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Implementation of STEM-Integrated Project-Based Learning Tools Based on Local Content (Jambi Coffee) to Improve Student Learning Outcomes

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Abstract

This study aimed to investigate the effectiveness of Project-Based Learning (PjBL) tools integrated with STEM and local content—specifically the cultural practice of Jambi coffee brewing—in enhancing students' learning outcomes in the physics topic of temperature and heat. The research employed a quasi-experimental method using a non-equivalent control group design. The participants were 11th-grade students from SMA Negeri 11 Muaro Jambi in the 2024/2025 academic year, selected through purposive sampling. A total of 54 students participated, divided evenly into two classes: the experimental class, which was taught using STEM-integrated PjBL tools incorporating local content, and the control class, which was taught using conventional PjBL tools without STEM or local context integration. Both groups underwent pretest and posttest assessments. Data were analyzed using paired sample t-tests and independent sample t-tests with a significance level of 0.05. The paired t-test results indicated a statistically significant improvement in both classes ($p = 0.000$). However, the independent sample t-test revealed a significant difference in posttest scores between the two groups ($p = 0.011$), with the experimental class showing greater gains. These results suggest that the integration of STEM and local cultural context into PjBL can deepen students' conceptual understanding, enhance engagement, and improve learning outcomes more effectively than PjBL alone. The contextualization of physics content using familiar real-world practices, such as coffee brewing, provides meaningful learning experiences that connect abstract scientific concepts to students' daily lives.

Keywords: Learning Tools, Project-based learning; STEM Education, Local content, Jambi coffee; Learning outcomes

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INTRODUCTION

Twenty-first century education requires students to develop higher-order thinking skills, including critical thinking, creativity, collaboration, and communication. In science education, these skills are crucial for helping students understand, connect, and apply scientific concepts in real-world contexts. Physics, as a branch of natural sciences, is not only studied to understand the laws of nature but also serves as a medium to develop scientific problem-solving abilities. It plays a vital role in building students' foundational understanding of phenomena such as motion, force, energy, heat, temperature, and other aspects of daily life.

According to the Ministry of Education and Culture (Kemendikbud, 2022), physics is taught as a standalone subject at the senior high school level for two key reasons: first, to enable students to apply scientific reasoning in addressing real-world problems; and second, to prepare them for higher education in science, engineering, and technology-related disciplines. Therefore, physics instruction should not merely focus on delivering theoretical knowledge but must also foster students' scientific thinking skills through contextualized and meaningful learning experiences.

The selection of appropriate instructional models is a critical component of effective learning design. One model that aligns with 21st-century learning characteristics is Project-Based Learning (PjBL). This model emphasizes active student engagement through the design and implementation of projects rooted in real-life issues. PjBL allows students to construct new knowledge through guided inquiry and practical experience (Muhali, 2019). Through this approach, learners develop not only cognitive understanding but also critical thinking, collaboration, and problem-solving skills (Solehah & Carolina, 2023).

Effective implementation of instructional models requires the support of well-structured learning tools. Teaching materials such as lesson modules and student worksheets (LKPD) serve as essential tools in directing the teaching and learning process. According to Nasution et al. (2023), such tools facilitate two-way communication between teachers and students and foster dynamic classroom interactions. They also provide students with structured guidance throughout each phase of the learning process, particularly in project-based activities.

Given that many physics concepts are abstract and often perceived as difficult by students, integrating the STEM approach—Science, Technology, Engineering, and Mathematics—into physics instruction offers a promising solution. The STEM approach emphasizes interdisciplinary integration to develop comprehensive solutions to complex problems. In the context of physics education, STEM integration enables students to apply theoretical concepts to practical projects involving planning, measurement, calculations, and the use of technology (Samsudin et al., 2020). This approach also supports the development of 21st-century skills that are increasingly necessary in today's digital and professional environments (Mahrunnisya, 2023).

Combining PjBL with STEM leads to a more meaningful and applicable learning experience. This hybrid model moves beyond rote learning by allowing students to create real-world projects that apply the physics concepts they have studied. It promotes active participation, student autonomy, and inquiry-based learning. Through real-life problem-solving tasks, students are guided to think systematically and analytically, from problem identification to designing and evaluating solutions.

To further enhance relevance, project-based STEM learning can be contextualized by incorporating local content. Using familiar local contexts helps bridge the gap between abstract theory and everyday experiences, making learning more relatable. According to Amaliyah et al. (2023), integrating cultural and local values into the learning process strengthens student engagement, increases motivation, and reinforces cultural identity.

In the context of Jambi Province, one example of potential local content that can be integrated into physics instruction is the coffee brewing process. Jambi coffee is not only economically significant but also offers learning opportunities related to heat transfer, temperature changes, and energy transformations. For example, during the coffee brewing process, heat is transferred from hot water to the coffee grounds—a phenomenon that can be explored through conduction and convection theories. Students can analyze such everyday phenomena through hands-on projects that apply their understanding of temperature and heat.

Preliminary observations and interviews conducted at SMA Negeri 11 Muaro Jambi revealed that while project-based instruction has been previously implemented, it has not fully integrated STEM elements or local content. Moreover, many 11th-grade students have not yet achieved the minimum learning outcomes in physics. Survey data indicated that only 50% of students felt assisted by the teacher's use of LKPD. These findings suggest a need for improved, contextualized instructional tools. Additionally, students noted that connecting physics concepts with local content, such as Jambi coffee, helped them better understand the subject matter.

This observation is consistent with findings by Ata et al. (2023), who reported that implementing PjBL-STEM improved students' critical thinking skills and curiosity. Moreover, integrating local content served not only as a contextual anchor but also as a source of motivation and deeper conceptual understanding (Lado et al., 2022). Fauzi et al. (2022) emphasized that physics learning enriched with local wisdom significantly enhances the meaningfulness of science education and captures students' attention and interest. Furthermore, a meta-analysis by Izzah et al. (2021) concluded that the PjBL model significantly improves students' learning outcomes, especially in cognitive domains, and is particularly effective when applied at the senior high school level, specifically in grade XI.

Based on the above rationale, this study aims to implement PjBL instructional tools integrated with the STEM approach and local content (Jambi coffee) in the teaching of physics—specifically in the topic of temperature and heat. The implementation is expected to enhance students' learning outcomes and foster critical thinking and problem-solving skills. By integrating real-world, multidisciplinary, and culturally relevant learning experiences, the study seeks to provide students with deeper, more engaging, and sustainable science education.

METHODS

This study employed a quantitative approach using a quasi-experimental method with a non-equivalent control group design, consisting of two groups: the experimental group and the control group. The subjects were not randomly assigned to the groups (Sugiyono, 2013). Both groups were given a pretest to assess students' initial knowledge on the topic of temperature and heat. Afterward, each group received different treatments: the experimental group was taught using a Project-Based Learning (PjBL) model integrated with STEM and local content (Jambi coffee), while the control group used a PjBL model without STEM or local content integration. A posttest was administered to both groups to evaluate the impact of the learning tools on student learning outcomes regarding the topic.

The population of the study comprised 11th-grade students (Phase F) at SMA Negeri 11 Muaro Jambi during the 2024/2025 academic year. The sample included two classes: XI F 1A (control group) and XI F 1B (experimental group), selected through purposive sampling. The criteria included students being taught by the same physics teacher, ensuring uniformity in instructional methods and materials, and students from the same academic level with equivalent academic achievement, with no special or high-performing class involved.

Data collection methods included interviews, questionnaires, and tests (pretest and posttest). Interviews and questionnaires were conducted to gather initial information about students' perceptions of the PjBL-STEM learning tools based on local content. The learning outcome tests were adapted from Handayani (2021) in the form of multiple-choice questions, targeting the cognitive domains of understanding (C2), application (C3), and analysis (C4) in the topic of temperature and heat. Both groups used the same test instruments.

The collected test data were statistically analyzed using parametric tests, specifically the t-test with a significance level of $\alpha = 0.05$. Data analysis was conducted using IBM SPSS Statistics 27. Two types of t-tests were employed: paired sample t-test to determine the significance of improvement within each group (pretest vs. posttest), and independent sample t-test to compare learning outcomes between the experimental and control groups. Before conducting the t-tests, prerequisite tests for normality and homogeneity were performed.

The instructional tools used in this study were adapted from the learning tools developed by Agustina (2024), which were originally designed under the 2013 curriculum. In line with the Ministerial Regulation No. 12 of 2024, which officially established the *Merdeka Curriculum* as the national curriculum, a validation process was required to adjust the instructional tools accordingly. The tools were developed for both experimental and control classes, including teaching modules and LKPD (student worksheets).

The modules for both groups were developed based on the *Alur Tujuan Pembelajaran* (Learning Objectives Flow) and instructional module templates provided by the Ministry of Education. The experimental class used a PjBL model integrated with STEM and local content (Jambi coffee), while the control class used a standard PjBL model without such integration. The validation checklist for the teaching modules is outlined in Table 1.

Table 1. Validation indicators for teaching modules

No	Indicator	Item Count	Statement Numbers
General Information			
1	Module Identity	1	1
2	Prior Competencies	1	2
3	Pancasila Student Profile	1	3
4	Facilities and Infrastructure	2	4, 5
5	Target Learners	3	6, 7, 8
6	Learning Model	1	9
7	Completeness of Learning Materials	3	10, 11, 12
Core Components			
1	Learning Outcomes	2	1, 2
2	Meaningful Understanding	1	3
3	Trigger Questions	1	4
4	Learning Activities	4	5, 6, 7, 8
5	Assessment	7	9–15
6	Remedial and Enrichment	2	16, 17
7	Teacher and Student Reflection	2	18, 19
8	Glossary	1	20
9	References	1	21
Appendices			

No	Indicator	Item Count	Statement Numbers
1	Student Worksheet or Task Sheet	1	1
2	Learning Material	1	2

The assessment scale used for validation followed a Likert scale, as shown in Table 2 (Source: Lubis, 2023).

Table 2. Scoring scale for module validation

Score	Category
1	Not Present / Not Appropriate
2	Incomplete / Less Appropriate
3	Appropriate
4	Very Appropriate

In addition to the teaching modules, the student worksheets (LKPD) were validated to ensure they met quality standards and were suitable for instructional use. The validation focused on content accuracy and clarity. The indicators for LKPD validation are presented in Table 3.

Table 3. Validation indicators for LKPD

No	Indicator	Item Count	Statement Numbers
1	Construction	4	1–4
2	Language	3	5–7
3	Content	2	8–9

The scoring scale for LKPD validation followed the criteria in Table 4.

Table 4. Scoring scale for LKPD validation

Score	Category
1	Poor
2	Fair
3	Good
4	Excellent

The data from both module and LKPD validation were analyzed to determine the eligibility of the products for instructional use. The total score for each indicator was converted into a percentage using the formula:

Percentage Score = (Total Score / Maximum Score) × 100%

The resulting percentage was then categorized according to the criteria in Table 5 (Source: Setiawan & Wiyardi, 2015).

Table 5. Eligibility criteria based on percentage

Score Interval	Eligibility Category
81%–100%	Very Eligible
61%–80%	Eligible
41%–60%	Moderately Eligible
21%–40%	Less Eligible
<20%	Not Eligible

RESULTS AND DISCUSSION

Product Validation Results

The learning tools validated in this study included teaching modules and student worksheets (LKPD), developed to support the learning process. Validation was carried out by two physics education lecturers as expert validators.

Validation of Experimental Class Teaching Module

The experimental class teaching module was designed using a Project-Based Learning (PjBL) model integrated with STEM and local content (Jambi coffee). The validation process involved two phases: initial review and post-revision. Each aspect (general information, core components, and appendices) was assessed and converted into a percentage score.

Figure 1. Experimental class teaching module

Table 6. Validation results of experimental class module by validator 1

No	Component	Phase I	Phase II	Category
1	General Info	93.75%	100%	Very Eligible
2	Core Components	100%	100%	Very Eligible
3	Appendices	87.5%	87.5%	Very Eligible
	Average	93.75%	95.83%	Very Eligible

Validation in the first phase involved improvements related to the adjustment of the PjBL stages integrated with STEM and local content. In the second phase, following revisions, the percentage of eligibility in the general information aspect increased to 100%, with the average percentage of module eligibility across all aspects reaching 95.83%, categorized as very eligible.

The results of the experimental class teaching module validation by the second validator, analyzed in percentage form, are presented in the Table 7.

Table 7. Validation results of experimental class module by validator 2

No	Component	Phase I	Phase II	Category
1	General Info	97.91%	97.91%	Very Eligible
2	Core Components	81.57%	96.05%	Very Eligible
3	Appendices	50%	87.5%	Very Eligible
	Average	76.49%	93.82%	Very Eligible

Based on Table 7, the first-phase validation of the experimental class teaching module by the second validator revealed a lack of clarity in the meaningful understanding component aligned with the learning objectives. In the appendices aspect, the eligibility percentage was only 50%, categorized as moderately eligible. Several appendices needed to be completed, such as presentation assessments, assignments, and enrichment evaluations. In the second-phase validation, following revisions, the percentage for core components increased to 96.05%, and the appendices aspect rose to 87.50%, both categorized as very eligible.

Overall, the validation results of the experimental class teaching module by both validators were classified as very eligible. These assessments indicate that the developed teaching module is appropriate for use as a learning tool and can be implemented to improve students' learning outcomes on the topic of temperature and heat.

Validation of Control Class Teaching Module

The control class module was based on a standard PjBL approach. Similar validation procedures were applied.

Table 8. Validation results by validator 1

Component	Score	Category
General Info	100%	Very Eligible
Core Components	100%	Very Eligible
Appendices	87.5%	Very Eligible
Average	95.83%	Very Eligible

Based on the validation percentage results of the control class teaching module by the first validator, the overall average score across all aspects was 95.83%, categorized as very eligible.

The validation results of the control class teaching module were not significantly different from the validation results of the experimental class module by the second validator. The validation data were analyzed in percentage form. The eligibility percentage of the control class module validation by the second validator is presented in Table 9.

Table 9. Validation results by validator 2

Component	Phase I	Phase II	Category
General Info	97.91%	97.91%	Very Eligible
Core Components	81.57%	96.05%	Very Eligible
Appendices	50%	87.5%	Very Eligible
Average	76.49%	93.82%	Very Eligible

Based on Table 9, the average eligibility percentage across the three aspects in Phase I was 76.49%, categorized as eligible. There were notes for improvement, particularly regarding a lack of clarity in the meaningful understanding component aligned with the learning objectives. Several appendices also needed to be completed, similar to the experimental class module. After revisions and Phase II validation, the average eligibility percentage increased to 93.82%, categorized as very eligible.

Overall, the validation assessments of the control class teaching module by both validators classified the module as very eligible. It can be concluded that the control class teaching module, developed using the PjBL approach for the topic of temperature and heat, is appropriate for use as a learning tool.

Validation of Student Worksheet (LKPD) in the Experimental Class

The Student Worksheet (LKPD) used in the experimental class was an integral part of the experimental module, designed based on the stages of Project-Based Learning (PjBL) integrated with STEM and local content (Jambi coffee).

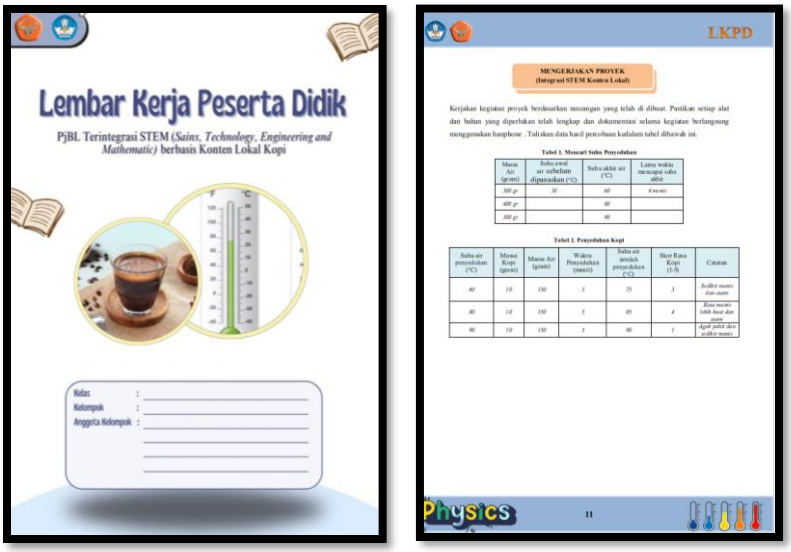

Figure 2. Student worksheet (LKPD) in the experimental class

The validation scores for each assessed aspect—format, language, and content—were converted into percentage values and categorized for eligibility, as shown in the Table 10 and Table 11.

Table 10. Validation results by validator 1

Component	Phase I	Phase II	Category
Format	100%	100%	Very Eligible
Language	100%	100%	Very Eligible
Content	81.25%	100%	Very Eligible
Average	88.19%	100%	Very Eligible

Based on Table 10, the LKPD validation score in Phase I was 88.19%, categorized as very eligible. In the content aspect, a score of 81.25% was obtained—still within the very eligible range—though revisions were required to better align the worksheet structure with the PjBL-STEM syntax and the context of local coffee. After the revisions, the content aspect improved to 100%, resulting in a perfect eligibility score across all aspects.

Table 11. Validation results by validator 2

Component	Phase I	Phase II	Category
Format	83.33%	100%	Very Eligible
Language	100%	100%	Very Eligible
Content	100%	100%	Very Eligible

Component	Phase I	Phase II	Category
Average	94.44%	100%	Very Eligible

Validator 2 suggested additional improvements such as including more illustrations in the material, adding page numbers, and differentiating covers between student and teacher versions of the LKPD. After implementing these revisions, the score for the format aspect increased to 100%, resulting in an overall validation score of 100% for all three aspects in Phase II.

The final validation results from both validators classified the experimental class LKPD as very eligible. This indicates that the LKPD based on the PjBL stages integrated with STEM and local content (Jambi coffee) on the topic of temperature and heat is suitable for classroom use.

Validation of Student Worksheet (LKPD) in the Control Class

The LKPD for the control class was developed based on the stages of Project-Based Learning (PjBL) without integration of STEM or local content. Validation data from both validators were analyzed in percentage form to determine the eligibility of the LKPD as a learning tool.

Table 12. Validation results by validator 1

Component	Score	Category
Format	100%	Very Eligible
Language	100%	Very Eligible
Content	100%	Very Eligible
Average	100%	Very Eligible

The validation results of the control class LKPD by the first validator indicated that all assessed aspects—format, language, and content—achieved perfect scores of 100%, placing the LKPD in the very eligible category.

The validation conducted by the second validator consisted of two phases: the initial review and the post-revision review. The detailed results are presented in the Table 13.

Table 13. Validation results by validator 2

Component	Phase I	Phase II	Category
Format	83.33%	100%	Very Eligible
Language	100%	100%	Very Eligible
Content	100%	100%	Very Eligible
Average	94.44%	100%	Very Eligible

The validation results from the second validator were consistent with those of the experimental class LKPD. The initial assessment showed that the format aspect required minor revisions, which were subsequently addressed. After improvements, all aspects reached 100%, indicating full eligibility.

Based on the validation results from both validators, the control class LKPD was classified as very eligible. This confirms that the developed worksheet, structured based on the PjBL model, is appropriate for use in the physics learning process.

Normality Test

The normality test was conducted to determine whether the sample data were derived from a population with a normal distribution (Supriadi, 2021). This test serves as a prerequisite before applying parametric statistical analyses, such as the t-test. The normality test was performed using the Kolmogorov–Smirnov method with the assistance of SPSS software. The results are presented in the Table 14.

Table 14. Normality test results for experimental and control classes

Group	Kolmogorov–Smirnov Statistic	df	Sig.
Pretest (Experimental)	0.163	27	0.063
Posttest (Experimental)	0.153	27	0.102
Pretest (Control)	0.155	27	0.093
Posttest (Control)	0.162	27	0.068

As shown in Table 14, all significance (Sig.) values are greater than 0.05. These results indicate that the data for both the experimental and control groups—before and after treatment—are normally distributed. Therefore, the assumptions of normality required for parametric testing are met.

Homogeneity Test

The homogeneity test was conducted to determine whether two or more groups of sample data were derived from populations with equal variances (Hajaro & Raehanah, 2021). This test is essential before performing parametric analyses, such as the independent sample t-test.

The homogeneity of the pretest data between the experimental and control classes was analyzed using Levene's Test. The results are presented in the Table 15.

Table 15. Homogeneity test results for pretest (experimental and control classes)

Test Basis	Levene Statistic	df1	df2	Sig.
Based on Mean	0.719	1	52	0.400
Based on Median	0.391	1	52	0.535
Based on Median and adjusted df	0.391	1	51.614	0.535
Based on Trimmed Mean	0.600	1	52	0.442

As shown in Table 15, the significance value based on the mean is 0.400 (> 0.05), indicating that the pretest data from the experimental and control groups have homogeneous variances.

The homogeneity test was also performed on the posttest data, and the results are shown in the Table 16.

Table 16. Homogeneity test results for posttest (experimental and control classes)

Test Basis	Levene Statistic	df1	df2	Sig.
Based on Mean	0.152	1	52	0.699
Based on Median	0.139	1	52	0.710
Based on Median and adjusted df	0.139	1	51.643	0.710
Based on Trimmed Mean	0.153	1	52	0.697

Based on Table 16, the significance value based on the mean is 0.699 (> 0.05), indicating that the posttest data between the experimental and control classes also have homogeneous variances.

Thus, it can be concluded that both the pretest and posttest data fulfill the assumption of homogeneity required for further parametric analysis.

Paired Sample t-Test

The paired sample t-test was conducted to determine whether there was a statistically significant difference between the pretest and posttest scores within each group—experimental and control. This test aims to evaluate whether the learning interventions led to measurable improvements in student learning outcomes.

Table 17. Paired sample t-test results – experimental class

Measure	Mean	SD	SE	95% Conf. Int.	t	df	Sig.
Pretest - Posttest	-46.667	16.172	3.112	[-53.064, -40.269]	-14.994	26	0.000

As shown in Table 17, the significance value (Sig. 2-tailed) is 0.000, which is less than 0.05. This indicates a significant improvement in the learning outcomes of the experimental class after the implementation of PjBL integrated with STEM and local content (Jambi coffee).

Table 18. Paired sample t-test results – control class

Measure	Mean	SD	SE	95% Conf. Int.	t	df	Sig.
Pretest - Posttest	-41.111	18.257	3.514	[-48.334, -33.889]	-11.700	26	0.000

According to Table 18, the significance value (Sig. 2-tailed) is also 0.000 (< 0.05), indicating that the control class also experienced a significant improvement in learning outcomes after treatment using the standard PjBL learning tools.

However, when comparing the mean difference in scores, the experimental class showed a greater improvement (46.667) than the control class (41.111). This suggests that while both approaches positively affected learning outcomes, the integrated PjBL-STEM approach based on local content resulted in a more substantial gain.

Independent Sample t-Test

The independent sample t-test was conducted to determine whether there was a statistically significant difference in the mean posttest scores between the experimental and control groups. This test assesses the effectiveness of the different instructional treatments applied to each group.

Table 19. Independent sample t-test results

Test Type	Levene's F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	SE Diff.
Equal variances assumed	0.152	0.699	2.629	52	0.011	8.519	3.240
Equal variances not assumed	–	–	2.629	51.658	0.011	8.519	3.240

As shown in Table 19, the Sig. (2-tailed) value in the row "Equal variances assumed" is 0.011, which is less than 0.05. This indicates that there is a statistically significant difference in learning outcomes between students who received instruction through PjBL integrated with STEM and local content (experimental class) and those who were taught using PjBL without such integration (control class).

Thus, it can be concluded that the implementation of learning tools using a PjBL model integrated with STEM and local content (Jambi coffee) had a significantly greater impact on improving students' understanding of the topic "temperature and heat" compared to PjBL alone.

Discussion

The improvement in student learning outcomes was evaluated based on the analysis of pretest and posttest data obtained from both experimental and control classes, each subjected to different learning treatments. The experimental group received instruction through Project-Based Learning (PjBL) integrated with STEM and local content (Jambi coffee), whereas the control group followed a conventional PjBL model without the integration of STEM or local cultural elements. Both groups participated in a three-session learning intervention aimed at enhancing their understanding of the physics concepts related to temperature and heat. Each meeting was structured in accordance with the syntactic steps of the PjBL model.

During the implementation, both classes began with preliminary activities such as greetings, attendance checks, and presentation of the learning objectives to prepare students for the core learning activities. Students were guided to analyze and solve contextual problems through collaborative project work using LKPD (student worksheets). In the experimental class, the problem context was derived from the local practice of coffee brewing, highlighting how heat and temperature influence the brewing process. The integration of STEM was evident in the students' need to apply scientific concepts, measure temperature with thermometers, and understand the underlying thermal dynamics. Conversely, the control class addressed general physics problems without the contextual support of STEM or local cultural integration. Throughout the sessions, students in both classes were actively involved in the learning phases.

Figure 3. The first session in the experimental class

Figure 3 illustrates the first session in the experimental class, where students were prompted with questions regarding the coffee brewing process and the types of coffee native to Jambi. Students responded by comparing ratios of coffee to water and the use of various containers. Popular local coffee brands such as "kopi bubuk paman" and "kopi bubuk cap AAA" were identified by the students. They were then divided into small groups of five to six members and assigned to analyze how water temperature affects coffee extraction. Based on this analysis, students designed a project involving different brewing temperatures. With the guidance of the LKPD, students engaged in group discussions to formulate the project's title, objectives, required materials, procedures, and the distribution of tasks among group members.

Figure 4. The second session of the experimental class.

Figure 4 depicts the second session of the experimental class, during which students executed the brewing experiments based on their prior planning. Each group member contributed to the project by taking on specific roles, though variations in group member participation levels were observed—an issue noted for future instructional reflection. Throughout the project, students explored thermal physics concepts, including heat transfer during water heating and the use of thermometers for precise temperature measurement. All project activities were documented using photos and videos to serve both as reflective material and presentation media. Upon completing the experiment, students conducted internal group discussions guided by analytical questions in the LKPD to deepen their conceptual understanding. This reflective discussion continued into the third session, which focused on preparing and delivering group presentations. Each group presented their project results, and the teacher facilitated a concluding discussion summarizing how the concepts of heat and temperature were manifested in a real-life context.

Figure 5. The first meeting in the control class

In contrast, Figure 5 shows the first meeting in the control class, where students were presented with general phenomena related to temperature and heat—such as the process of water freezing into ice and melting back into liquid form. These prompts guided students into forming groups and developing a project to demonstrate and analyze the phenomenon. Each group was provided with an LKPD to guide their planning process, which involved analyzing the problem, choosing appropriate materials and tools, and outlining the project execution steps. The students followed the PjBL stages as outlined in the worksheet.

Figure 6. The second session in the control class

Figure 6 represents the second session in the control class, in which students began the execution of their planned projects. The researcher closely observed the project work to ensure that students remained focused and engaged. After conducting the experiments, students answered the analysis questions embedded in the LKPD to assess the outcomes of their projects. The third session was dedicated to group presentations, followed by reflective evaluations where students reviewed their engagement, conceptual understanding, and how the project activities related to everyday life.

Both classes exhibited significant improvements in learning outcomes, as evidenced by the results of the paired sample t-tests. There were statistically significant differences between pretest and posttest scores in both the experimental and control groups. These findings are consistent with previous studies, such as Nusa et al. (2022), which reported that PjBL positively impacts student learning achievement. However, when comparing the magnitude of improvement between the two groups, the experimental class demonstrated higher average gains than the control class. The results of the independent sample t-test further supported this observation, revealing a statistically significant difference in posttest scores between the two classes.

The integration of STEM and local content into the PjBL framework clearly contributed to the superior performance of the experimental group. Embedding real-life, culturally relevant contexts into physics education enhanced the meaningfulness of learning, increased student engagement, and fostered deeper conceptual understanding. These findings are in line with research by Fauzi et al. (2022), which emphasized that incorporating local wisdom in science education adds relevance, attracts student interest, and serves as an effective motivational tool.

Despite the positive outcomes, the learning process in both classes posed several challenges. Implementing a PjBL approach requires thorough planning and time management. Students unfamiliar with this model initially struggled with designing project plans, especially when required to link scientific knowledge to problem-solving through STEM-based reasoning. Therefore, providing clear guidance and scaffolding is essential to help students navigate the PjBL process effectively.

Another critical insight from this study is the role of local content integration in promoting cognitive and affective learning. When students encountered scientific concepts within familiar cultural practices—such as the brewing of Jambi coffee—they were more engaged and better able to relate abstract physics principles to everyday experiences. This suggests that leveraging local context not only supports content mastery but also nurtures students' cultural identity and sense of place within the learning process.

In summary, the integration of STEM and local content within a PjBL framework significantly enhanced student engagement and learning outcomes. The experimental group's experience with a culturally contextualized project allowed for greater conceptual internalization and practical application of knowledge. While both instructional approaches led to learning improvements, the contextualized PjBL-STEM model proved more effective. These findings reinforce the value of culturally responsive and interdisciplinary pedagogy in science education and highlight the potential of local content as a powerful vehicle for meaningful learning.

CONCLUSION

The results of the data analysis indicate that there was an improvement in student learning outcomes following the implementation of Project-Based Learning (PjBL) tools integrated with STEM and local content (Jambi coffee) on the topic of temperature and heat. This improvement was supported by the results of the paired sample t-test, which revealed a significant difference between the pretest and posttest scores, with a Sig. (2-tailed) value of $0.000 < 0.05$. This finding confirms that the use of PjBL integrated with STEM and local content positively influenced student achievement.

Furthermore, the results of the independent sample t-test showed a significant difference in learning outcomes between students taught using the integrated PjBL-STEM-local content model and those taught using PjBL without such integration. The independent sample t-test produced a Sig. (2-tailed) value of $0.011 < 0.05$, indicating that the learning outcomes of students differed significantly between the two groups. It can thus be concluded that the integration of STEM and local content into PjBL had a more substantial impact on improving students' understanding of physics concepts than PjBL alone.

RECOMMENDATION

Future research is encouraged to explore other local content potentials that can be integrated into Project-Based Learning (PjBL) combined with STEM approaches. Such research should not only focus on improving learning outcomes but also on enhancing students' collaborative skills. Additionally, it is recommended that further studies be conducted over a longer period of time to better understand the sustained impact of this integrated model on the consistent development of students' competencies.

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