Poor	The relevant item has very weak embedding power and is considered to lack good discriminatory power.

The magnitude of the Item Discrimination Index (D)	Classification	Interpretation
0.21 – 0.40	Satisfactory	Has sufficient (moderate) distinguishing power.
0.41 – 0.70	Good	The items in question have good discriminatory power.
0.70 – 1.00	Excellent	The items in question have excellent distinguishing characteristics.

Analysis to test the effectiveness of teaching materials using the normality gain test (N-Gain), according to Meltser's formula (Oktavia et.al, 2019).

$$\langle N\text{-gain}\rangle = \frac{Spost - Spre}{Smax - Spre}$$

Explanation:

N-gain	:	Conceptual understanding values
S_{pre}	:	Pre-test Score
S_{post}	:	Post-test Score
S_{max}	:	Maximum Score

The level of conceptual understanding in Table 3.

Table 3. Level of Conceptual Understanding

Score	Criteria
$0.7 \leq g \leq 1$	High
0.3 g 0.7	Medium
0< g 0.3	Low

Analysis of student response data through respondent questionnaires on teaching materials developed using a Likert scale.

$$P = \frac{\sum R}{N} x\ 100\%$$

Description:

P : score percentage

$\sum$R : total score given by each respondent

N : total ideal score in one criterion item

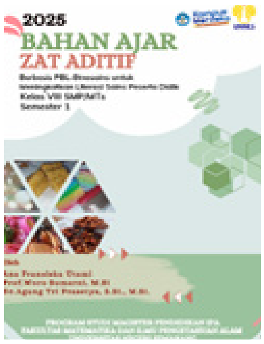
Table 7. Criteria for Assessing Student Responses

Score	Criteria
81% - 100%	Strongly agree
61 % - 80%	Agree
41% - 60%	Quite agree
21% - 40%	Somewhat disagree
0 – 20%	Disagree

RESULT AND DISCUSSION

The results of qualitative data analysis through subject matter and media validators aim to determine the extent to which the teaching materials that have been created meet content standards, conceptual accuracy, and are relevant to ethno-science-based learning materials. Subject matter expert validation assessments are not only scientific but also contextual and relevant to lives of students. The validation assessment covers several aspects, including content suitability, material presentation, language use, PBL-Ethnoscience integration, and science literacy. The interview results showed that there was a lack of understanding of the learning material among students, and that the lecture method, Scientific Science, and Project Based Learning (PJBL) were not very engaging. The researchers then developed a Problem Based Learning (PBL) method supplemented with ethnoscience to improve science literacy.

Table 8. The section of teaching materials

Teaching Material	Description
	The cover displays the title
	Questions related to science literacy components and supporting PBL syntax
	The teaching material sub-topic containing group activities has been supplemented with the word 'exploration' to emphasise it as the initial stage of PBL syntax.

Teaching Material	Description
	The learning objectives consist of four aspects including: Condition (learning conditions), Audience (students), Behaviour (expected behaviour) and Degree (level of achievement)
	Questions to evaluate

Validation by several expert validators of teaching materials was carried out to ensure that the content of the teaching materials developed was truly appropriate and meaningful for students. This process not only assesses the accuracy of concepts and the suitability of materials to the curriculum, but also reviews how the materials are able to build contextual understanding that is relevant to everyday life. Through the perspectives of experts, the materials in the teaching materials are examined in terms of scientific accuracy, depth of concept, and suitability to the Ethnoscience-based Problem Based Learning model. Validation by media experts is carried out to ensure that teaching materials not only present content but also have a visual appearance that attracts readers' attention and is easy for students to understand (Juwitaningrum, et al., 2025). Good design is expected to increase students' interest in learning and make it easier for them to understand the learning concepts presented.

The results of the item validity analysis using the Corrected Item-Total Correlation SPSS technique with a table r of 0.349 showed that 22 items were declared valid because they had a calculated r greater than the table r. Meanwhile, there were 8 items that had a calculated r smaller than the table r, so they were declared invalid and needed to be revised before being used in the experimental class trial. Reliability was tested using Cronbach's Alpha coefficient with the help of SPSS. The results showed that the 30 questions given to 32 students scored 0.886, which is in the highly reliable category and therefore suitable for use in research.

The results of the difficulty level analysis show that most of the questions were in the easy category, with 21 questions, 7 questions were classified as moderate and 2 questions were classified as difficult. However, with different question types, students were able to demonstrate a good initial understanding of the material. The discrimination power test was conducted based on data from instrument trials involving 31 students. The results in Table 11 show that most of the items had a positive discrimination coefficient with a range of -0.017 to 1.00. Approximately 85% of the items were in the fair to very good category, with values above the table r (0.349). Meanwhile, several items with low discrimination power needed to be revised.

A small-scale trial was conducted on 12 eighth-grade students using a questionnaire on the use of PBL-Ethnoscience-based teaching materials that had been developed. The questionnaire consisted of 21 questions covering four aspects, namely (1) learning aspects, (2) content aspects, (3) appearance aspects, and (4) readability aspects. Each question used a 1-5 Likert scale. Based on the results obtained through the processing of the questionnaire, the total score was 992 with an average score of 82.67 out of a maximum score of 100. The average score was categorised as good with a range of 64-84, meaning that the students responded positively to the teaching materials developed.

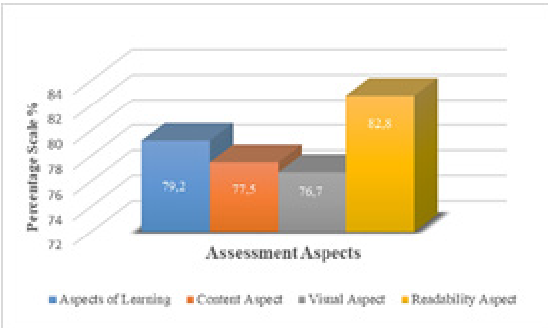


Figure 2. Small-Scale Trial Results

Based on the pretest and posttest results Table 12, there was a clear improvement in the learning outcomes of students after using PBL-Ethnoscience-based teaching materials. Before learning, most students were in the low category (22.60%) and medium category (29.00%), while only 35.50% and 12.90% were in the high and very high categories. After using the teaching materials, there were no longer any students in the very low or low categories. Conversely, the number of students in the high and very high categories increased significantly to 41.90% each. This improvement indicates that PBL-Ethnoscience-based teaching materials are effective in helping students understand additive substances more deeply through the context of everyday life and local culture (Herayanti et al., 2025). This approach not only improves conceptual knowledge but also fosters critical thinking skills and a positive attitude towards science (AlAli, 2024). These results reflect that learning that links science to real-life experiences and cultural values can create a more meaningful learning process, empowering students to learn actively, think reflectively, and appreciate the role of science in their lives (Rizal et al., 2023). Based on the results of testing the effectiveness of students' science literacy analysis through pre-test and post-test questions, a significant improvement was obtained after the implementation of PBL-Ethnoscience teaching materials on the subject of additives (Sarkingobir & Bello, 2024).

Table 9. Effectiveness Test

N-Gain Category	Number of Students	(%)
Low	6	19.35 %
Medium	12	38.70 %
High	13	41.95 %
Total	31	100 %

Analysis results showing improvement in learning outcomes using N-Gain test show that 41.95% of students are in the high category, 38.70% in the medium category, and 19.35% in the low category. Thus, overall, 80.65% of students experienced an improvement in learning outcomes in the medium to high categories. These results prove that PBL-Ethnoscience-based teaching materials are effective in improving the science literacy of junior high school students on the subject of additives (Khotimah, et al., 2024). This improvement is not merely a rise in numbers, but rather a reflection of the growth in students' ability to understand scientific phenomena that are relevant to their lives. Students not only master concepts, but are also able to think critically, solve problems, and develop a positive attitude towards science (Sanova & Malik, 2023).

The result of a large-scale feasibility test, the average percentage scores for the four assessment aspects are as follows: content and material feasibility aspect 82.1%, involvement in PBL aspect 75.7%, science literacy aspect 81.3%, and appearance and language aspect 91%. All aspects are categorised as highly feasible for use in learning.

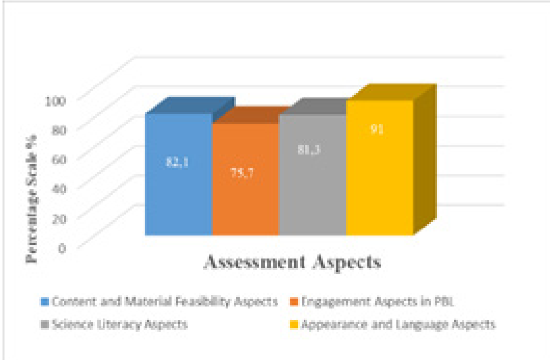


Figure 3. Results of Large-Scale Trials

From a humanistic perspective, these results show that PBL-Ethnoscience-based teaching materials not only meet content standards and are visually appealing, but also encourage active student engagement in the learning process (Tika & Artawan, 2025). The integration of local cultural context, problem-solving approaches, and communicative visual presentations makes learners feel closer to the material being studied (Garzon-Diaz, 2021). Thus, these teaching materials effectively support the development of science literacy while fostering positive attitudes and a sense of belonging towards culture and science. The response of students to Problem Based Learning (PBL) teaching materials with an ethnoscience approach aims to analyse the extent to which students accept and understand the use of teaching materials in the learning process (Wahyuni, et al., 2023).

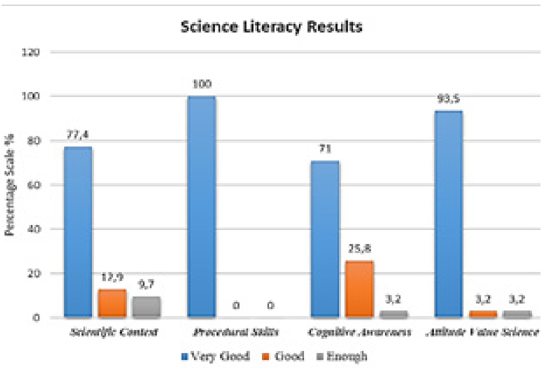


Figure 5. Science Literacy Results

Figure 5 show the results of student development after using PBL-Ethnoscience-based teaching materials. In the Scientific Context aspect, moststudents were able to relate the concept of additives toeveryday life phenomena. The Procedural Skills aspect obtained very high results, with all students in the excellent category, meaningthey were able to follow the steps and solve problems (Arzamnur, 2023). In the CognitiveAwareness aspect, the majority of students were able to think critically anddraw logical conclusions, although a small number still needed assistance in integrating scientific concepts comprehensively. Meanwhile, theAttitude Value Science aspect showed positive results from studentstowards science. Overall, the application of PBL-Ethnoscience not onlyimproved science literacy but also fostered scientific skills in students' learning (Sholahuddin, et al., 2021).

CONCLUSION

The product is PBL-Ethnoscience-based teaching material on food and beverage additives, validated by subject matter experts as 'highly suitable' for use as teaching material, and validated by teaching material media experts as 'highly suitable', as well as small-scale test results analysed as "good" and large-scale analysis results analysed as 'very good'. Integrated Problem-Based Learning (PBL) teaching materials containing Ethnoscience on food and beverage additives to equip students with scientific literacy are assessed through scores in each domain of scientific content, process science, context application, and attitudes and values science. The students' response to the developed teaching materials showed positive results, with this assessment reflecting the students' interest, ease of understanding the material, and motivation to learn, thereby improving their results. For future researchers, this study still has limitations in terms of the scope of the trial. Therefore, it is necessary to conduct further research on a broader scale and develop similar teaching materials for science subjects in order to obtain more comprehensive results.

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