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Integration of Local Potential in Project-Based Learning: Its Impact on Critical Thinking and Scientific Attitudes of Students of SMAN 1 Darussalam

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Abstract: This study aims to analyze the effectiveness of the implementation of the Project-Based Learning (PjBL) model based on local potential on biotechnology material in improving students' critical thinking skills and scientific attitudes. The study used a quantitative approach with a one-group pretest-posttest design for 35 students. The instruments were a critical thinking test and a scientific attitude observation sheet that had been declared valid and reliable (Cronbach's Alpha = 0.789). The results showed a significant increase in critical thinking skills, with an average pretest score of 17.63 increasing to 37.71 in the posttest, and an N-Gain value of 0.897 (high category). The increase occurred in all indicators, with the highest value in the indicator providing simple explanations (0.9226) and the lowest in the indicator organizing strategies and tactics (0.8723), but all in the high category. Students' scientific attitudes also increased, indicated by an average pretest score of 17.49 to 29.51 in the posttest, with an N-Gain value of 0.808 (high category). The highest improvement was found in the critical thinking indicator (0.93), while the lowest was in the collaboration indicator (0.63). Thus, the local potential-based PjBL model effectively improves students' critical thinking skills and scientific attitudes through contextual and project-based learning.

Keywords: Biotechnology; Critical thinking; Local potential; Project-Based learning; Scientific attitudes

Introduction

The 21st-century learning approach demands pedagogical innovations capable of developing students' higher-order thinking skills and scientific character. In this context, learning is no longer teacher-centered but rather student-centered, emphasizing active involvement in the knowledge construction process. One learning model deemed relevant to these demands is Project-Based Learning (PjBL). This model places projects at the core of learning activities, enabling students to explore real-world problems, develop solutions, and produce meaningful products (Zulkarnaen et al., 2025).

Conceptually, PjBL is a learning approach that integrates investigation, problem-solving, and product creation into a systematic series of activities. This model provides opportunities for students to learn contextually through direct experience, thereby increasing engagement, motivation, and critical and collaborative thinking skills (Ningsih et al., 2011; Utari, 2018; Kartini et al., 2019). Recent research shows that the consistent implementation of PjBL contributes to improved students' critical thinking skills, creativity, and problem-solving abilities, particularly in science and STEM learning (Arrafiq et al., 2024; Muhari, 2021; Rambe & Khaeruddin, 2024; Surya et al., 2018; Ulfa et al., 2024). Thus, PjBL functions not only as a learning strategy but

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also as a means of developing 21st-century competencies (Velina et al., 2018; Utami et al., 2024).

One of the important competencies focused on in modern education is critical thinking skills. This ability encompasses the processes of analysis, evaluation, interpretation, and drawing conclusions based on valid evidence. The low critical thinking skills of students in Indonesia remain a serious problem, as demonstrated by various international research and assessments. Recent studies reveal that many students still struggle with lower-level thinking, making it difficult to solve complex and contextual problems. Therefore, a learning approach that stimulates higher-level cognitive activity is needed, one example of which is the application of real-world problem-based PjBL (Yafie et al., 2020; Suastra & Ristiati, 2019).

In addition to critical thinking skills, another equally important aspect of learning is scientific attitude. Scientific attitude reflects students' character in approaching phenomena and problems objectively, openly, honestly, and with a strong sense of curiosity (Garrison, 1992; Manurung, 2012; Saleh, 2013). Indicators of scientific attitude include curiosity, openness to facts, perseverance, and concern for the environment. Research shows that students' scientific attitudes are still relatively low, necessitating learning innovations that can systematically cultivate these values. In this regard, PjBL holds great potential because it actively engages students in the scientific inquiry process, fostering a scientific attitude through hands-on experience.

However, the implementation of PjBL will be more effective if contextualized with students' real-life contexts, one way of doing this is through the integration of local potential or local wisdom. Local potential encompasses cultural values, traditions, the environment, and resources found in a region that can be used as learning resources (Parmiti et al., 2021). Integrating local potential into learning provides a more meaningful learning experience because students can relate the subject matter to their daily lives. This aligns with the principles of contextual learning, which emphasize the relevance of learning materials to students' social and cultural realities.

Several recent studies have shown that integrating local wisdom into PjBL can significantly improve the quality of learning. For example, a systematic study by Aulia et al. (2026) found that PjBL based on local wisdom is effective in improving students' critical thinking skills, creativity, and environmental awareness. Furthermore, other research has shown that learning based on local potential can strengthen conceptual understanding and build students' character, leading to greater concern for the local environment and culture (Mustika et al., 2020). Thus, the integration of local potential not only serves as a learning context but also as a means of cultural preservation and strengthening local identity.

Furthermore, the integration of local potential in PjBL also positively impacts other 21st-century skills, such as collaboration and creativity (Yahya, 2014). Project-based learning with a local context encourages students to work together to solve real-life problems relevant to their environment. This not only improves social skills but also strengthens students' emotional engagement in the learning process. Research by Anwar et al. (2024) shows that the integration of local wisdom in PjBL significantly improves students' critical thinking, collaboration, and creativity.

On the other hand, although various studies have proven the effectiveness of Project-Based Learning (PjBL) and the integration of local potential, its implementation in schools still faces various challenges (Purnama, 2023; Henri & Pelletier, 1991). Some of these include teachers' limited understanding of project-based learning design, a lack of locally based learning resources, and minimal institutional support. Therefore, further research is needed to empirically examine how the integration of local potential in Project-Based Learning (PjBL) can be implemented effectively, particularly in improving students' critical thinking skills and scientific attitudes at the secondary school level (Nurhamidah & Nurachadijat, 2023; Budiyanti & Utami, 2024).

SMAN 1 Darussalam, as an educational institution, possesses local potential that can be integrated into learning, including cultural, environmental, and social aspects. Utilizing this local potential in the PjBL model is expected to create more contextual, meaningful, and relevant learning for students. Thus, students not only gain theoretical knowledge but also are able to apply it in real life and develop scientific attitudes and critical thinking skills (As'ari et al., 2023; Fadholi & Mahmud, 2024).

Based on this description, it can be concluded that integrating local potential in Project-Based Learning is a potential approach to improving the quality of learning, particularly in developing students' critical thinking skills and scientific attitudes (Wahyuni & Fitriana, 2021). Therefore, this research is crucial to conduct in-depth to examine the impact of integrating local potential into PjBL on students' critical thinking skills and scientific attitudes at SMAN 1 Darussalam. The results are expected to contribute to the development of innovative learning models relevant to the needs of 21st-century education and the local Indonesian context (Mariskhantari et al., 2022; Sidampoi et al., 2024; Anggraini et al., 2021).

Method

This research methodology used a quantitative approach with a quasi-experimental pretest-posttest design to examine the effect of implementing a Project-Based Learning (PjBL) model based on local potential on students' critical thinking skills and scientific attitudes (Lubis, 2018; Suharjito, 2019; Putro et al., 2020). This design was chosen because it allowed researchers to systematically measure changes in students' abilities before and after treatment, allowing for empirical analysis of the effectiveness of the learning intervention.

The research was conducted in the odd semester of the 2025/2026 academic year at SMAN 1 Darussalam, encompassing data collection, analysis, and reporting. The study population included all 35 tenth-grade students. The sampling technique used total sampling, thus utilizing the entire population as the research sample. This aimed to obtain a comprehensive picture of the impact of implementing the PjBL model within a complete classroom context.

Data collection was conducted using several instruments: a biotechnology teaching module as a learning tool, a critical thinking ability test, and an instrument for measuring scientific attitudes (Nurazizah & Nurjaman, 2018; Ratnasari et al., 2018; Susilawati, 2022). The critical thinking test consisted of a pretest and posttest to measure students' analytical skills related to conventional and modern biotechnology concepts. Meanwhile, students' scientific attitudes were measured through observations and tests that included indicators of curiosity, openness, and objectivity.

The research procedure consisted of three main stages: preparation, implementation, and data processing. Data on critical thinking skills and scientific attitudes were obtained by comparing pretest and posttest scores, then analyzed to determine the level of improvement. Data analysis was conducted quantitatively by calculating the mean, standard deviation, and standard error. Furthermore, learning outcomes were analyzed using the normalized gain index (N-gain) with categories of low, medium, and high (Mulyono & Agustin, 2020; Winarti et al., 2022).

The instrument's validity and reliability were tested through a pilot test on students at SMAN 1 Darussalam, who had similar characteristics to the research subjects. The data were analyzed using Microsoft Excel 2019, SPSS version 29.0, and Anates version 4. Therefore, this methodology was designed to ensure the accuracy, consistency, and validity of the research results in measuring the effectiveness of the implementation of locally-based PjBL.

Result and Discussion

Research Data Description

Test testing and analysis were conducted through the following stages: calculating test validity, item reliability, difficulty level, and discriminatory power using SPSS 29.0. The test results indicated that the questions in the research instrument met the criteria and were suitable for use in the study. The following summarizes the results of the research instrument trial:

Table 1. Data Validity Results

Discrimination Index	Correlation	Difficulty Level	Remarks
0.51	0.45	Moderate	Used
0.66	0.611	Easy	Used
0.66	0.37	Easy	Used
0.60	-0.155	Moderate	Used after revision
0.66	0.21	Easy	Used
0.54	0.475	Moderate	Used
0.49	0.489	Moderate	Used
0.89	-0.009	Very Easy	Not used
0.63	0.458	Easy	Used
0.37	0.291	Difficult	Not used
0.60	-0.479	Moderate	Used
0.34	-0.143	Difficult	Used after revision
0.57	0.604	Moderate	Used
0.71	0.287	Easy	Used
0.77	0.365	Easy	Used after revision
0.60	0.453	Moderate	Used
0.63	0.418	Easy	Used
0.71	0.343	Easy	Used
0.66	0.517	Easy	Used
0.51	0.297	Moderate	Used
0.69	0.404	Easy	Used
0.51	0.627	Moderate	Used
0.54	0.487	Moderate	Used
0.57	0.194	Moderate	Used
0.54	0.258	Moderate	Used
0.66	0.084	Easy	Used
0.46	0.34	Moderate	Used
0.74	0.541	Easy	Used
0.63	0.444	Easy	Used
0.46	0.251	Moderate	Used
0.57	-0.408	Moderate	Used after revision
0.60	0.518	Moderate	Used
0.54	0.233	Moderate	Used
0.69	0.213	Easy	Used
0.60	0.155	Moderate	Used
0.40	0.285	Moderate	Used
0.63	0.418	Easy	Used
0.74	0.439	Easy	Used after revision
0.74	0.251	Easy	Used after revision
0.71	0.511	Easy	Used

Table 1 above shows that of the 40 test questions, only 3 were not used because they were deemed too difficult for students. Thus, 37 questions could be used in the learning process.

The testing and analysis of the instrument refer to Arikunto (2009). The steps to produce a truly sound instrument and ensure data validity include the following tests:

Validity Test

In this study, researchers used a questionnaire consisting of 40 statements about students' critical thinking skills in biology learning, specifically on biotechnology (Insyasiska et al., 2017; Facione, 1990). To measure validity, researchers distributed the questionnaires to students, then entered the results into a table to calculate the correlation coefficient. The coefficient results from this study were statistically tested using the Anates application. Interpretation of correlation coefficient values can be done based on the following criteria according to Arikunto (2009): (a) Between 0.800 and 1.000 = Very High, (b) Between 0.600 and 0.799 = High, (c) Between 0.400 and 0.599 = Fair, (d) Between 0.200 and 0.399 = Low, (e) Between 0.000 and 0.199 = Very Low.

Based on the test results and correlation calculations, the validation coefficients for each item on the student critical thinking test are as follows:

Table 2. Summary of the Validity Results of the Student Critical Thinking Test

Validity Interpretation	Item Numbers	Total	Percentage
Very High	–	0	0%
High	2, 22, 3	3	7.5%
Moderate	1, 6, 7, 9, 16, 17, 19, 21, 23, 28, 29, 32, 37, 38, 40	15	37.5%
Low	3, 5, 10, 14, 15, 18, 20, 25, 27, 30, 33, 34, 36, 39	14	35.0%
Very Low	4, 8, 11, 12, 24, 26, 31, 35	8	20.0%
Total		40	100%

Reliability Testing

Reliability testing can be conducted after all statement items have been validated. This reliability test is conducted to determine the extent to which the measurement results remain consistent and reliable. After the researcher completed distributing the questionnaire and obtained the results, the researcher then entered the data into the reliability test formula using SPSS 25.0. This instrument is considered reliable if the α value is greater than r table (0.666).

This reliability test was conducted using Cronbach's alpha using SPSS 25.0. The test results can be seen in the table 3. Based on table 3, it can be seen that the alpha value for the variable, namely the critical thinking ability variable, obtained an alpha value of 0.772. At a significance level of α = 0.05 or a significance level of 5%, it was found that the reliability measurement α > r table where r table on the same number of samples was 0.632, thus it can be concluded that all statement items were declared reliable.

Table 3. Reliability Test Results

Variable	Cronbach's Alpha	r-table	Remarks
Critical thinking ability	0.789	0.632	Reliable

Difficulty Level

Calculate the difficulty level using Anates. The difficulty level criteria used are based on Arikunto's (2009) opinion: (a) Questions with a P of 0.00 to 0.29 are considered difficult. (b) Questions with a P of 0.30 to 0.69 are considered moderate. (c) Questions with a P of 0.70 to 1.00 are considered easy.

Based on the test results and correlation calculations, the difficulty level for each item on the critical thinking test is as follows:

Table 4. Summary of Results of the Difficulty Level of Students' Critical Thinking Test Questions

Difficulty Level Interpretation	Item Numbers	Total	Percentage
Difficult	10, 12	2	5%
Moderate	1, 4, 6, 7, 11, 13, 16, 20, 22, 23, 24, 25, 27, 30, 31, 32, 33, 35, 36, 37	20	50%
Easy	2, 3, 5, 8, 9, 14, 15, 17, 18, 19, 21, 26, 28, 29, 34, 38, 39, 40	18	45%
Total		40	100%

Discriminating Power

Calculate discriminating power using Anates. The criteria for the level of discriminating power used are based on Arikunto's (2009) opinion: (a) D = 0.00 to 0.20 is Poor. (b) D = 0.21 to 0.40 is Adequate. (c) D = 0.41 to 0.70 is Good. (d) D = 0.71 to 1.00 is Excellent.

Based on the results of the testing and calculation of discriminating power, the discriminating power for each item on the student critical thinking test is as follows:

Table 5. Summary of the Results of the Discriminating Power of Student Critical Thinking Test Items

Discrimination Index Interpretation	Item Numbers	Total	Percentage
Very Good	8, 14, 15, 18, 28, 38, 38, 40	8	20%
Good	1, 2, 3, 4, 5, 6, 7, 9, 11, 13, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 32, 34, 35, 37	29	72.5%
Fair	10, 12, 36	3	7.5%
Poor	–	0	0%
Total			

Students' Critical Thinking Skills

Data on students' critical thinking skills were obtained through tests administered before and after learning (pre-test) and after learning (post-test). Based on the data analysis, the average (mean), highest score, lowest score, and standard deviation were obtained, indicating the level of variation in the student data. The following data on students' critical thinking skills on conventional biotechnology material in making Pliek U were obtained from the results of the pre-test and post-test (Mardatillah, 2024). The collected data were then calculated using SPSS 29.0. The results of the study showed an increase in scores from the pre-test to the post-test. For more clarity, the students' critical thinking data for the pre-test and post-test are presented in the following table:

Table 6. Descriptive Statistics of Students' Critical Thinking Pre-Test and Post-Test Scores

Test Type	N	Ideal Score	Min Score	Max Score	Mean	Std. Deviation
Pre-Test	35	40	13	20	17.63	1.497
Post-Test	35	40	34	40	37.71	1.655
N-Gain	–	–	0.75	1.00	0.897	0.074

Based on Table 6 above, the average pre-test score of the students in the study sample was 17.63, increasing to 37.71 after using problem-based learning on conventional biotechnology material on making Pliek U. The table above shows the average N-Gain value of 0.897 and the standard deviation of 0.074.

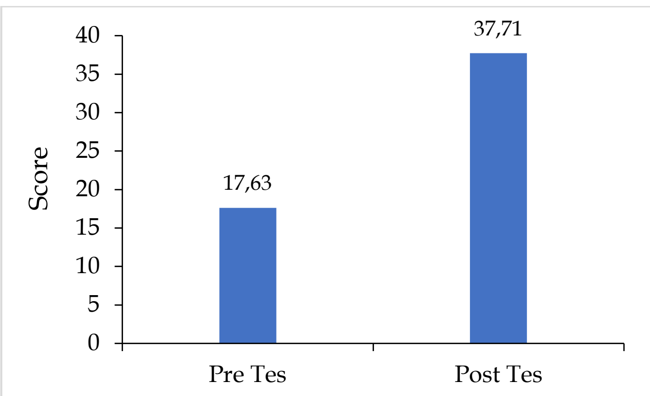

Figure 1. Pre-test and Post-test scores of students' critical thinking skills

Descriptive pre-test and post-test scores for learning on conventional biotechnology material on making Pliek U are shown in the figure 1. Based on the figure 1, the increase in the average score from the pre-test to the post-test was very significant after the learning process, thus PjBL learning is very suitable to be applied to the biotechnology learning process, especially in conventional biotechnology material for making Pliek U.

Analysis of students' critical thinking skills across 5 indicator groups

Analysis of critical thinking skill improvement was conducted by calculating the N-Gain score for each critical thinking indicator group based on Robert Ennis's definition, namely: (1) Providing simple explanations, (2) Building basic skills, (3) Summarizing, (4) Providing further explanations, and (5) Organizing strategies and tactics. Based on the research results, students' critical thinking skills were as follows:

Table 7. Descriptive Statistics of Students' Pre-Test and Post-Test Critical Thinking N-Gain Scores

Improvement per Indicator	Pre-Test	Post-Test	Gain (Post–Pre)	Ideal Score	N-Gain	N-Gain (%)
Providing Simple Explanations	44.643	95.714	51.071	55.36	0.9226	92.258%
Building Basic Skills	42.143	93.929	51.786	57.86	0.8951	89.506%
Drawing Conclusions	41.786	94.286	52.500	58.21	0.9018	90.184%
Providing Further Explanations	42.500	93.929	51.429	57.50	0.8944	89.441%
Managing Strategies and Tactics	49.643	93.571	43.929	50.36	0.8723	87.234%

Based on table 7 above, it can be seen that there was an increase in the pre-test and post-test scores for each student's critical thinking indicator, resulting in a difference in the N-gain value for each student's critical thinking indicator.

Students' Scientific Attitude

Data on students' scientific attitudes were obtained through observations conducted on each student using observation sheets before and after the lesson (pre-test) and after the lesson (post-test). Based on the data analysis, the average (mean), highest score, lowest score, and standard deviation were obtained. The following data on observations of students' scientific attitudes in conventional biotechnology learning, particularly in the production of Pliek U, were obtained from the initial and final observations. The collected data were then calculated using SPSS 29.0. The results of the study indicate an increase in scores from the pre-test to the post-test. For further clarity, the data on students' critical thinking skills in the pre-test and post-test are presented in the following table:

Table 8. Descriptive Statistics of Pre-Test and Post-Test Observation Scores for Students' Scientific Attitudes

Test Type	N	Ideal Score	Min Score	Max Score	Mean	Std. Deviation
Pre-Test	35	40	9	25	17.49	3.518
Post-Test	35	40	36	32	29.51	1.755
N-Gain	–	–	0.43	1.00	0.808	0.151

Based on Table 8 above, it is known that the average score of students’ scientific attitudes in the pre-test was 17.49. After the implementation of problem-based learning on the topic of conventional biotechnology, specifically the production of Pliek U, the average score increased to 29.51. Furthermore, the table shows that the mean N-Gain value is 0.808 with a standard deviation of 0.151.

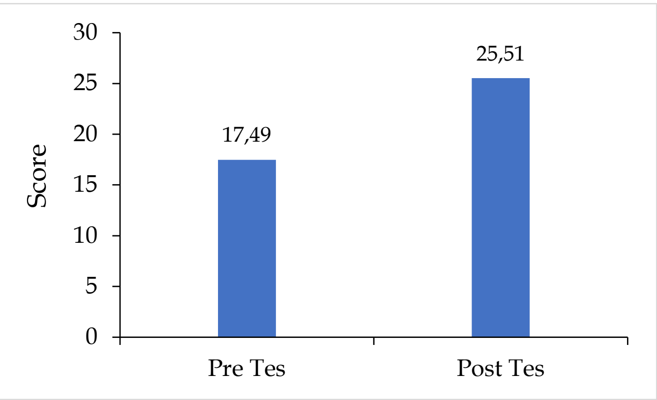

Figure 2. Pre-test and post-test observation scores of students’ scientific attitudes

The descriptive scores of students’ scientific attitudes in the pre-test and post-test on the conventional biotechnology topic of Pliek U production are presented in the figure 2. Based on the figure 2, there is a clear increase in the average scores of students’ scientific attitudes from the pre-test to the post-test following the implementation of the learning process. This indicates that students’ scientific attitudes improved through the application of Project-Based Learning (PjBL), particularly in biotechnology learning, specifically on the topic of conventional biotechnology in the production of *Pliek U*

Analysis of Students’ Scientific Attitudes Based on Six Indicator Groups

The analysis of the improvement in students’ scientific attitudes was conducted by calculating the N-Gain value for each indicator group. These indicators are based on the framework proposed by Harlen, as cited in Dimyati and Mudjiono (2004: 141–150), which includes: (1) Curiosity, (2) Critical Thinking, (3) Environmental Awareness, (4) Perseverance, (5) Open-mindedness, and (6) Cooperation.

Based on the results of the study, the improvement in students’ scientific attitudes is presented as follows:

Table 9. Descriptive Statistics of N-Gain Scores from the Observation of Students’ Scientific Attitudes

Improvement per Indicator	Pre-Test	Post-Test	Gain (Post–Pre)	Ideal Score	N-Gain	N-Gain (%)
Curiosity	52.86	93.21	40.36	47.14	0.86	85.61%
Critical Thinking	59.29	97.14	37.86	40.71	0.93	92.98%
Environmental Awareness	52.86	87.88	35.00	47.14	0.74	74.24%
Perseverance	56.43	94.29	37.86	43.57	0.87	86.89%
Open-mindedness	52.86	95.71	42.86	47.14	0.91	90.91%
Cooperation	69.29	88.57	19.29	30.71	0.63	62.79%

Based on Table 9, it can be observed that there is an increase in both pre-test and post-test scores across each indicator of students’ scientific attitudes. Consequently, there are variations in the N-Gain values for each indicator of students’ critical thinking.

In addition to supporting the theories proposed by Ennis and Harlen, the findings of this study are also consistent with the principles of constructivist learning, which emphasize that knowledge is more effectively understood when students are actively involved in the learning process. The Project-Based Learning (PjBL) model provides opportunities for students to construct knowledge through direct experience, thereby not only enhancing conceptual understanding but also fostering students' critical thinking skills and scientific attitudes.

Thus, the results of this study reinforce the theories of Ennis and Harlen, which suggest that learning approaches involving active student participation and problem-centered activities can significantly improve students' critical thinking abilities and scientific attitudes.

However, the implementation of Project-Based Learning (PjBL) integrated with local potential in biotechnology learning also revealed several challenges encountered by teachers during the instructional process (Husna et al., 2024). These challenges are related to students' readiness, time constraints, availability of facilities and infrastructure, as well as classroom management.

Conclusion

Based on the results and discussion of the study, it can be concluded that the research instrument used was valid and reliable, as evidenced by the results of validity, reliability, difficulty level, and discriminating power tests. Out of 40 items, 37 were declared suitable for use, with the majority having moderate to easy difficulty levels and good to very good discriminating power. The reliability test also showed that the instrument met the criteria for consistency, indicating that it was appropriate for measuring students' critical thinking skills. The implementation of Project-Based Learning (PjBL) based on local potential in biotechnology learning, specifically on the topic of conventional biotechnology in making Pliek U, was proven to significantly improve students' critical thinking skills. This is indicated by the increase in the average pre-test score (17.63) to the post-test score (37.71), with a high N-Gain value of 0.897. Furthermore, improvements occurred across all critical thinking indicators, including providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and managing strategies and tactics, all of which showed high N-Gain categories. In addition, students' scientific attitudes also showed significant improvement after the implementation of PjBL. The average score increased from 17.49 in the pre-test to 29.51 in the post-test, with an N-Gain value of 0.808, indicating a high level of improvement. This enhancement was observed across all six indicators of scientific attitude, namely curiosity, critical thinking, environmental awareness, perseverance, open-mindedness, and cooperation, although with varying levels of improvement. Overall, the findings confirm that the integration of local potential within the PjBL model effectively enhances both students' critical thinking skills and scientific attitudes. These results are in line with constructivist learning theory as well as the perspectives of Ennis and Harlen, which emphasize active, problem-based learning. However, the implementation of this model also presents several challenges, including students' readiness, limited instructional time, inadequate facilities, and classroom management issues, which need to be addressed for optimal learning outcomes.

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Author Contributions

Conceptualization, methodology, draft editing, data collection, writing original draft, R. and E.A.; data verification, writing review, N.A., J.F., and I. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

All author declares no conflict of interest.

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