The Effect of Local Wisdom-Integrated Problem-Based Learning (PBL) Models on Learning Outcomes in Temperature and Heat Concepts

Muznawaty Pilobu[1], Abdul Haris Odja[1,4], Felipe Xavier[2] Suparmin Fathan[1,3], Tirtawaty Abdjul[1], Citron S. Payu[1], Masrid Pikoli[1], Muhammad Yusuf[1], Mursalin[1,4], & Ramli R. Ali[1,4]
[1]Master Program in Science Education, Gorontalo State University, Indonesia
[2]Lecturer of Chemistry, Universidade Nacional Timor Lorosa'e, Timor Leste
[3]Animal Science Program, Gorontalo State University, Indonesia
[4]Physics Education Study Program, Gorontalo State University, Indonesia
*Corresponding author: abdlharis@ung.ac.id

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Abstract - *This study aims to analyze the effect of local wisdom-based Problem Based Learning (PBL) on junior high school students' learning outcomes in temperature and heat. The method used was a quantitative experiment with a one-group pretest–posttest design; the independent variable was PBL based on local wisdom integrated through Google Sites (e-modules, worksheets, videos, and contextual tasks), while the dependent variable was learning outcomes measured by achievement tests that had been validated by experts and declared to be highly valid. Data analysis included descriptive statistics, Shapiro–Wilk test for normality, Wilcoxon Signed-Rank test for paired comparisons, and N-Gain for effectiveness. The results show a significant increase: the class average increased from 45 to 84 and from 41 to 84; the posttest data was not normal, so Wilcoxon was used with results of $Z = 4.111$ and $Z = 4.021$ ($p < 0.001$), confirming a significant difference between the pretest and posttest. The average N-Gain = 0.69 (moderate category) with individual distribution in the moderate to high range, indicating that PBL based on local wisdom is effective in strengthening conceptual understanding and encouraging learning engagement. It is recommended to continuously integrate the local cultural context into science units through digital platforms, strengthen teacher training to facilitate PBL, and conduct further research with control groups, larger samples, and mixed approaches to examine conceptual changes and misconception reduction more comprehensively. It is recommended that local cultural contexts be continuously integrated into science units through digital platforms, that teacher training be strengthened to facilitate PBL, and that further research be conducted with control groups, larger samples, and mixed approaches to examine conceptual changes and misconception reduction more comprehensively.*

Keywords*: Problem-Based Learning; Local Wisdom; Learning Outcomes; Temperature and Heat; Google Sites*

INTRODUCTION

Understanding the concepts of temperature and heat is the foundation of science literacy and physics learning at the junior high school level, but research shows that there are still high levels of misconceptions that impact students' conceptual weaknesses (Septiyani & Nanto, 2021; Busyairi et al., 2022). The relationship between temperature and heat with the science/physics and chemistry curriculum makes addressing misconceptions key to understanding concepts scientifically (Setyaningrum & Sopandi, 2021). A number of studies confirm that mastery of this concept contributes to increased science literacy, namely the ability to interact critically and contextually with science content and daily decision-making (Amala et al., 2023; Santhalia & Yuliati, 2021). Consequently, mastery of temperature and heat not only improves academic performance but also equips students with the skills to make knowledge-based decisions in their daily lives (Kibirige, 2021; Palines & Cruz, 2021). Taken together, these findings indicate that persistent misconceptions in heat and temperature must be addressed through learning designs that contextualize abstract thermodynamic ideas in students' everyday experience and cultural environment as a basis for deeper science literacy (Zulyusri et al., 2022; Astuti et al., 2022).

Research in physics education has identified several dominant misconceptions: students often equate temperature with the amount of heat, thus considering temperature to be a measure of the "amount of heat" in an object; this misconception has been identified in a significant percentage of various studies (Septiyani & Nanto, 2021; Appiah-Kubi et al., 2021). Errors also extend to the idea that "heat" and "cold" move as physical entities, or that cold objects have no heat, often rooted in everyday experiences that replace scientific definitions and obscure the essence of thermodynamic concepts (Busyairi et al., 2022; Kibirige, 2021). Therefore, learning interventions that target misconceptions are necessary because of their significant impact on students' overall understanding and engagement with related science concepts (Dewi & Wulandari, 2021; Indratno et al., 2023). Because these misconceptions are strongly influenced by learners' intuitive interpretations of everyday thermal phenomena, they point directly to the need for contextualized instruction that deliberately re-anchors students' prior ideas in scientifically accurate, locally meaningful experiences (Amala et al., 2023; Astuti et al., 2022).

Several contextual factors also explain the low learning outcomes in this topic. The explanation of abstract scientific concepts, including temperature and heat, without the support of direct interaction and opportunities for observation or practical experience in the laboratory, makes it difficult for many students to develop a meaningful understanding (Wakhidah et al., 2021). On the other hand, deep-rooted fundamental misconceptions continue to hinder the processing of material, exacerbated by limited mathematical skills to solve problems related to heat and energy transfer (Sari et al., 2023; Septiyani & Nanto, 2021). These mathematical barriers also reduce the ability to apply concepts in problem solving (Puspita & Sugiyono, 2021). The quality of education also plays a role, with the literature emphasizing the need for improved teacher training and innovative teaching strategies to close the existing gap (Maison et al., 2022; Lailis et al., 2021). In this context, contextualized pedagogies that connect school physics with students' lived environments become strategically important to remediate both conceptual and motivational barriers (Zahroh et al., 2022; Sobach et al., 2023).

The relationship between understanding temperature and heat and scientific thinking skills and 21st-century skills is clear. Students who master these concepts tend to be better prepared to engage in higher-order thinking, analysis, synthesis, and evaluation, and demonstrate stronger science literacy (Zulyusri et al., 2022; Firdaus et al., 2023). An inquiry-based approach further strengthens critical thinking and scientific literacy by contextualizing concepts in real-life situations (Sobach et al., 2023). The capacity to articulate and apply knowledge of temperature and heat is an essential indicator of scientific reasoning for responding to contemporary socio-technological issues (Fauzi et al., 2022; Jones, 2024) while science literacy is recognized as a key competency of the 21st century (Astuti et al., 2022; Zahroh et al., 2022).

Theoretically, Problem-Based Learning (PBL) shifts the focus from memorization to authentic problem solving that fosters critical thinking, problem solving, collaboration, and independence, while developing inquiry skills relevant to science literacy (Ariyani et al., 2025; Smith et al., 2022). Empirical evidence shows that PBL promotes deep understanding and retention because students not only learn content but also how to apply it, accompanied by increased responsibility and learning autonomy as the foundation of self-regulated learning (Evendi & Hardiani, 2021; Dharma et al., 2020; Lestari et al., 2023). This model also has a positive impact on metacognitive skills and learning motivation, strengthening lifelong learning skills (Aristin et al., 2023; Choi et al., 2022). In the realm of temperature and heat, the implementation of PBL has been shown to improve learning outcomes (Mahmud et al., 2024; Rahadiyani et al., 2023), while meta-analyses show its effectiveness across science disciplines and its superiority over conventional teaching (Uluçınar, 2023; Rehman et al., 2024). In the Indonesian context, meta-analytic and empirical evidence confirms improvements in problem-solving skills in physics and a strengthening of understanding of temperature, heat, and pressure, accompanied by scientific process skills and environmental literacy when PBL is appropriately contextualized (Sukri, 2023; Yusa et al., 2023).

However, implementation challenges remain real. Pre-existing misconceptions have the potential to derail the PBL inquiry process if not explicitly addressed (Dewi & Wulandari, 2021; Maison et al., 2020). The level of learning engagement is also greatly influenced by interest and motivation, so the success of PBL requires active participation and a conducive learning climate (Subagja, 2023; Kim & Kim, 2021). In addition, teacher readiness, substantial design requirements, and facilitation support are often obstacles in the classroom (Trullàs et al., 2022; Mohammed et al., 2024). These challenges strengthen the argument that PBL for heat and temperature should not only present generic problem scenarios but also be anchored in students' own thermal experiences so that inquiry is meaningfully guided from naïve ideas toward scientific conceptions (Hidayati et al., 2020; Widyawati et al., 2023).

The integration of local wisdom offers a powerful contextualization pathway to bridge the gap between the ideal and the actual. Modules and activities based on local cultural knowledge help students see the direct connection between scientific concepts and everyday experiences, while strengthening their science skills (Nabila et al., 2023; Mulyani et al., 2023). The use of local cultural elements, such as traditional games or craft practices, has been shown to spark curiosity and increase engagement in physics learning (Anantanukulwong et al., 2022; Putra et al., 2022). In addition to enriching relevance, this approach strengthens students' character and cultural identity and fosters an attitude of caring for the environment (Zahroh et al., 2022; Damopolii et al., 2024). Compared to conventional PBL, which relies on standard scenarios, PBL based on local wisdom links authentic problems that are in line with the context of students' lives, thereby increasing motivation, depth of understanding, and learning outcomes (Roza et al., 2023; Cahayu et al., 2024). Specific evidence on the topic of temperature and heat has also emerged, such as the use of Lampung batik motifs in physics e-modules that impact scientific attitudes, as well as the strengthening of problem solving through PBL and the development of local wisdom-based physics comics that support creative thinking and mathematical representation (Pela et al., 2023; Dewi et al., 2023; Sari et al., 2020). At the same time, the literature highlights research gaps that remain open, including the need for a comprehensive framework to operationalize cultural contexts in PBL, more nuanced measurement of cognitive and affective processes, and the preparation of teachers and resources so that culturally rooted PBL practices can be implemented consistently (Jumriani et al., 2021; Zahroh et al., 2022).

In line with the direction of *Merdeka Belajar*, the integration of local wisdom supports the Pancasila student profile, global diversity, and the utilization of local excellence in science learning (Andita & Tirtoni, 2024; Suratno et al., 2020). Within this framework, local thermal phenomena such as culturally specific practices involving heat, cooling, and material processing constitute a particularly rich context for re-anchoring students' misconceptions about temperature and heat through PBL tasks mediated by digital resources (Nabila et al., 2023; Ristiana, 2023). Previous studies have not examined the integration of local thermal phenomena in a digitally-supported PBL module; thus, this study contributes by systematically designing and implementing a local wisdom-based PBL module on temperature and heat, delivered via Google Sites, to address students' misconceptions and enhance their science literacy (Verawati & Wahyudi, 2024; Yuliana et al., 2023). In doing so, the study connects (a) well-documented misconceptions in heat, (b) the need for contextualization through culturally meaningful thermal experiences, and (c) the integration of local wisdom into a digitally supported PBL framework that aligns with the national curriculum's emphasis on relevance, agency, and 21st-century competences (Pela et al., 2023; Dewi et al., 2023).

RESEARCH METHODS

This study is a quantitative experiment that examines the effect of implementing local wisdom-based Problem Based Learning (PBL) on student learning outcomes in temperature and heat material. Referring to the quantitative experimental framework, the independent variable is the PBL model based on local wisdom integrated through Google Sites media (containing e-modules, student worksheets, videos, and local context links), while the dependent variable is students' learning outcomes on temperature and heat measured through a post-treatment learning outcome test. The design used was a one-group pretest–posttest (Fraenkel et al., 2012), in which one class was given a pretest before the PBL treatment and a posttest after the treatment. This design was chosen to identify changes in learning achievement that occurred after the intervention under controlled conditions (Sugiyono, 2019). The research subjects were one class at the junior high school level, selected based on class availability and school willingness. The treatment was carried out in several meetings on the topic of temperature and heat using the PBL flow: orientation to contextual problems based on local wisdom, learning organization, independent/group investigation, solution development and presentation, and reflection. The context of local wisdom was used as a source of authentic problems (e.g., the phenomenon of heat in daily activities and local cultural practices) so that students could link scientific concepts with local realities through the material presented on Google Sites.

The main instrument is a test of learning outcomes on temperature and heat, which is compiled based on relevant competency indicators and cognitive domains. Items can be in the form of multiple choice and/or short essays as required for measurement. In addition, the learning tools used include lesson plans, e-modules/student worksheets integrated with local wisdom on Google Sites, and other supporting teaching materials. All tools and instruments underwent expert validation (expert judgment). The validity level criteria (scores of 0–100) refer to Riduwan (2012): 0–20 invalid, 21–40 less valid, 41–60 fairly valid, 61–80 valid, and 81–100 highly valid. The results of the validation of the Google Sites-assisted local wisdom integrated learning tools showed a highly valid category. In terms of appearance, two validators gave a total of 161 and 163, respectively, a percentage of 95.83% and 97.02%, with a criterion of "highly valid". The average for each validator was 3.83 and 3.88, while the overall average for all validators was 3.85. In terms of Language/Readability, two validators gave a total of 61 and 62, a percentage of 95.31% and 98.42%, with a criterion of "highly valid". The average for each validator was 3.81 and 3.87, and the overall average for validators was 3.84. Based on Riduwan's (2012) classification, all of these percentages were in the range of 81–100, meaning that the tools were suitable for use in research. The Learning Tool Validation Sheet and the Learning Outcome Test Validation Sheet both show consistency in the "highly valid" category, as indicated by the figures. The Learning Device Validation Sheet and the Learning Outcome Test Validation Sheet both show consistency in the "highly valid" category, as indicated by the figures in the validation table above. Thus, the instruments and tools developed are considered adequate in terms of appearance, language/readability, and substance suitability for measuring the effect of the local wisdom-based PBL model on temperature and heat material.

Table 1. One Group Pretest-Posttest Design Research Design

Pretest	Treatment	Posttest
O_1	X_1	O_2

The research data was analyzed in several stages. The first stage involved calculating the pretest and posttest scores of each student to determine their initial ability profile before the treatment and the results after the application of the local wisdom-based Problem Based Learning (PBL) model. This initial analysis aimed to describe the improvement in student learning outcomes on the subject of temperature and heat after receiving the learning treatment. Next, a normality test was conducted using the Shapiro–Wilk method to ensure that the data distribution followed a normal pattern. If the data did not meet the normality assumption, the analysis was continued with non-parametric techniques. In this study, the Wilcoxon Sign-Rank Test was used to test the significant difference between students' pretest and posttest scores (Sugiyono, 2019).

In addition to using the hypothesis test for mean differences, the effectiveness of the PBL model based on local wisdom was also analyzed using the N-Gain test to assess the improvement in student learning outcomes after participating in the learning process. According to Hake (1999), the normalized average gain value is obtained by comparing the actual gain achieved by students with the maximum gain that can be obtained. Thus, the N-Gain test provides an overview of how much improvement in understanding the concepts of temperature and heat was achieved by students after the local wisdom-based Problem-Based Learning model was systematically applied in learning activities.

Table 2. N-Gain Categories

Indeks Gain (⟨g⟩)	Kriteria
⟨g⟩ ≥ 0,7	High
0,3 ≤ ⟨g⟩ < 0,7	Medium
⟨g⟩ < 0,3	Low

To measure the effectiveness of the treatment in this study, N-Gain analysis was used as an indicator of improvement in student learning outcomes. The normalized average gain value was used as a measure of learning effectiveness. If the N-Gain calculation results show a moderate or high category, then the local wisdom-based Problem-Based Learning (PBL) model can be said to be effective in improving student learning outcomes on the subject of temperature and heat.

RESULTS AND DISCUSSION

Results

To describe the effect of the intervention on student learning outcomes, data were collected using a 25-item multiple-choice pretest and posttest on temperature and heat. Descriptive statistics for the two experimental classes are presented in Tables 3, 4, 5, and 6, while individual N-Gain distributions are shown in Figures 2 and 3.

Table 3. Average Pretest and Posttest Scores

Class	Average Pretest	Average *Posttest*
Experiment 1	45	84
Experiment 2	41	84

In experimental class 1, the mean score increased from 45 (pretest) to 84 (posttest). In experimental class 2, the mean score increased from 41 (pretest) to 84 (posttest).

Table 4. Normality test

Class		Statistics	Sig	Description
Experiment 1	Pretest	0.943	0.224	Normally Distributed
	Posttest	0.853	0.004	Abnormally Distributed
Experiment 2	Pretest	0.941	0.232	Normally Distributed
	Posttest	0.836	0.002	Abnormally Distributed

The pretest scores for both classes met the normality assumption ($p > 0.05$), whereas the posttest scores did not ($p < 0.05$). On this basis, differences between pretest and posttest scores were analysed using the nonparametric Wilcoxon Signed-Rank test.

Table 5. Wilcoxon Single-Rank Test Hypothesis Test

Z.	Asymp. Sig
4.111	< 0.001
4.021	< 0.001

For both experimental classes, the Wilcoxon test yielded Z values of 4.111 and 4.021 with Asymp. Sig < 0.001, indicating statistically significant differences between pretest and posttest scores in each class.

Table 6. Average N-Gain Pretest and Posttest Scores

Class	N-Gain	Description
Experiment 1	0.69	Medium
Experiment 2	0.69	Medium

Both experimental classes obtained a mean N-Gain of 0.69, which falls within the “medium” category according to the applied classification.

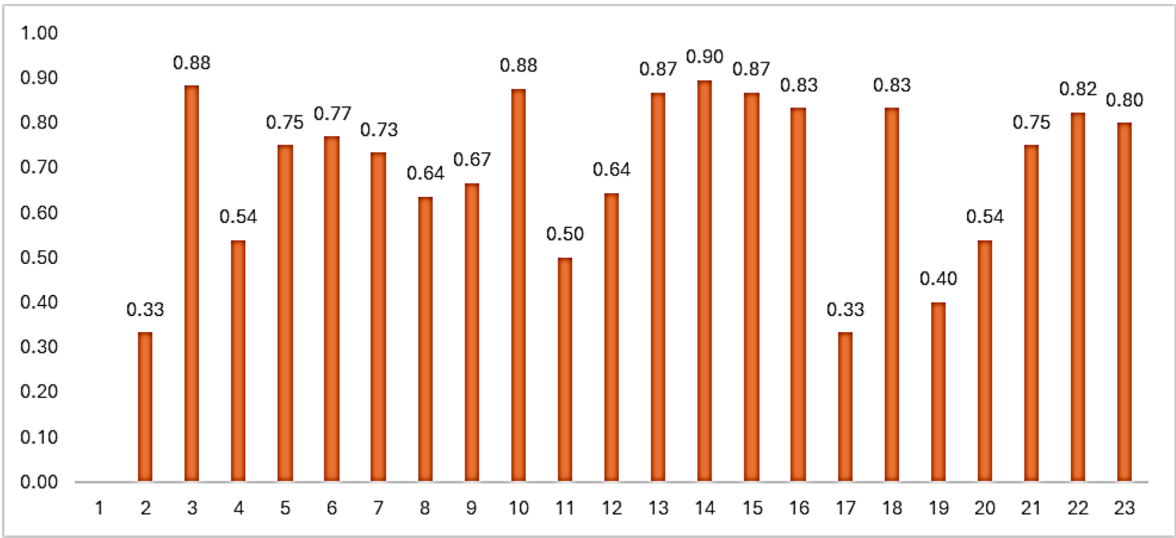

Figure 1. N-Gain values from the pretest and posttest for Class B

The distribution of individual N-Gain scores in experimental class B is depicted in **Figure 1**. N-Gain values in this class ranged from 0.33 to 0.90, with most students achieving N-Gain scores above 0.60.

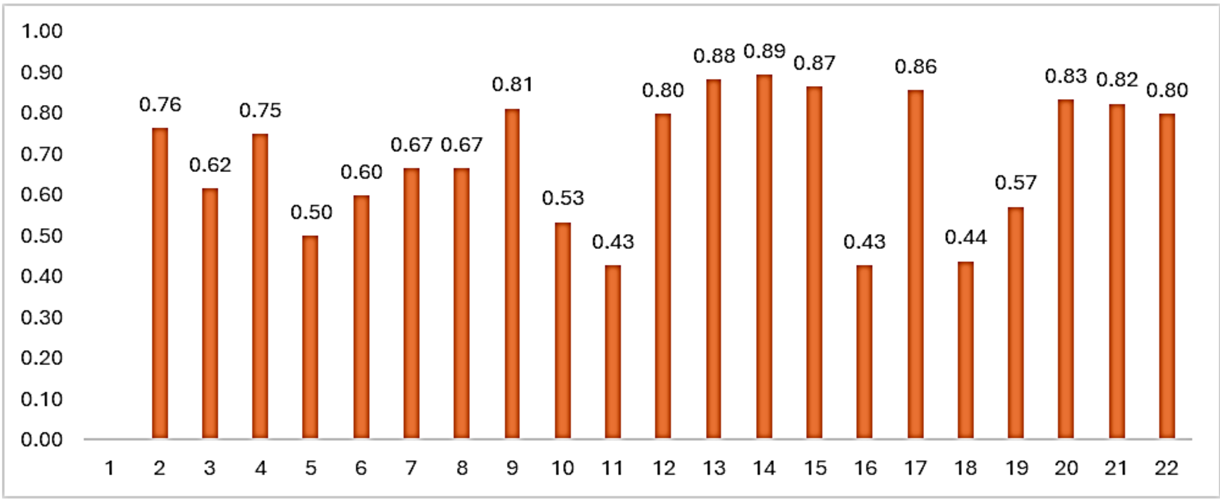

Figure 2. N-Gain values from the pretest and posttest for Class C

Similarly, **Figure 2** shows the N-Gain distribution for experimental class C. In this class, N-Gain values ranged from 0.43 to 0.89, and the majority of students also achieved N-Gain scores above 0.60.

Discussion

The results of the study indicate that the application of the local wisdom-based Problem-Based Learning (PBL) model has a significant effect on improving student learning outcomes in the subject of temperature and heat. This finding is in line with various studies that confirm that PBL can improve science learning outcomes, especially in understanding the concepts of temperature and heat. Empirical evidence shows that PBL encourages higher-order thinking skills and fosters a positive attitude towards science, thereby impacting academic achievement in various disciplines, including physics (Uluçınar, 2023; Nurhayati et al., 2023; Dewi et al., 2023). Students who learn through a PBL environment have been shown to have better problem-solving skills than those who learn through conventional methods. Research shows that students who participate in PBL on temperature and heat material experience a significant increase in problem-solving skills compared to students who are taught using traditional methods (Rahadiyani et al., 2023; Dewi et al., 2023). In addition, PBL encourages active collaboration among students, allowing them to engage more deeply with scientific principles and improve critical thinking skills, which are important prerequisites for mastering complex concepts (Gürses et al., 2022; Smith et al., 2022; Razak et al., 2022).

Various studies also confirm the effectiveness of PBL in improving conceptual understanding and scientific thinking skills across disciplines. Ramadhan and Mardin show that PBL improves science literacy through independent learning and critical problem solving (Ramadhan & Mardin, 2023). A meta-analysis by Funa and Prudente revealed a large effect size of PBL implementation on secondary school student achievement, with an effect size of 0.871 indicating a significant positive impact (Funa & Prudente, 2021). Pertiwi (2022) reported that PBL-based science modules improved students' critical thinking skills with a normalized gain of 0.37 in the moderate category, while Evendi and Verawati (2021) confirmed that PBL strengthens conceptual knowledge while improving long-term retention of scientific information. Thus, PBL emerges as an important pedagogical strategy that is effective in improving conceptual understanding and scientific thinking skills in various educational contexts.

The N-Gain value of 0.69 in this study is in the moderate category, indicating a significant improvement in learning outcomes in the context of PBL implementation. This finding is in line with Sukri's research results, which reported an N-Gain of 0.68 with a moderate improvement in environmental literacy (Sukri, 2023). Conversely, Wilujeng and Suliyanah found an N-Gain value of 0.31, indicating that the effectiveness of PBL can vary depending on the implementation context (Wilujeng & Suliyanah, 2022). Higher results were found by Kumala and Widiawati, who recorded an N-Gain of 0.77 in the high category for the improvement of critical thinking skills (Kumala & Widiawati, 2022). This difference shows that although an N-Gain of 0.69 is considered moderate, the results still indicate strong progress, while confirming that the effectiveness of PBL is highly dependent on instructional design, the role of teachers, and the relevance of the learning context.

Several important factors that influence variations in learning outcomes in the application of PBL include the duration of learning, the role of the facilitator, and the relevance of the local context. Previous studies have confirmed that sufficient time allocation for problem-based activities affects student engagement and deeper conceptual understanding (Evendi & Verawati, 2021; Mahmud et al., 2024). In addition, the role of teachers as facilitators is a key element in ensuring the success of PBL. Teachers who are able to guide discussions and create a supportive learning atmosphere have been shown to increase student motivation and learning outcomes (Evendi & Hardiani, 2021; Dharma et al., 2020). When teachers act as mentors who guide students' thinking processes, they encourage collaboration and problem-solving skills, which are at the core of the PBL model (Evendi & Hardiani, 2021). Furthermore, the integration of relevant local contexts—whether in the form of cultural phenomena, community activities, or environmental issues—can strengthen students' connection to the material being studied, increase engagement, and deepen scientific understanding (Yusa et al., 2023; Aprilita & Handican, 2023; Mahmud et al., 2024).

The integration of local wisdom into science education has been proven to increase the relevance and meaning of learning for students in Indonesia. By linking scientific principles to local cultural narratives and practices, students build stronger connections with the material, thereby increasing motivation and understanding. Research shows that local wisdom enriches students' learning experiences and develops scientific process skills and critical thinking abilities (Arjaya et al., 2024; Cahayu et al., 2024). For example, local contexts allow students to see the real-world application of scientific concepts in everyday life, fostering a sense of ownership and relevance to learning (Purba et al., 2024; Trisnowati et al., 2023). Furthermore, the integration of local wisdom also plays a role in character building, as it instills cultural and ethical values in the curriculum (Hidayati et al., 2020). This approach helps students understand the connection between cultural heritage and scientific principles, resulting in a more comprehensive educational framework (Putra et al., 2023; Arrafi' et al., 2023).

Empirical evidence shows that incorporating cultural context into science learning can improve concept transfer, motivation, and student engagement. Verawati and Wahyudi (2024) found a significant increase in science literacy in the experimental group taught with the integration of local wisdom compared to the control group. Sumarni and Kadarwati (2020) emphasized that local culture plays an important role in developing critical and creative thinking skills through its connection with scientific concepts. These results are in line with Jones (2024), who states that culture-based pedagogy increases the connection between students' lives and science content, as well as with Thoman et al. (2025), who emphasize the importance of social relevance in learning to increase students' identification with science. The findings of Kim et al. (2021) also reinforce the view that local culture-based activities can improve understanding and learning motivation through connections with students' family and cultural backgrounds.

The integration of cultural values in PBL significantly improves engagement and science learning outcomes. Yusa et al. (2023) show that a PBL model based on local culture effectively improves motivation and cognitive achievement by linking abstract scientific concepts to real-world contexts. Hikmawati et al. (2021) added that local wisdom in science learning also improves students' critical thinking and communication skills, as well as reinforces positive scientific attitudes. Verawati and Wahyudi (2024) emphasized that local wisdom plays a major role in improving science literacy, although its implementation must be adapted to the cultural context of the students. Trisnowati et al. (2023) also highlight that the application of local wisdom in STEM learning makes education more meaningful by contextualizing scientific inquiry in students' daily experiences.

In addition, local culture-based learning is effective in reducing misconceptions of physics concepts, particularly temperature and heat. Mahmud et al. (2024) showed that the application of PBL significantly improved understanding of these concepts and corrected common misconceptions among students. Dewi and Wulandari (2021) also confirmed that a specifically targeted learning approach can correct conceptual errors. Windiani et al.

(2023) used a three-level test to show that contextual learning interventions successfully reduced misconceptions and strengthened students' conceptual frameworks. Setyaningrum and Sopandi (2021) and Maison et al. (2020) added that locally-based diagnostic assessments, such as four-level tests, can systematically identify and correct misconceptions. Verawati and Wahyudi (2024) emphasize that a culture-based pedagogical approach not only improves scientific knowledge but also fosters critical thinking, thereby minimizing misconceptions.

The results of the Wilcoxon Signed-Rank Test with an Asymp. Sig value < 0.001 show strong evidence that the local wisdom-based PBL model is effective in improving student learning outcomes. This value confirms a significant difference between the pretest and posttest, which indicates an increase in conceptual understanding after treatment. Widyawati et al. (2023) showed that the combination of PBL and scaffolding significantly improved students' critical thinking skills, while Safitri et al. (2024) found that e-worksheets based on local wisdom within the PBL framework significantly improved critical thinking skills. Thus, these statistical results reinforce the effectiveness of the local culture-based PBL approach in increasing student engagement and understanding of scientific concepts.

Other studies also report significant differences between pretest and posttest scores after implementing PBL in science learning. Haulia et al. (2022) found an increase in scientific thinking skills through an ethnoscience-based PBL model, while Shofawati et al. (2023) proved that the integration of interactive multimedia in PBL improves students' science literacy. Meral et al. (2024) showed that STEM-based education influenced decision-making abilities, while Rahmani and Mahyana (2022) reported an increase in elementary school students' problem-solving skills through PBL. Sarkingobir and Bello (2024) also showed that the integration of ethnoscience into PBL significantly improved critical thinking skills. Overall, these findings support the effectiveness of PBL in improving learning outcomes in various fields of science.

From a methodological perspective, the use of the Wilcoxon Signed-Rank Test nonparametric test in this study is relevant because the posttest data are not normally distributed. According to Irma et al. (2023) and Ņikitina & Chernukna (2021), nonparametric tests are suitable for ordinal data or when the assumption of normality is not met. Şimşek (2023) emphasizes that this method is more reliable in assessing the effectiveness of Likert scale-based educational interventions. The Wilcoxon test is superior for paired samples and robust against distribution deviations (Irma et al., 2023; Yusa et al., 2023), and is not affected by outliers as described by Kumar & Singh (2024). Therefore, the selection of the Wilcoxon test in this study is appropriate for producing accurate and meaningful interpretations.

In general, previous research results show the consistency of PBL's effectiveness in improving learning outcomes at various levels and disciplines. Safitri et al. (2024) reported an increase in critical thinking skills in the context of biology and geology, while Fadli and Irwanto (2020) showed an increase in problem-solving skills through the ELSII model based on local wisdom. Arrafi' et al. (2023) found that a local wisdom-based approach in PBL had a positive effect on high school students' science literacy, while Hidayati et al. (2020) emphasized that integrating cultural values into the education curriculum strengthens character and learning outcomes. Muzana et al. (2021) also showed that E-STEM project-based learning improves ICT literacy and problem-solving skills. Dulyapit et al. (2023) and Alvionita et al. (2020) added that the application of PBL is effective at the elementary to high school levels, confirming its flexibility and adaptability.

These findings also reinforce constructivist theory, which emphasizes active learning and knowledge building through real-world experiences. Uliyandari et al. (2021) showed that PBL improves students' conceptual understanding and critical thinking skills by transforming learning from passive to active. Yusa et al. (2023) also confirm that PBL increases student motivation and engagement, in line with the views of Rahmani and Mahyana (2022), who found an increase in problem-solving skills as a reflection of the constructivist process. Leasa et al. (2024) add that PBL fosters metacognitive awareness and self-reflection, which deepens the learning experience. Thus, the application of PBL is proven to be in line with the principles of constructivism, where students build understanding based on experience and interaction.

This study contributes significantly to the development of a culturally-based contextual learning model in the digital age, particularly through the integration of Google Sites. Educational technology plays an important role in increasing student engagement and interaction in a multicultural context. Ristiana (2023) shows that Google Sites can improve the quality of education and students' technological literacy. These findings align with Ajani (2024), who emphasizes the importance of TPACK competencies for teachers to create culture-based learning through technology. Pradana et al. (2024) assert that digital literacy combined with local wisdom promotes sustainable development and strengthens local cultural identity. Nurhusain et al. (2025) also show that innovations such as ethnomathematics in the Merdeka Curriculum strengthen contextual learning amid technological changes.

In practical terms, the implementation of PBL based on local wisdom has important implications for learning planning, teacher training, and the development of digital teaching materials. In terms of planning, Fadli and Irwanto (2020) show that the integration of local wisdom enriches the curriculum and enhances critical thinking through real issues relevant to the students' culture. Safitri et al. (2024) emphasize that the success of implementation depends heavily on the readiness of teachers to integrate cultural context and technology. Rahmasari and Kuswanto (2023) show that augmented reality-based learning resources can visualize local culture interactively, while Mudjid et al. (2022) emphasize the importance of digital teaching materials that integrate cultural values to enrich the learning experience. Thus, the application of a PBL model based on local wisdom not only improves learning outcomes and science literacy but also strengthens cultural relevance and educational readiness in the digital age.

Limitations, Threats to Validity, and Future Research Directions

Although the findings of this study indicate that the PBL model based on local wisdom is associated with a significant improvement in student learning outcomes regarding temperature and heat, several limitations and threats to validity need to be acknowledged. First, this study used a single pre-test and post-test design with a complete experimental class but without a comparison or control group. As a result, alternative explanations such as history, maturation, test effects, or concurrent school programs cannot be completely ruled out as contributors to the observed improvement. Second, the sample was drawn from a limited number of classes in a single school context, which limits the external validity and generalizability of the results to other regions, grade levels, or school types. Third, the same teacher acted as both the facilitator of local wisdom-based PBL and a collaborator in data collection, so teacher expectations and fidelity of implementation may have influenced student performance. Finally, this study relied primarily on cognitive test scores and N Gain scores; affective variables such as motivation, scientific attitudes, or perceptions of local wisdom were not systematically measured, even though previous studies have highlighted the importance of these variables in PBL and culture-based learning (Yusa et al., 2023; Verawati & Wahyudi, 2024; Arjaya et al., 2024; Cahayu et al., 2024). In addition, this study is still limited to analyzing cognitive learning outcomes through multiple-choice test scores and N Gain calculations, so it is not yet able to specifically map students' misconceptions about temperature and heat. Multi-level diagnostic instruments widely used in previous studies, such as two-level, three-level, and four-level tests to identify and trace changes in misconceptions (e.g., Dewi & Wulandari, 2021; Septiyani & Nanto, 2021; Setyaningrum & Sopandi, 2021; Maison et al., 2020; Windiani et al., 2023), have not been implemented in this study. Therefore, further research needs to combine locally-based PBL modules supported by digital technology with the use of two-level, three-level, and four-level diagnostic tests to obtain a more comprehensive picture of the effectiveness of interventions in reducing misconceptions while improving conceptual understanding of temperature and heat.

CONCLUSION

This study indicates that the integration of local wisdom into a digitally supported Problem-Based Learning (PBL) model is effective in improving junior high school students' learning outcomes and conceptual understanding on the topic of temperature and heat. The findings suggest that culturally grounded, problem-oriented instruction can simultaneously support physics content mastery and the development of science literacy.

Practical implications

In classroom practice, teachers can design PBL scenarios that draw on local thermal phenomena and implement them through digital platforms (such as Google Sites) that integrate e-modules, student worksheets, videos, and formative assessments to monitor students' conceptions over time. Teacher professional development should prioritize strengthening competence in authentic problem design, discussion facilitation, and the formative use of diagnostic information on students' thinking.

Policy recommendations.

At the policy level, curriculum developers, school leaders, and education authorities are encouraged to provide explicit curricular space, resources, and institutional support for local wisdom-based PBL within science and physics programs. Collaboration with local cultural stakeholders is important to systematically identify, curate, and sustain relevant local thermal contexts so that similar models can be replicated across science topics and different school settings.

Directions for future research.

Future studies should employ comparison or control groups, larger and more diverse samples, and mixed-method designs to strengthen causal claims and explore how learning duration, facilitation quality, and depth of cultural integration mediate learning outcomes. It is also important to incorporate multi-tier diagnostic tests on temperature and heat (two-tier, three-tier, and four-tier instruments) to track misconception reduction explicitly and to evaluate how local thermal phenomena embedded in PBL tasks contribute to more robust conceptual change.

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