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Empowering Higher-Order Thinking Skills: STEM-PjBL with Jambi (Malay) Local Content for Madrasah Tsanawiyah Students

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ABSTRACT

This study investigates the effectiveness of a Project-Based Learning (PjBL) model integrated with STEM and infused with local Jambi (Malay) cultural content in enhancing students' higher-order thinking Skills (HOTS) in science education at MTS Bina Insan. An experimental design using a non-equivalent control group was employed, involving two classes—experimental and control—each comprising 13 students. The experimental group received instruction through the PjBL-STEM model incorporating local content, while the control group followed traditional methods. Both groups underwent pre-tests and post-tests. Data were analyzed using normality tests and independent t-tests. Pre-test and post-test data met the assumption of normality ($p > 0.05$). An independent t-test indicated a statistically significant difference between the post-test scores of the experimental and control groups ($p < 0.005$), supporting the alternative hypothesis. The results suggest that the PjBL-STEM model, when contextualized with local Jambi culture, significantly enhances students' HOTS. The integration of cultural elements made the learning process more relevant and engaging, supporting deeper cognitive engagement. The study demonstrates that integrating local cultural content into STEM-based PjBL strategies effectively improves students' higher-order thinking skills. This finding highlights the value of culturally responsive pedagogy in creating meaningful and contextually appropriate science education.

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1. INTRODUCTION

In the 21st century, education has undergone a profound transformation, shifting its focus from traditional learning to a more comprehensive approach aimed at equipping students with essential skills for a rapidly evolving world. The primary goal of modern education is no longer just the acquisition of facts; instead, it prioritizes the development of students' ability to think critically, solve complex problems, and apply knowledge in practical, real-world contexts (Ramamonjisoa, 2024). These skills, collectively known as Higher-Order Thinking Skills (HOTS), are increasingly recognized as fundamental for effective learning, as they enable students to engage deeply with content, synthesize information, and make informed decisions. However, despite its recognized importance, implementing HOTS-based pedagogies often faces challenges, such as the need for teacher training, resource availability, and student readiness to engage in higher-level cognitive tasks. These challenges highlight the need for research into innovative and contextual approaches that make HOTS implementation more effective and sustainable.

Higher-order thinking skills are especially critical in today's globalized, knowledge-driven society, where the capacity to adapt and think creatively is vital. HOTS not only helps students master subject-specific knowledge but also prepares them to navigate the complexities of the modern world, from workplace challenges to societal issues. By fostering HOTS, educators can help students develop the intellectual flexibility and resilience needed to thrive in diverse environments, thereby ensuring that they are well-prepared to contribute meaningfully in a range of professional and personal contexts. The project-based learning model (PjBL) is one that can significantly improve students' ability to solve problems and provide a deeper comprehension of the subject (Krajcik & Blumenfeld, 2006).

Project-based learning (PjBL) is an effective pedagogical approach that significantly enhances students' critical thinking, problem-solving abilities, and the application of knowledge in real-world contexts. Research indicates that PBL fosters higher-order thinking skills by engaging students in authentic, complex projects that require them to analyze, evaluate, and synthesize information (Anazifa and Djukri, 2017; Şahin, 2024). This method encourages collaborative problem-solving, allowing students to work together to address real-life challenges, thereby improving their ability to think critically and creatively (Usmeldi, 2019). Furthermore, PBL emphasizes the practical application of knowledge, bridging the gap between theoretical concepts and their implementation in everyday situations, which is crucial for vocational education (Dewi, 2024; Dogara et al., 2020). Overall, PjBL not only cultivates essential skills but also prepares students for future academic and professional success. Nevertheless, the effectiveness of PjBL can vary depending on the context in which it is implemented, underscoring the importance of integrating culturally and environmentally relevant elements to enhance its impact.

STEM education (Science, Technology, Engineering, and Mathematics) plays a key role in developing students' HOTS. By integrating STEM disciplines, students are encouraged to approach problems from multiple perspectives, utilizing scientific inquiry, engineering design, and mathematical reasoning to find solutions. Studies have shown that STEM-based PjBL can enhance students' critical thinking, creativity, and ability to connect theory with practical applications (Capraro, Capraro, & Morgan, 2013). Additionally, incorporating STEM education into science subjects aligns with the goals of developing students' HOTS as it encourages them to apply higher-level cognitive skills such as analysis, evaluation, and synthesis.

Jambi (Malay) local content offers a unique cultural and environmental context that makes it particularly suitable for integration into STEM-PjBL. The region is known for its rich cultural heritage, including traditional ecological knowledge and practices rooted in sustainable interactions with the environment. These elements provide authentic, locally relevant contexts that align with the goals of STEM education. By embedding this cultural content into the learning process, students can connect abstract scientific concepts with familiar, real-world examples, thereby enhancing their engagement and understanding. Nasution (2018) highlighted that integrating local culture into education not only helps preserve cultural heritage but also enhances students' learning experiences by connecting global knowledge with local traditions.

This research aims to implement and evaluate a PjBL-integrated STEM learning model based on local Jambi (Malay) content at MTs Bina Insan, a secondary school in Jambi. The goal is to improve students' HOTS in science subjects by using culturally relevant STEM projects. By embedding local content into the STEM framework, students can see how scientific principles apply to their everyday lives and local environment, thus making learning more meaningful and impactful (Gunawan et al., 2017). Additionally, this study addresses a key gap in the literature by exploring the integration of local cultural content into STEM-PjBL frameworks, an area that has been under-researched despite its potential to improve student outcomes in diverse educational contexts. According to (Ainiyah, Q & Mustofa, A. 2022) research The implementation of the jigsaw to improve students' fiqh achievement at MTs Al Ichsan Brangkal Sooko Mojokerto increase of cognitive aspects can be seen from increasing students' scores on the test of stage (TS) 1 and 2. By addressing these questions, this study aims to contribute to the literature on STEM education, PjBL, and the integration of local cultural content, offering insights that can help educators develop more effective and culturally relevant teaching strategies.

The scope of educational design and development research starts with design validation. The design produced through this research is detailed in the academic manuscript. The research design process begins with the synthesis of learning models, interventions, and their impacts (Rusdi,M, 2018). Based on the validation of the academic manuscript and expert interviews, the intervention chosen for this study is the Project-Based Learning (PjBL) model integrated with STEM and local Jambi content. A key procedure in design and development research involves field trials to assess the impact of the developed products and tools (Richey, R. C., & James,D. K., 2014). The PjBL model, integrated with the STEM approach and Jambi local content, as used in this study, is illustrated in Figure 2.

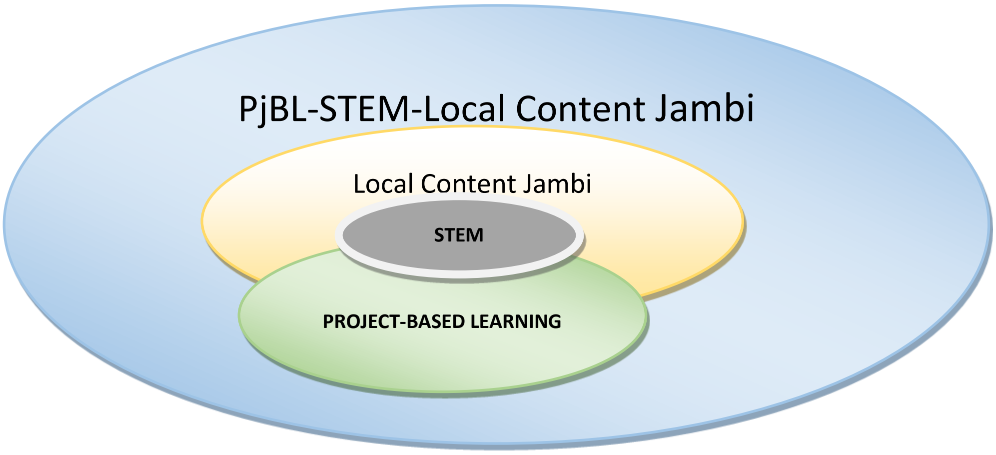

Figure 1. Integration of PjBL, STEM, and Jambi Local Content models (Pathoni, H, 2023)

2. METHODS

This study employed an experimental research design to evaluate the effectiveness of the integrated STEM Project-Based Learning (PjBL) model enriched with local Jambi (Malay) cultural content. The implementation of this model, along with its accompanying instructional materials, functioned as a summative evaluation phase, aimed at assessing the overall effectiveness of the learning approach following earlier formative assessments (Arikunto, 2010). This evaluation also focused on the model's capacity to foster students' higher-order thinking skills (HOTS).

To ensure internal validity and reduce confounding variables, the experimental and control groups were matched based on comparable characteristics. These included students' prior knowledge—determined through diagnostic tests administered before the pre-test—and teacher consistency, as both groups were instructed by the same educator.

A non-equivalent control group design, a widely adopted method in educational research, was used to measure the intervention's impact (Rusdi, 2020; Pathoni et al., 2023). This quasi-experimental design involved two classes: the experimental group (n = 13), which received instruction through the STEM-PjBL model contextualized with local culture, and the control group (n = 13), which followed a conventional, lecture-based approach.

The study followed a structured procedure:

- A pre-test was administered to both groups to establish a baseline.

- The experimental group engaged in STEM-PjBL activities, including culturally relevant projects such as static electricity.
- The control group continued with textbook-based instruction emphasizing rote memorization and problem-solving.
- A post-test was conducted in both groups to evaluate changes in student outcomes.

The research design is visually represented in Figure 2.

O_1	X_1	O_2
O_3	X_2	O_4

Figure 2. The experimental research design of non-equivalent control group design.

From Figure 2. it can be seen that in this study there are 2 types of variables, namely independent variables and dependent variables.

O_1 = Pre-test in experiment class
X_1 = Treatment (implementation of STEM-integrated PjBL model based on local Jambi content)
O_2 = Post-test in experiment class
O_3 = Pre-test in control class
X_2 = Treatment (Conventional model)
O_4 = Post-test in the control class

This study aimed to examine the effectiveness of a STEM learning model that integrates Project-Based Learning (PjBL) with local Jambi (Malay) cultural content in enhancing students' Higher Order Thinking Skills (HOTS) in science. The research employed a quasi-experimental design with a non-equivalent control group. Each group consisted of 13 students, a sample size that presents limitations regarding the generalizability of the findings. Consequently, the results should be interpreted with caution and viewed as indicative rather than conclusive. Future research involving larger and more diverse samples is recommended to validate and expand upon these findings.

Prior to conducting inferential statistical analyses, the data were tested for normality using the Shapiro-Wilk test, which is considered suitable for small sample sizes ($n < 50$) (Khatun, 2021). A significance value greater than 0.05 ($p > 0.05$) indicates that the data are normally distributed, thus meeting the assumptions required for parametric testing.

Three statistical tests were employed using SPSS 23:

- Paired t-test: Used to evaluate the difference in mean scores between pre-test and post-test within the same group. A significance value ($p < 0.05$) indicates a statistically significant difference between the two-time points.
- Independent t-test: Used to compare post-test scores between the experimental and control groups. A significance value below 0.05 indicates a significant difference in learning outcomes between the two groups.

These tests provided the basis for assessing whether the STEM-PjBL model with local content had a statistically significant impact on students' HOTS development.

3. FINDINGS AND DISCUSSION

3.1 Findings

Data were collected from pre-test and post-test assessments administered to both the experimental and control classes. The experimental class was taught using a Project-Based Learning (PjBL) model integrated with STEM and enriched with local Jambi (Malay) cultural content, while the control class followed a conventional, lecture-based instructional model. This study aimed to evaluate the impact of the PjBL-integrated STEM approach on students' Higher-Order Thinking Skills (HOTS) in science.

The results were analyzed using statistical procedures, including the Shapiro-Wilk normality test and paired t-tests to compare pre-test and post-test scores within each group. The normality test was conducted first to ensure the data met the assumptions for parametric testing. The Shapiro-Wilk test was chosen due to its reliability with small sample sizes ($n < 50$). Table 1 presents the results of the normality test.

Both groups exhibited normal distributions ($p > 0.05$), allowing for the use of paired t-tests. The results showed a statistically significant improvement in HOTS scores in the experimental group compared to the control group. This indicates that students exposed to the PjBL-STEM model with local content demonstrated greater learning gains than those who received traditional instruction.

Furthermore, the comparable pre-test scores between the two groups validated the equivalence of initial abilities, thereby confirming that the post-test improvements in the experimental group were likely attributable to the intervention itself.

Table 1. Test of normality Shapiro Wilk

Data	Experiment Class (Sig Value)	Control Class (Sig Value)	Result
Pre-test	0.338	0.065	> 0.05 (normal distribution)
Post-test	0.109	0.083	> 0.05 (normal distribution)

As shown in Table 1, the significance values for the pretest and posttest data for the experiment class are 0.338 and 0.109, and the significance values for the pretest and posttest data for control class are 0.065 and 0.083, respectively. The result of the normality test also can be shown in Figure 3

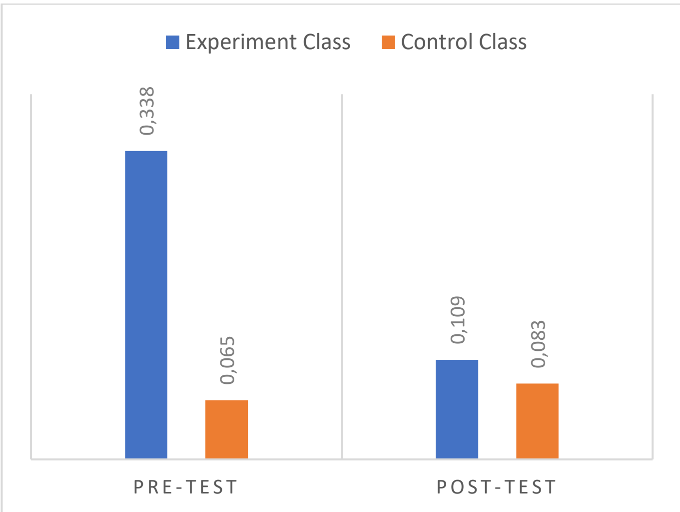

Figure 3. Significance value of pre-test and post-test

According to the decision rule, if the significance value exceeds 0.05 (Sig. > 0.05), the data is considered normally distributed. The Shapiro-Wilk test confirmed that both the pretest and posttest data follow a normal distribution for the experiment and control class. With these conditions met, a paired t-test was conducted testing in this study. This test assesses whether there are significant differences between the pre-test and post-test data experiment and control class. The paired t-test results are presented in Table 2.

Table 2. Paired T Test

No.	Experiment class (Sig Value)	Control class (Sig Value)	Result
1	0.000	0.000	< 0.05 Ha accepted

According to Table 2, the significance (Sig) value is 0.000 with experiment and control class. Based on the criteria for decision-making, a Sig value below 0.05 indicates a significant difference between the average pretest and posttest data in control and experiment class. This implies a significant change between the pretest and posttest data in the experiment and control class. Upon analyzing the mean values of both datasets, the posttest average is noticeably higher than the pretest average, which clearly points to an enhancement in students' higher-order thinking skills (HOTS) and control class with a conventional learning model. With these conditions met, a Independent t-test was conducted hypothesis testing in this study. This test assesses whether there are significant differences between post-test data experiment and control class. The independent t-test results are presented in Table 3

Table 3. Independent T test

No.	Sig.	Result	Sig. (2-tailed)	Result
1	0.272	>0.05 (Homogen distribution)	0.000	< 0.005 Ha accepted

According to Table 3, the significance (Sig) value 0.272 > 0.05 is the homogen distribution data experiment and control class. The significance Sig. (2-tailed) value 0.000 in the experiment and control class. Based on the criteria for decision-making, a Sig value below 0.05 indicates a significant difference between the average posttest data in control and experiment classes. This implies a significant change between post test data in experiment and control class. Upon analyzing the mean values of both datasets, the posttest average in the experiment class is noticeably higher than the post test average in control class, which clearly points to an enhancement in students' higher-order thinking skills (HOTS) and control class with conventional learning model. The independent t-test, conducted in this study's hypothesis testing, further supports these findings. The test confirms that the difference between the posttest experiment class means is not due to random variation but reflects a statistically significant improvement in students' HOTS ability. The increase in the posttest mean compared experiment and control class mean highlights that the educational intervention likely had a positive impact on enhancing these cognitive skills. This result aligns with the objective of improving HOTS, demonstrating that students' critical thinking, problem-solving, and analytical skills were effectively developed during the study.

The results of this study indicate that the Project-Based Learning (PjBL) integrated STEM learning model with local Jambi (Malayu) content had a positive and significant impact on students' HOTS in science subjects than the conventional model. The substantial increase in the class's post-test scores supports the hypothesis that this teaching approach can enhance HOTS ability. The integration of STEM education with PjBL aligns with the core principles of developing HOTS, as students are required to engage in higher-level cognitive tasks such as analyzing, evaluating, and creating solutions to complex problems. The class-marked improvement in HOTS is consistent with previous research that suggests STEM-based PjBL promotes deeper learning and the development of critical thinking skills (Capraro, Capraro, & Morgan, 2013).

In contrast, the conventional model, which often emphasizes rote memorization and passive learning, appears less effective in promoting the same cognitive growth. In the conventional approach, students typically engage with science concepts in a more theoretical, abstract manner, with limited opportunities to apply their learning to real-world contexts. This lack of active engagement and real-world problem-solving means that students in the control group may not have had as much opportunity to develop higher-order cognitive skills such as analysis, evaluation, and creation of innovative solutions. The Project-Based Learning (PjBL) model has been shown to offer several advantages over conventional teaching methods, particularly in fostering active engagement and collaborative skills among students (Guo et al., 2020; Wijnia et al., 2024; Zhang et al., 2024). Research indicates that PjBL enhances critical thinking, creativity, problem-solving abilities, and teamwork, which are essential in modern educational contexts (Rehman et al., 2024; Yu, 2024). Furthermore, the conventional model does not emphasize collaborative learning or allow students to take ownership of their projects, which are key components of HOTS development.

Moreover, these results challenge traditional methods and highlight the potential of a more holistic and student-centered approach in fostering deeper understanding and critical thinking in science education. The hands-on nature of project-based learning allows students to explore scientific concepts in a meaningful way, fostering a deeper understanding of the material. The class begins with the teacher demonstrating static electricity using Phet simulation, illustrating how such tools can be effectively used to create more interactive and engaging learning experiences.

In this study, HOTS development was measured primarily through post-test scores, which assessed students' ability to apply knowledge, analyze problems, and create solutions. These findings may have limited generalizability due to the relatively small sample size (13 participants per group). Therefore, the results should be considered preliminary rather than conclusive. To overcome this limitation, future research with larger and more diverse participant groups is recommended to confirm these findings.

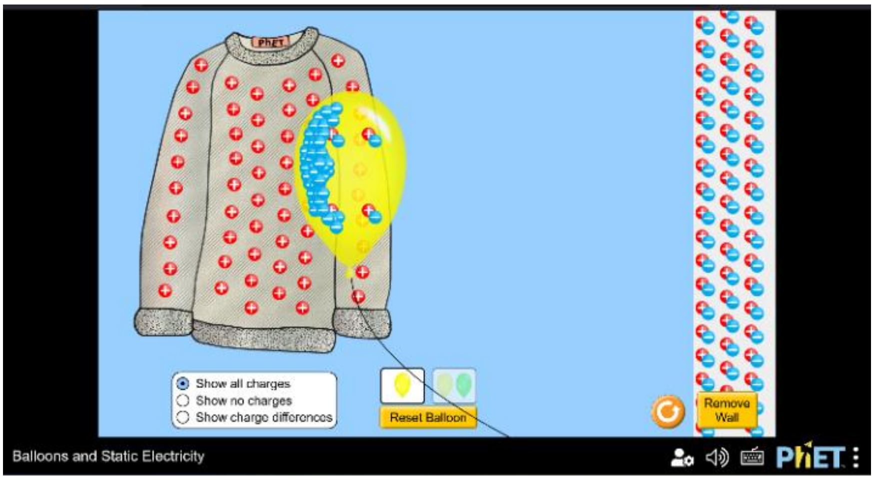

Figure 4. Static electricity with phet simulation (https://phet.colorado.edu/)

Students are asked to observe the Phet simulation and understand the concept of static electricity. From Figure 4 it can be seen that the balloon will be attracted to the sweater when rubbed. The process of static electricity where rubbing two objects together (the sweater and the balloon) causes electrons to transfer from one object to the other, creating a charge imbalance. This charge imbalance results in an attractive force between the objects, causing them to stick together.

For student projects, the teacher asks students to prepare a ruler (technology) and scraps of paper (engineering). Students were asked to rub their hair with a ruler and then hold it close to a piece of paper. The piece of paper will be attracted by the ruler because of the excess negative charge. As a follow-up to the simple project, students are tasked with completing a worksheet and answering specific questions such as what happens to the pieces of paper when the ruler is brought close? Why are the pieces of paper attracted to the ruler after it is rubbed on hair? What happens to the electric charge on the ruler after it is rubbed on hair? Student activity rubs their hair with a ruler then brings it closer to the pieces of paper as in Figure 5.

Figure 5. Student activity rubbing their hair with a ruler

To incorporate Jambi Malay cultural content, the teacher contextualized the science lesson by discussing the frequent occurrence of forest fires and smoke haze in the Jambi region. These environmental issues were linked to natural phenomena such as lightning and friction between trees during extended dry seasons.

During prolonged dry spells, forests become highly flammable due to the accumulation of dry leaves and twigs. In such conditions, friction between tree branches or vegetation can produce sparks, potentially igniting fires. Additionally, lightning, a natural manifestation of static electricity, is another significant cause of forest fires. This occurs when large clouds release electrical charges due to the buildup of positive and negative ions. Although lightning most commonly occurs during rainfall, it can still strike dry trees and foliage, leading to ignition even without rain.

To further integrate the local context into learning, the teacher designed Higher-Order Thinking Skills (HOTS) questions related to the topic of forest fires, static electricity, and environmental conditions in the Jambi Malay region. These questions encouraged students to analyze causes, evaluate consequences, and propose solutions based on real-world, culturally relevant scenarios.

Kerinci Seblat National Park in Jambi has many unique plant species. Some plants produce sap that can conduct electricity. A researcher wants to use the sap to make a simple electric charge measuring device. Make a conceptual design of the device based on the principle of Coulomb's Law, and explain how it works!

3.2 Discussion

Incorporating local Jambi (Malay) content into the STEM framework provided students with a culturally relevant context for their learning. This approach not only made the learning experience more relatable and engaging but also strengthened students' connection to their local environment and culture. This aligns with the findings of Nasution (2018), who emphasized the importance of integrating local culture into education to make learning more meaningful and impactful for students. By linking scientific concepts to local wisdom, students were able to better appreciate the real-world applications of their learning, which in turn enhanced their HOTS.

A growing body of research supports the integration of culture-based learning in science education as an effective strategy for improving students' critical thinking and communication skills. By connecting academic content with local wisdom and cultural practices, students develop a more profound and contextualized understanding of scientific principles (Hikmawati et al., 2021). This approach not only strengthens conceptual grasp but also fosters higher-order thinking skills (HOTS) through real-world application (Su'ad et al., 2022).

Experiential learning that incorporates local environmental and cultural contexts further encourages student engagement. It motivates learners to interact actively with their surroundings, promoting deeper comprehension and long-term retention of the material (Mashfufah et al., 2020). Authentic learning strategies, which emphasize real-life relevance, also enhance students' ability to become self-directed learners, equipping them with the tools needed for future academic and professional challenges (Baskaran & Abdullah, 2021). As such, connecting educational content with local culture creates a learning environment that is both meaningful and effective.

Research by Chasanah et al. (2024) confirms the effectiveness of STEM-based course modules developed using a project-based learning (PjBL) framework. These modules demonstrated strong validity, practicality, and effectiveness as learning resources. In the current study, the PjBL approach encouraged collaboration and active participation, essential conditions for cultivating HOTS. Students worked in groups to address local environmental problems, such as forest fires in Jambi. This collaborative problem-solving process fostered critical and creative thinking, likely contributing to the significant improvement in HOTS observed in the experimental group.

Krajcik and Blumenfeld (2006) emphasize that PjBL enhances student engagement and autonomy, allowing learners to take ownership of their educational journey. The findings of this study align with their assertions, as students in the experimental group demonstrated higher motivation, participation, and performance.

Further studies support the integration of PjBL with local cultural elements, highlighting its potential to deepen scientific understanding by connecting classroom concepts with students' daily experiences and local knowledge (Hujjatusnaini et al., 2022; Rahayu, 2023). This contextual learning strategy has been shown to enhance not only cognitive development but also creativity and problem-solving—key components of HOTS (Rati et al., 2023).

Nida et al. (2023) found that STEM-based digital physics workbooks incorporating PjBL are highly effective for junior high school students. Similarly, Fitriyana et al. (2024) concluded that ongoing professional development in STEM is crucial for enabling teachers, particularly in chemistry, to implement project-based learning successfully.

The success of the current study reinforces the importance of embedding local content in STEM education. For culturally rich regions like Jambi, incorporating local wisdom into the curriculum adds relevance and meaning to students' learning experiences. Moreover, this approach provides a scalable framework for other schools in Indonesia to adopt, promoting improved HOTS outcomes through contextualized and culturally responsive STEM instruction.

4. CONCLUSION

The implementation of a STEM learning model integrated with Project-Based Learning (PjBL) and grounded in local Jambi (Malay) cultural content significantly enhanced students' Higher-Order Thinking Skills (HOTS) in science at MTs Bina Insan. These findings underscore the effectiveness of combining culturally relevant content with experiential learning approaches to foster deeper engagement, critical thinking, and problem-solving abilities among students. The study demonstrates that integrating local wisdom into STEM education not only enriches academic understanding but also makes learning more meaningful and contextually relevant. However, the research was limited by its small sample size (n = 13 per group), which may affect the generalizability of the findings. Therefore, the results should be interpreted with caution. Future research is recommended to replicate and expand this study with larger and more diverse populations across different regions to validate the outcomes and explore the long-term impact of culturally integrated STEM education. This approach holds promise as a scalable model for improving science education through context-driven, student-centered learning.

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Conflicts of Interest: "All of The authors declare no conflict of interest in this paper."

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