Effectiveness of Google Sites–Assisted Problem-Based Learning in Enhancing Students' Critical Thinking on Heat and Temperature

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Abstract - *This study aims to analyze the effectiveness of the Google Sites-assisted Problem-Based Learning (PBL) model in improving students' critical thinking skills on temperature and heat material. The PBL model was selected because it emphasizes problem-solving and active student participation in learning. Its strength lies in training students to think logically, collaborate, and develop solutions through direct experiences. However, PBL often faces challenges such as limited time, insufficient contextual learning resources, and a lack of media that support independent learning. To address these limitations, this study integrates PBL with Google Sites as a technology-based learning platform. The use of Google Sites provides flexible, engaging, and easily accessible learning resources that enhance students' readiness before class. It serves as a medium for presenting materials, guiding activity steps, offering interactive simulations, and providing spaces for reflection. This integration allows students to build conceptual understanding independently and participate more effectively in classroom learning. The novelty of this study lies in the use of Google Sites not merely as a supporting tool but as a digital learning environment that strengthens the orientation of students' critical thinking. A quantitative method with a quasi-experimental design (pretest–posttest control group design) was employed, involving two classes: an experimental class using the PBL model assisted by Google Sites and a control class applying the Direct Instruction model. The results showed that the Google Sites-assisted PBL model was more effective in improving students' critical thinking skills, independence, and active engagement compared to the Direct Instruction model.*

Keywords*: Critical Thinking Skills; Problem-Based Learning; Google Sites; Temperature and Heat*

INTRODUCTION

Physics is the science that studies natural phenomena, both those that can be observed directly and those that cannot. At the high school/MA level, physics material varies in difficulty, from simple to complex. This variation causes differences in student responses, such as varying levels of understanding, interest, and difficulty in mastering basic physics concepts (Nursyamsi et al., 2018). This condition requires learning strategies that not only focus on mastering concepts but also foster critical thinking skills so that students can understand, reason, and solve problems in the context of physics.

21st-century education requires the harmonious integration of knowledge, skills, and attitudes, as well as comprehensive mastery of information and communication technology (Affilia et al., 2023; Ermawati et al., 2023). One of the key concepts in 21st-century learning is the application of six core competencies known as the 6Cs, namely Character, Citizenship, Critical Thinking, Creativity, Collaboration, and Communication (Anggraeni et al., 2022; Anugerahwati, 2019). According to The Partnership for 21st Century Skills, critical thinking skills are the main foundation in the learning process because they play an important role in shaping analytical, evaluative, and rational decision-making abilities. Therefore, the development of critical thinking skills needs to be a focus in education, given their essential role in

building and expanding students' knowledge (Febriani et al., 2025).

Critical thinking skills are also one of the aspects measured in the PISA study, which assesses the extent to which students are able to apply their knowledge to solve problems in real-life contexts. However, the 2022 PISA results show that Indonesian students' achievements are still relatively low, ranking 68th out of 81 countries in science (OECD, 2023).

Various studies indicate that students' critical thinking skills remain relatively low, particularly when examined using the five categories of critical thinking proposed by Ennis (2011), namely: giving simple explanations, building basic skills, making inferences, providing further explanations, and setting strategies and tactics. A study by Ihsan et al. (2022) conducted at SMAN 8 Makassar revealed that students' abilities in the indicators of interpretation, analysis, and inference were classified as low, with percentages of 29.97 percent, 31.30 percent, and 38.73 percent, respectively. Similar findings were reported by Syarif et al. (2024) in Jeneponto Regency, where most students only reached the low category for the indicators of simple explanation, basic skills, and inference. Research by Mahir and Martawijaya (2025) also showed that although students' overall critical thinking ability was categorized as moderate, the indicator of providing further explanations remained relatively low at 57.3 percent. Furthermore, Prabayanti et al. (2023) reported that students' critical thinking skills in the analysis and evaluation indicators at SMAN 5 Sidrap were still below the expected standard. Wardani and Sumendap (2022) likewise found that in conventional learning on hydrocarbon combustion topics, most students were not yet able to develop critical thinking skills in accordance with Ennis' indicators.

Based on these findings, the five indicators proposed by Ennis were selected in this study because they are considered the most comprehensive framework for systematically measuring critical thinking skills, ranging from basic abilities such as providing simple explanations to more complex stages involving strategy and tactic formulation. In addition, these indicators are widely applied in physics education research, possess clear operational definitions for instrument development, and have been empirically proven to be valid and reliable in assessing students' critical thinking development.

The Problem-Based Learning (PBL) model has been widely recognized as one of the most effective approaches for fostering critical thinking skills, as it encourages students to actively identify problems, analyze information, and develop solutions based on logical reasoning (Arends, 2014; Wenno et al., 2021). Moreover, PBL emphasizes collaboration and communication within groups, which supports deeper conceptual understanding (Baran and Sozbilir, 2018). However, the implementation of PBL in classroom practice is often not optimal. Several studies have applied PBL to enhance students' critical thinking skills, yet the results have not been fully satisfactory. Ghufron et al. (2022) reported that although PBL improved students' critical thinking skills, the improvement remained in the moderate category. Similar results were found by Weni Sartika et al. (2023), who showed that PBL enhanced high school students' critical thinking skills, but the inference and evaluation indicators were still relatively low. In addition, Auliya and Muchlis (2023) found that the application of Scientific Literacy-Oriented PBL improved learning outcomes, although not all students reached the high category. Arafat et al. (2023) also

reported significant improvements; however, time constraints and limited sample size prevented optimal results.

These conditions indicate that although PBL has strong potential, it also faces limitations such as time-consuming implementation, limited learning resources, and a lack of interactive learning media. This situation highlights the need for instructional innovation through the integration of digital technology, one of which is the use of Google Sites as a web-based learning medium that can support each stage of PBL more effectively.

Several recent studies have begun integrating PBL with Google Sites as an interactive digital learning medium. Fitri and Setiawan (2025) found that Google Sites-assisted PBL helped students understand science concepts and increased learning engagement, although the improvement was still moderate. Pradana et al. (2024) showed that Google Sites strengthened student collaboration through multimedia integration, although limited internet access remained a challenge. Meanwhile, Safaatullah et al. (2025) reported that Google Sites facilitated access to learning resources, but reflective learning activities were not optimally implemented by all students. To address these limitations, the present study provides structured guidelines for implementing Google Sites-assisted PBL and incorporates reflective evaluation activities to encourage students to review and improve their thinking processes. This approach is expected to strengthen the findings of Muslimin and Purwaningsih (2023) regarding the importance of active engagement at each stage of PBL, while adding an innovative dimension through dynamic digital learning technology.

In physics learning, particularly on the topic of temperature and heat, the use of Google Sites is highly relevant because these concepts are abstract and frequently lead to misconceptions among students, such as assuming that temperature and heat are identical concepts (Yuliani and Suparwoto, 2023; Oktaviani et al., 2022). Misconceptions also commonly occur in subtopics such as specific heat, Black's principle, and the distinction between temperature and heat (Serevina, 2018; Yuliana, et al., 2023). These misconceptions arise because the phenomena involved are difficult to observe directly, leading students to rely on everyday experiences that may result in incorrect interpretations. Through Google Sites, teachers can present interactive simulations, virtual experiments, and visual representations that help students understand heat transfer processes more concretely. The integration of digital media also enables students to critically analyze physical phenomena encountered in daily life, which aligns with the characteristics of the PBL model.

The novelty of this study lies in the integration of the PBL model with the Google Sites digital platform, which functions as a collaborative medium supporting each stage of problem-based learning. Muslimin and Purwaningsih's (2023) meta-analysis demonstrated that PBL-based student worksheets significantly improve critical thinking and problem-solving skills in physics; however, their study did not involve digital technology as a learning medium. Therefore, the present study extends previous research by adapting PBL principles to a web-based environment through the use of Google Sites as an interactive learning space that facilitates collaboration, documentation, and reflective learning.

The findings of Septarini et al. (2024) further support the importance of integrating digital media into PBL through the development of interactive e-book-based

learning resources, which were shown to be effective in improving critical thinking skills. However, such media tend to be one-directional and do not fully support collaboration and open discussion, as facilitated by Google Sites. Google Sites plays a strategic role in supporting PBL implementation because it allows the integration of various digital features such as videos, documents, and assignment pages that help students access and organize learning activities. This platform supports each stage of PBL as described by Arends (2014), from presenting authentic problems and independent exploration to result presentation and reflection.

The relationship between the PBL syntax and the use of Google Sites in this study can be explained through the role of each learning stage in developing students' critical thinking skills. In the problem orientation stage, students are introduced to real-world problems related to temperature and heat through text, images, and interactive videos provided on Google Sites. This stage helps students develop the ability to provide simple explanations by identifying the core problems being addressed (Wardani and Fiorintina, 2022). In the learning organization stage, students determine the required information and design problem-solving strategies. Google Sites provides access to reference materials, simulations, and online discussion spaces, enabling students to build basic skills through independent exploration of diverse digital sources (Fitri and Setiawan, 2025; Wahyuni et al., 2024).

During the independent and group investigation stage, students analyze data, conduct virtual experiments, and interpret simulation results to identify relationships between temperature and heat concepts. This process develops inference skills, as students must connect empirical observations with theoretical principles (Auliya and Muchlis, 2023). In the development and presentation stage, students compile reports or digital presentations using Google Sites features to communicate their findings. This activity trains students to provide further explanations by presenting solutions and justifications based on the data obtained (Pradana et al., 2024). Finally, in the analysis and evaluation stage, students reflect on the learning process, evaluate the effectiveness of the strategies used, and formulate improvement plans for future activities. This stage strengthens students' ability to organize strategies and tactics, which is essential for developing advanced critical thinking skills (Safaatullah et al., 2025).

Through the integration of PBL and Google Sites, students not only develop a conceptual understanding of temperature and heat but are also trained to think analytically, reflectively, and creatively in solving contextual scientific problems relevant to the twenty-first century. Consistent with the findings of Gunawan et al. (2019) and Ramli et al. (2021), the use of interactive digital media within PBL expands learning exploration and enhances higher-order thinking skills. In this study, Google Sites functions not merely as a content delivery tool, but as a reflective and analytical platform that supports the development of critical thinking skills in accordance with Ennis' indicators.

Although numerous studies have demonstrated the effectiveness of PBL in developing higher-order thinking skills, most have not focused specifically on physics learning, particularly on temperature and heat topics (Nicholus, 2023). At the same time, Google Sites offers advantages as an accessible, flexible, and collaborative learning medium. However, empirical evidence regarding the effectiveness of Google Sites-assisted PBL in improving

students' critical thinking skills remains limited. Therefore, this study focuses on implementing a Google Sites-assisted PBL model to address misconceptions and enhance students' critical thinking skills in temperature and heat learning.

RESEARCH METHODS

The type of research used was quantitative with a quasi-experimental design, namely a pretest-posttest control group design. The research subjects were 11th grade science students at Sumenep High School, Sumenep Regency. The research sample consisted of 1 control class that used the direct instruction learning model as a comparison (30 students) and 1 experimental class (30 students) that used Google Sites-assisted problem-based learning.

The instrument used to measure students' critical thinking skills is a multiple-choice test consisting of 10 questions. The questions are grouped according to the five categories of critical thinking skills proposed by Ennis (2011): (1) providing simple explanations, (2) building basic skills, (3) drawing conclusions, (4) providing further explanations, and (5) organizing strategies and tactics.

The critical thinking test used in this study has undergone expert validation by lecturers from the Master's Program in Physics Education at Malang State University. Based on the results of the validation, the test instrument was deemed suitable for use in a pilot test with revisions. The revisions consisted of editorial improvements to several questions in accordance with the comments and suggestions provided by the experts. The test instrument, which had been validated by experts and revised, was then empirically validated through a pilot test on 100 high school students who had studied the material on temperature and heat. This empirical test aimed to determine the validity and reliability of the questions in measuring students' critical thinking.

The empirical validation results of the critical thinking test show that of the 14 questions tested, 10 questions were declared valid as listed in Table 1.

Table 1. Critical Thinking Test Validation Results

Question No.	r_{xy}	r_{tabel}	Description
1	0,415	0,195	Valid
2	0,498	0,195	Valid
3	0,551	0,195	Valid
4	0,554	0,195	Valid
5	0,585	0,195	Valid
6	0,607	0,195	Valid
7	0,183	0,195	Invalid
8	0,578	0,195	Valid
9	0,672	0,195	Valid
10	0,525	0,195	Valid
11	-0,143	0,195	Invalid
12	0,115	0,195	Invalid
13	0,628	0,195	Valid
14	0,096	0,195	Invalid

Questions 7, 11, 12, and 14 are categorized as invalid because they have values $r_{xy} < r_{tabel}$. Furthermore, the reliability test results shown in Figure 1 indicate a reliability coefficient of 0.781 with a total of 10 items.

Figure 1. Critical Thinking Ability Test Reliability Results

Reliability Statistics

Cronbach's Alpha	N of Items
.781	10

Based on the interpretation of the reliability coefficient, this value falls into the high category, which means that this instrument has an acceptable level of internal consistency in measuring students' critical thinking skills.

After the test instruments have been tested for validity and reliability, the next step is to analyze the level of difficulty and discriminating power of each item. This is to determine the extent to which the developed items are able to distinguish between high and low ability students, and whether the level of difficulty of the items is appropriate for the characteristics of the students. The results of the level of difficulty of each item are listed in Table 2.

Table 2. Difficulty Level Results

Question No.	Mean	Category
1	0,59	moderate questions
2	0,65	moderate questions
3	0,55	moderate questions
4	0,53	moderate questions
5	0,55	moderate questions
6	0,48	moderate questions
7	0,51	moderate questions
8	0,49	moderate questions
9	0,48	moderate questions
10	0,55	moderate questions

The data above can be interpreted to mean that 10 critical thinking skill questions are in the moderate category and can be said to be of good quality. According to Susanto et al. (2015), questions in the moderate category should be recorded in a question bank because they have been proven to be of good quality in measuring student ability. Furthermore, these questions can be reused in future learning outcome tests, both for learning evaluation and further research purposes.

Discrimination power aims to determine the extent to which a question can distinguish between students who have mastered the competency and those who have not or have not fully mastered it. The discrimination power results are listed in Table 3.

Table 3. Item Discrimination Index

Question No.	Corrected Item-Total Correlation	Category
1	0,342	Adequate
2	0,388	Adequate
3	0,419	Good
4	0,398	Adequate
5	0,452	Good
6	0,470	Good
7	0,519	Good
8	0,577	Good
9	0,437	Good
10	0,487	Good

Based on the results of the discriminating power analysis presented in Table 3, the Corrected Item-Total Correlation values ranged from 0.342 to 0.577. These values indicate that all items have a fairly good ability to distinguish between students with high and low abilities. Of the ten items analyzed, three items were categorized as adequate (items 1, 2, and 4), and seven items were categorized as good (items 3, 5, 6, 7, 8, 9, and 10).

The hypothesis in this study was formulated to determine the effect of implementing Google Sites-assisted problem-based learning on students' critical thinking skills in temperature and heat. Based on this objective, the statistical hypothesis proposed is as follows: (1) the null hypothesis (H_0) states that there is no significant difference between the critical thinking skills of students who learn using the Google Sites-assisted problem-based learning model -Based Learning model assisted by Google Sites and students who learn using the Direct Instruction model, and

(2) the alternative hypothesis (H_a) states that there is a significant difference between the critical thinking skills of students who learn using the Problem-Based Learning model assisted by Google Sites and students who learn using the Direct Instruction model. Thus, if the statistical test results show a significance value (Sig.) < 0.05, then H_0 is rejected and H_a is accepted, which means that the application of Google Sites-assisted Problem-Based Learning has a significant effect on improving students' critical thinking skills.

This study uses inferential analysis to test the research hypothesis. A normality test is conducted first to determine the type of test to be used, with the condition that the data is normally distributed if the significance value is > 0.05. If the data is normally distributed, a t-test and N-Gain analysis are used to see the increase in students' critical thinking skills. If the data were not normally distributed, the Wilcoxon nonparametric test was used. The N-Gain value was used to determine the level of improvement in critical thinking skills in the low, medium, or high categories. Furthermore, to determine the difference in the improvement of critical thinking skills between the experimental and control classes, the Mann–Whitney test was used.

RESULTS AND DISCUSSION

This study was conducted in five face-to-face meetings. The activity began with a pretest in the first meeting for both classes. The second, third, and fourth meetings were filled with learning about temperature and heat. The experimental class received treatment through the application of problem-based learning assisted by Google Sites during three meetings, while the control class followed the direct instruction model with the same implementation time. The posttest was given at the last meeting for both classes. The results of the analysis of students' critical thinking skills on the material of temperature and heat are presented in the following research results section.

Results

The descriptive analysis results show the minimum, maximum, standard deviation, and average scores of the pretest and posttest between the control class and the experimental class. More details can be seen in Table 4.

Table 4. Descriptive Statistical Analysis

Description	Control Class		Experimental Class	
	Pretest	Posttest	Pretest	Posttest
N	30	30	30	30
Range	30	40	40	40
Minimum	20	50	20	60
Maximum	50	90	60	100
Mean	33.33	72.33	35.67	84.00
St.Deviasi	10.933	11.943	10.726	10.700

From the table above, it can be seen that both classes experienced an increase in critical thinking test scores. Despite this increase, the experimental class outperformed the control class. In the pretest, both the control and experimental classes had the same minimum score of 20, while the maximum score of the control class was 10 points lower than that of the experimental class. In the posttest, the minimum and maximum scores of the experimental class were higher than those of the control class.

The results of the pretest and posttest score analysis show that both the control and experimental classes experienced an increase after being given treatment. The average pretest score in the control class was 33.33, which then increased to an average of 72.33 in the posttest. Meanwhile, in the experimental class, the average pretest score was 35.67 and also increased in the posttest

to 84.00. This striking difference in improvement shows that the learning method applied in the experimental class had a greater impact on students' critical thinking skills than the method used in the control class. However, to ensure that the difference is statistically significant and not just a coincidence, inferential analysis is needed.

Before conducting inferential tests, it is necessary to conduct a prerequisite test, namely a normality test using Kolmogorov-Smirnov. This test aims to determine whether the sample used is normally distributed or not. The results of the normality test can be seen in Table 5.

Table 5. Normality test results

Class	Kolmogorov Smirnov	Shapiro Wilk
	Sig.	Sig.
Pretest Control	0.001	0.001
Posttest Control	0.023	0.021
Pretest Experimental	0.003	0.016
Posttest Experimental	0.015	0.018

The results of the analysis show that the Asymp.Sig (2-Tailed) of the pretest and posttest in both classes (control and experimental) is less than 0.05, which means that the data is not normally distributed. The abnormality of the pretest and posttest data indicates that nonparametric tests should be used for further statistical analysis. Therefore, in this study, the Wilcoxon test was used to determine the difference in students' critical thinking skills before and after the treatment was applied. The results of the Wilcoxon test can be seen in Table 6.

Table 6. Wilcoxon Test Results

Class		Asymp. Sig. (2-tailed)
Control	Pre Post	0.000
Experimental	Pre Post	0.000

Based on the analysis results, an Asymp. Sig. (2-tailed) value of 0.000 was obtained in both the control and experimental classes. This value is smaller than the significance level of 0.05 ($p < 0.05$), which means that there is a significant difference between the pretest and posttest results in the control and experimental classes. Then, to see how much the students' critical thinking skills have improved in each class, an N-gain test is needed. The following are the results of the N-gain test in Table 7.

Table 7. N-Gain Test Results

N-Gain Critical Thinking	Control	0,6
	Experimental	0,77

N-Gain analysis is used to determine the increase in students' critical thinking skills after participating in learning in each class. Based on the calculation results, the average N-Gain value obtained was 0.60 for the control class and 0.77 for the experimental class.

Based on Hake's (1998) interpretation of N-Gain categories, a value of 0.60 falls into the moderate category, while a value of 0.77 falls into the high category. This shows that both the control class and the experimental class experienced an increase in critical thinking skills after learning, but the experimental class showed a higher increase than the control class. The greater improvement in the experimental class indicates that the application of Google Sites-assisted problem-based learning contributed significantly to developing students' critical thinking skills in the subject of temperature and heat.

Then, to determine whether the difference in improvement was statistically significant, further analysis was conducted using the Mann–Whitney U test. This test was used because the N-Gain data was not

normally distributed and the two groups were independent. Through the Mann–Whitney test, it was possible to determine whether there was a significant difference between the experimental class and the control class. The results of this test form the basis for assessing the effectiveness of Google Sites-assisted problem-based learning compared to conventional learning in improving students' critical thinking skills. The results of the Mann Whitney test are shown in Table 8.

Table 8. Mann-Whitney Test Results

	Posttest Results
Mann Whitney-U	222.000
Wilcoxon W	687.000
Z	-3.463
Asymp. Sig. (2-tailed)	.001

Based on the test results conducted using the SPSS program, the values obtained were U = 222.000, Z = -3.463, and Asymp. Sig. (2-tailed) = 0.001. Since the significance value is less than 0.05 ($p < 0.05$), it can be concluded that there is a significant difference between the posttest results of critical thinking skills of students in the experimental class and the control class.

The Mean Rank value shows that the experimental class had an average rank of 38.10, higher than the control class, which had an average rank of 22.90. This indicates that the critical thinking skills of students in the experimental class were significantly better than those in the control class.

Discussion

The analysis results indicate that the N-Gain value of the experimental class is greater than that of the control class. A high N-Gain category implies that the learning model applied has succeeded in contributing significantly to the development of students' abilities, especially when compared to conventional learning approaches. Furthermore, the Mann-Whitney test analysis revealed that the Asymp. Sig. (2-tailed) value reached 0.001, which is lower than the threshold of 0.05. This indicates a statistically significant difference between the posttest scores in the control class and the experimental class.

The findings underscore that the implementation of the Problem-Based Learning (PBL) model supported by Google Sites has a substantial impact on advancing students' critical thinking skills. The results of this study are also in line with Nicholus' (2023) study, which found that students who participated in PBL learning experienced significant progress in the dimensions of analysis, evaluation, and inference, especially when compared to traditional learning methods.

The integration of Problem-Based Learning with Google Sites plays an important role in developing students' critical thinking skills through authentic tasks, collaboration, and access to structured materials. This combination has been proven effective in facilitating active learning that requires analysis and evaluation (Nurdin et al., 2023). Various studies show that the application of Problem-Based Learning (PBL) assisted by Google Sites increases student engagement, motivation, and learning outcomes, which indirectly supports the development of critical thinking (Mustika, 2024). This platform creates an interactive learning environment, allowing students to access materials, assignments, and learning resources flexibly and independently. The collaborative and reflective features of Google Sites also facilitate metacognitive learning so that the critical thinking process is more focused and documented (Hidayati, 2024). The best results are obtained when the PBL problem

design is authentic and accompanied by digital activity guidelines, with teachers trained in online PBL design (Basori, 2024).

As stated by Wahyudi (2023), the use of Google Sites in the learning process is effective in strengthening students' independence in learning, while also facilitating understanding of concepts through attractive and well-structured digital content. On the other hand, Purwita (2023) emphasizes that web-based media such as Google Sites can increase students' active participation levels and encourage them to engage in more in-depth critical thinking when solving problems presented by teachers.

These findings are further reinforced by research conducted by Serevina et al. (2018), who developed an e-module based on Problem-Based Learning (PBL) for temperature and heat material, and found substantial progress in students' critical thinking abilities and science process skills. This improvement can be explained by the fact that problem-based learning facilitates students in building conceptual understanding autonomously through a process of in-depth exploration and reflection. As described by Paul and Elder (2019), critical thinking involves the ability to evaluate information logically and structurally, followed by decision-making based on empirical evidence and sound reasoning. Thus, the high N-Gain value and statistically significant test results underscore the success of integrating PBL with Google Sites in fostering students' critical thinking skills on the topics of temperature and heat.

Overall, the results of this study are consistent with Mulyaningsih's (2023) study, which shows that the integration of web-based learning can enrich students' critical thinking skills by providing a collaborative, adaptive, and problem-solving-oriented learning space. Similar findings were also reported by Rahmawati & Prasetyo (2022), who emphasized that the integration of interactive digital media in problem-based learning not only increases student engagement but also fosters analytical and evaluative skills, which are at the core of critical thinking. Furthermore, a study by Putra et al. (2021) shows that the use of web platforms such as Google Sites encourages learning autonomy and self-reflection, which strengthens decision-making and logical reasoning processes in the context of physics learning. Therefore, the N-Gain analysis and Mann-Whitney test not only confirm the effectiveness of Google Sites-supported PBL in improving learning outcomes but also emphasize the crucial role of digital learning media innovation in supporting the development of critical thinking skills that are essential for the 21st century.

CONCLUSION

Based on the findings of this study, it can be concluded that the implementation of problem-based learning (PBL) supported by Google Sites on the subject of temperature and heat successfully advanced students' critical thinking skills. N-Gain analysis revealed a value of 0.60 (moderate category) for the control class, while the experimental class achieved 0.77 (high category). The Mann-Whitney test further confirmed this, with an Asymp. Sig. (2-tailed) value of 0.001 (< 0.05), indicating a significant difference between the posttest groups. In addition, the Mean Rank of the experimental class (38.10) was superior to that of the control class (22.90), proving that Google Sites-assisted PBL is more effective than conventional approaches in developing critical thinking skills.

Therefore, combining PBL with digital technology such as Google Sites can

be used as a potential alternative strategy for physics learning, especially on the topics of temperature and heat. It is recommended that teachers make more intensive use of digital media in the teaching process, while future research should involve larger samples, other physics materials, or comparisons with alternative digital platforms.

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