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The Effect of Collaborative Learning on High School Students' Problem-Solving Ability in Heat and Temperature

Nur Fadilla, Safriana Safriana*, Desy Sary Ayunda, Nanda Novita, Tulus Setiawan
Physics Education Study Program, FKIP, Malikussaleh University, Aceh, Indonesia

Correspondence E-mail: safriana@unimal.ac.id

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ABSTRACT

This research is motivated by the low problem-solving ability of students in physics classes, which is still dominated by teacher-centered teaching. The purpose of this study is to determine the influence of collaborative learning models on students' problem-solving skills. This study uses a quantitative approach using a quasi-experimental design (Nonequivalent Control Group Design) involving two classes: an experimental class that implements a collaborative learning model and a control class that implements a hands-on instruction model. The research sample consisted of 22 students in the experimental class and 22 students in the control class. The research instrument consisted of a test of problem-solving ability given as a pretest and posttest. The results showed that the average pretest and posttest scores in the experimental class increased from 14.00 to 90.68, while in the control class it increased from 12.91 to 46.91. The results of the hypothesis test using the Independent Sample t-test showed a significance value of 0.000 < 0.05, indicating a significant difference between the two classes. Furthermore, the average N-Gain score in the experimental class was 89.20% (high category), while in the control class it was 39.04% (medium category). Thus, it can be concluded that the collaborative learning model has a significant influence on students' problem-solving abilities in physics learning.

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1. INTRODUCTION

Advances in science and technology require the education sector to develop higher-order thinking skills, one of which is problem-solving ability (Redhana, 2019). Students' problem-solving skills are a crucial aspect of learning because they relate to students' ability to formulate problems, design solution steps, and evaluate the results of those solutions systematically, enabling students to independently solve problems that require analysis, decision-making, and strategy formulation during the learning process (Ropi'i, 2025). In high school physics education, students are expected to be able to analyze problems, determine solution strategies, and evaluate results based on the principles and laws of physics. Physics education is not only focused on delivering content but also on developing problem-solving skills through analytical and contextual problem-solving. In practice, physics instruction is still often dominated by lecture-based methods and procedural problem-solving exercises, so students' opportunities to develop problem-solving skills through interaction and collaboration with peers remain limited (Hariyanto, 2022).

Based on observations and interviews with physics teachers at MAS Syamsuddhuha in North Aceh Regency, it appears that student participation in physics classes is still not optimal. Students tend to be passive during the learning process, particularly when it comes to asking questions, expressing opinions, or responding to problems presented by the teacher. This indicates that students' active engagement in the thinking process and their problem-solving skills still need to be improved. From the perspective of problem-solving skills, students tend to apply formulas directly without a sufficient understanding of the underlying concepts. When faced with physics problems that differ in terms of variables or context from the provided examples, some students struggle to determine the appropriate steps for solving them. This situation indicates that key stages in the problem-solving process such as understanding the problem, planning a solution strategy, and evaluating the solution have not yet developed optimally.

This phenomenon is related to the context of physics education in schools, which still faces limitations in supporting facilities and infrastructure, particularly physics laboratories. These limitations result in the learning process being conducted primarily through verbal conceptual explanations, without the support of hands-on laboratory experiences. Consequently, students have limited opportunities to connect physics concepts with real-world phenomena, so their ability to solve problems independently and systematically has not yet been fully developed.

Previous research has shown that students tend to solve physics problems by memorizing formulas without understanding the underlying basic concepts (Jannah et al., 2022). Consequently, physics learning outcomes remain suboptimal, particularly when students are faced with contextual problems in temperature and heat that require systematic reasoning. This underscores the importance of instructional innovations capable of stimulating students' analytical thinking and problem-solving skills (Anggraini, 2024).

One alternative instructional model that has the potential to positively influence students' problem-solving skills is the collaborative learning model. This model emphasizes cooperation among students in small groups through discussion, the exchange of ideas, and joint problem-solving (Fitriyani et al., 2025). Through these interactions, students have the opportunity to build a deeper conceptual understanding while developing their problem-solving skills.

In the context of physics education, collaborative learning models provide students with opportunities to express their opinions, test ideas, and reflect on their thought processes when solving problems related to temperature and heat. These activities align with social constructivism, which posits that knowledge is constructed through social interaction and shared learning experiences (Marlina, 2021).Thus, collaborative learning not only enhances conceptual understanding but also trains students to identify problems, devise solutions, and draw logical conclusions.

Previous research has shown that the implementation of collaborative learning in physics instruction has a positive impact on students' problem-solving skills and learning outcomes compared to conventional instruction (Setiawan, 2024). However, research specifically examining the impact of collaborative learning models on high school students' problem-solving skills regarding temperature and heat remains limited, particularly studies that analyze problem-solving skills based on structured physics problem-solving stages.

2. METHODS

This study employs a quantitative approach because the data collected were statistically analyzed to test the research hypotheses (Rukminingsih, 2022). The method used was a quasi-experimental study with a Nonequivalent Control Group Design. In this design, both the experimental and control groups were administered pre- and post-tests to determine the effect of the treatment administered (Siregar, 2023). The research sample was selected using purposive sampling. The experimental group received instruction using the collaborative learning model, while the control group received conventional instruction. The data obtained were analyzed to determine the effect of the collaborative learning model on students' problem-solving skills.

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Description:
O_1 : Pretest for the experimental class
O_2 : Posttest for the experimental class
O_3 : Pretest for the control class
O_4 : Posttest for the control class
X : Collaborative learning

The research instruments consisted of an observation sheet for teaching implementation and an essay-based test of students' problem-solving skills administered as a pretest and a posttest. The test items were developed based on the problem-solving ability indicators used in this study. According to (Aprasela, 2025), the indicators include: (1) understanding the problem, (2) planning a solution, (3) implementing the solution, and (4) evaluating the results.

Prior to data collection, the research instruments underwent content and construct validation by two experts in physics education. The content validation process assessed the relevance, clarity, and appropriateness of each item with the research objectives, learning objectives, and the four indicators of problem-solving skills. Construct validity was established by ensuring that each essay item represented the intended problem-solving construct. The instruments were revised based on the suggestions provided by the validators before being administered to the participants.

To minimize subjectivity in scoring the essay responses, a scoring rubric with predetermined assessment criteria was used consistently throughout the assessment process. Furthermore, the reliability of the problem-solving test was examined using Cronbach's Alpha, yielding a coefficient of 0.965, indicating excellent internal consistency. Therefore, the instrument was considered highly reliable for measuring students' problem-solving skills.

Data analysis was conducted using the N-Gain test to assess improvements in students' problem-solving skills, the Shapiro–Wilk test for normality, Levene's test for homogeneity, and an independent samples t-test for hypothesis testing.

The results of the lesson implementation observation sheets were analyzed using the percentage of lesson implementation as follows:

$$Percentage\ \% = \frac{Actual\ score}{Expected\ score} \times 100 \quad (1)$$

The percentage of implementation of the learning model was then interpreted based on the following criteria:

Table 2. Criteria for the Implementation of the Collaborative Model

Implementation Rate	**Criteria**
$k \geq 90$	Excellent
$80 \leq k < 90$	Good
$70 \leq k < 80$	Fair
$60 \leq k < 70$	Poor
$k < 60$	Very Poor

Source: (Silviah et al., 2022)

The pretest and posttest results for problem-solving skills were analyzed using the following formula:

$$Percentage\ \% = \frac{Score\ obtained}{160} \times 100 \quad (2)$$

The maximum score of 160 represents the highest possible score that could be obtained on the essay test. The instrument consisted of 10 essay questions, and each question had a maximum score of 16 based on the scoring rubric developed according to the four problem-solving indicators. Therefore, the maximum total score for the entire test was 160 (10 × 16 = 160).

This study also analyzed students' problem-solving skills for each indicator using the following formula:

$$Percentage\ \% = \frac{\text{Average score for each indicator}}{40} \times 100 \quad (3)$$

The denominator of 40 represents the maximum possible score for each problem-solving indicator. Since the total maximum score of the test was 160 and the assessment consisted of four problem-solving indicators, each indicator had a maximum score of 40 (160 ÷ 4 = 40). This calculation was used to determine the percentage achievement for each indicator.

Table 3. Average score for each indicator

Score	Criteria
88 - 100	Excellent
74 - 87	Good
60 - 73	Fair
< 60	Poor

Source: (Ayu et al., 2025)

Next, the students' pretest and posttest scores on problem-solving skills were used for the N-Gain test. The N-Gain test was used in this study to determine the improvement in high school students' problem-solving skills regarding temperature and heat after participating in lessons using. The calculation of N-Gain in this study uses the following formula:

$$\text{N} - \text{Gain} = \frac{posttest\ score\ -\ pretest\ score}{100 - pretest\ score} \quad (4)$$

The N-gain category for improvements in problem-solving skills can be seen in Table 4

Table 4. N-Gain Interpretation Criteria

No.	Limitations	Category
1.	(g) < 0,3	Low
2.	0,3 < (g) ≤ 0,7	Medium
3.	(g) > 0,7	High

Source: (Mustika Wati, 2021)

3. RESULT AND DISCUSSION

3.1 Problem-Solving Skills Results for the Experimental Class

Students problem-solving skills were assessed using pretest and posttest questions. Each test consisted of 10 essay-type questions designed to measure students' problem-solving skills. The pretest results are shown in the following table:

Table 5. Problem-solving skills of the experimental class

Results	Pretest	Posttest
Maximum	18	99
Minimum	10	81
Mean	14,00	90,68
Standard Deviation	2,469	5,331

Based on Tabel 5, the highest pretest score was 18 and the lowest was 10, with an average score of 14.00. Meanwhile, the posttest results showed an improvement, with the highest score reaching

99 and the lowest 81. The posttest average increased to 90.68, indicating an improvement in students' problem-solving skills after being taught using the collaborative learning model.

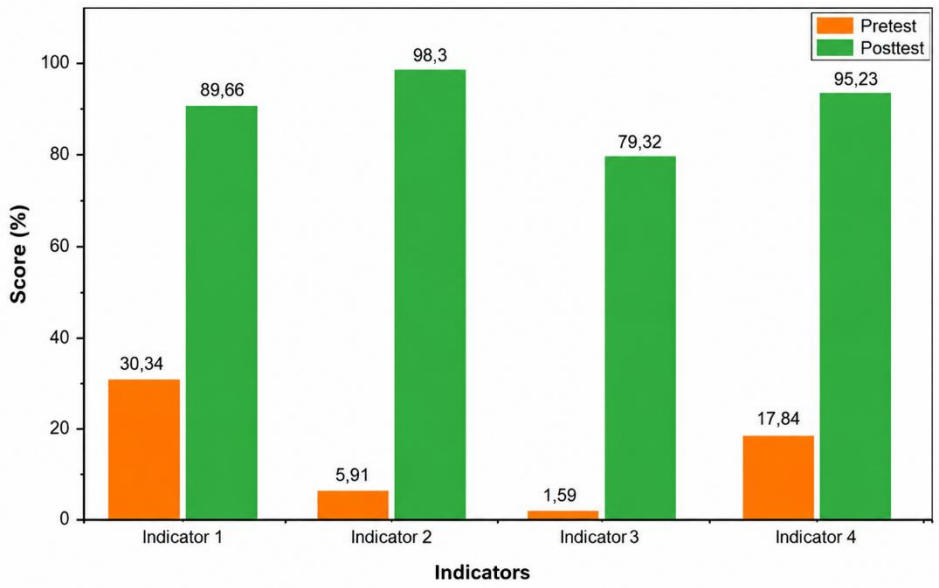


Figure 1. Graph of Problem-Solving Ability Indicator Scores for the Pretest and Posttest in the Experimental Class

Based on Figure 1, problem-solving ability scores were obtained before and after the implementation of the collaborative learning model. Before the collaborative learning model was implemented, the highest average score obtained was 30.34 on the first indicator and 1.59 as the lowest average score on the third indicator. After the collaborative learning model was implemented, the highest average score obtained was 98.3 on the second indicator and 79.32 as the lowest average score on the third indicator. These posttest results illustrate an improvement in students' problem-solving skills.

Although all four indicators of problem-solving skills improved after the implementation of the collaborative learning model, the third indicator (implementing the solution) obtained the lowest posttest score (79.32). This finding indicates that students still experienced difficulties when applying physics concepts to solve problems systematically, despite being able to understand the problem and formulate an appropriate solution plan. The implementation stage requires students to integrate conceptual understanding, mathematical reasoning, and procedural accuracy simultaneously (Kilpeläinen et al., 2025). In the topic of temperature and heat, students were expected to identify the appropriate physical principles, select the correct equations, substitute variables accurately, perform mathematical calculations, and interpret the results correctly. These multiple cognitive demands make the implementation stage more challenging than the other problem-solving indicators.

From a pedagogical perspective, the collaborative learning model successfully facilitated students' understanding of problems and planning of solution strategies through peer discussion, knowledge sharing, and collaborative reasoning, which contributed to the high achievement observed in the first and second indicators (Diani, 2023). However, the successful execution of the solution still depended largely on each student's individual ability to apply physics concepts and complete mathematical procedures accurately. Consequently, although collaborative learning significantly improved students' overall problem-solving skills, additional instructional support, such as guided practice, scaffolded problem-solving activities, and formative feedback, is needed to strengthen students' ability to implement solution procedures independently. This finding is consistent with recent studies reporting that collaborative learning enhances conceptual understanding and collaborative reasoning, but students often continue to experience difficulties

during the implementation stage because it requires the integration of conceptual knowledge, procedural skills, and mathematical reasoning simultaneously.

3.2 Results of Problem Solving Ability Control Class

Table 6. Problem-Solving Skills Results for the Control Class

Results	Pretest	Posttest
Maximum Value	16	60
Minimum Value	10	36
Mean	12,91	46,91
Standard Deviation	1,743	6,879

Based on Table 6, the highest pretest score is 16 and the lowest is 10, with an average score of 12.91. Meanwhile, the posttest results showed improvement, with the highest score reaching 60 and the lowest of 36. The average posttest increased to 46.91, showing an improvement in students' problem-solving skills after being taught using a Direct Intruction.

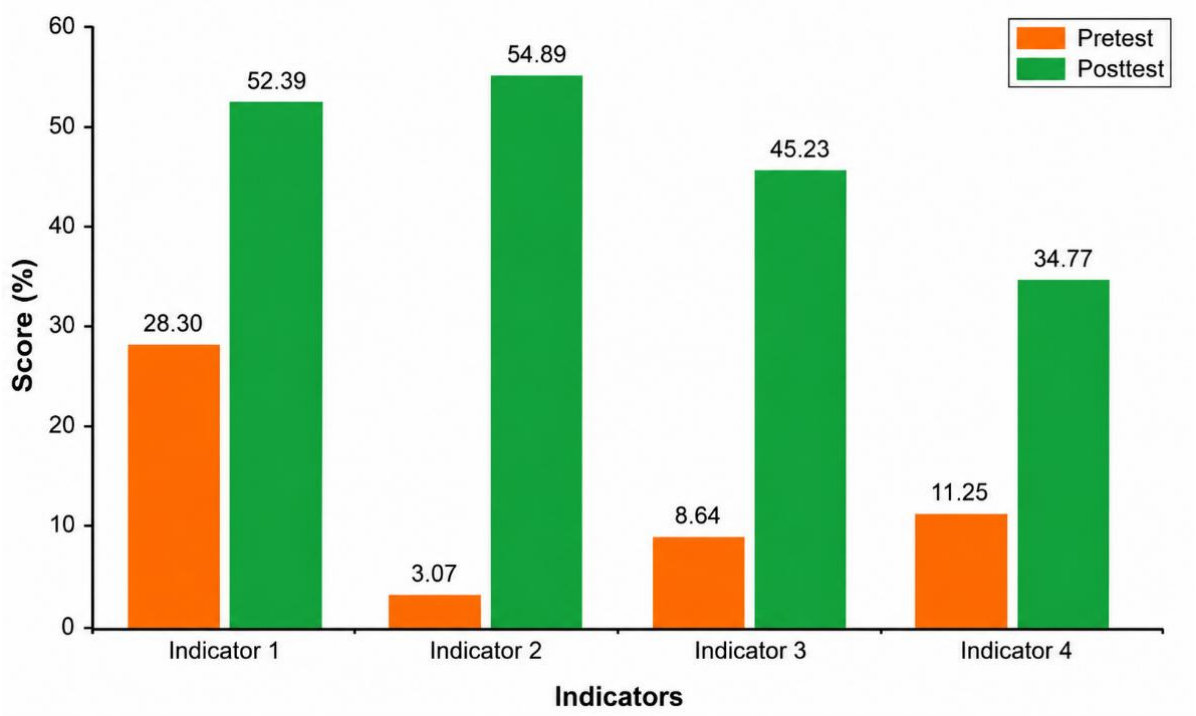


Figure 2. Graph of Pretest and Posttest Results for the Problem-Solving Skills Indicator by Class Control

Figure 2 shows the problem-solving ability scores obtained before and after the implementation of the conventional learning model. Before the conventional learning model was implemented, the highest average score obtained was 28.3 on the first indicator and 3.07 as the lowest average score on the second indicator. After the conventional learning model was implemented, the highest average score obtained was 54.89 on the second indicator and 34.77 as the lowest average score on the third indicator. These posttest results illustrate an improvement in students' problem-solving skills. However, the improvement observed was still not optimal and lower compared to the improvement in the experimental class that used the collaborative learning model.

The collaborative learning model was implemented in the experimental class over three sessions. Observations were conducted using an observation sheet for the implementation of the collaborative learning model, which consisted of several observation aspects in accordance with the collaborative learning syntax.

Tabel 7. Results of Observations on the Implementation of the Collaborative Learning Model

Session	O1	O2	O3	O4	Session Average	Category
1	84	88	80	84	84	Good
2	88	92	88	92	90	Very Good
3	92	96	92	96	94	Very Good
Final average					89,33	Good

Based on Tabel 7 the results of observations on the implementation of the collaborative learning model show an improvement in each session. The average implementation score in the first session was 84 (good category), increased to 90 (very good category) in the second session, and reached 94 (very good category) in the third session. Overall, the average implementation of learning was 89.33, categorized as very good. These results indicate that the collaborative learning model was implemented effectively during the learning process in the experimental class.

Tabel 8. Independent Samples t-Test Results

Test	Levene's Sig.	t	df	Sig. (2-tailed)	Decision
Independent Samples *t*-Test	0.171	23.727	42	< 0.001	H_0

Table 8 presents the results of the Independent Samples *t*-test. The Levene's Test significance value was 0.171 (> 0.05), indicating that the assumption of homogeneity of variance was satisfied. Therefore, the Equal Variances Assumed results were used for interpretation. The analysis showed a statistically significant difference in students' problem-solving skills between the experimental and control groups (t (42) = 23.727, p < 0.001). Thus, the null hypothesis (H_0) was rejected, indicating that the collaborative learning model had a significant positive effect on students' problem-solving skills.

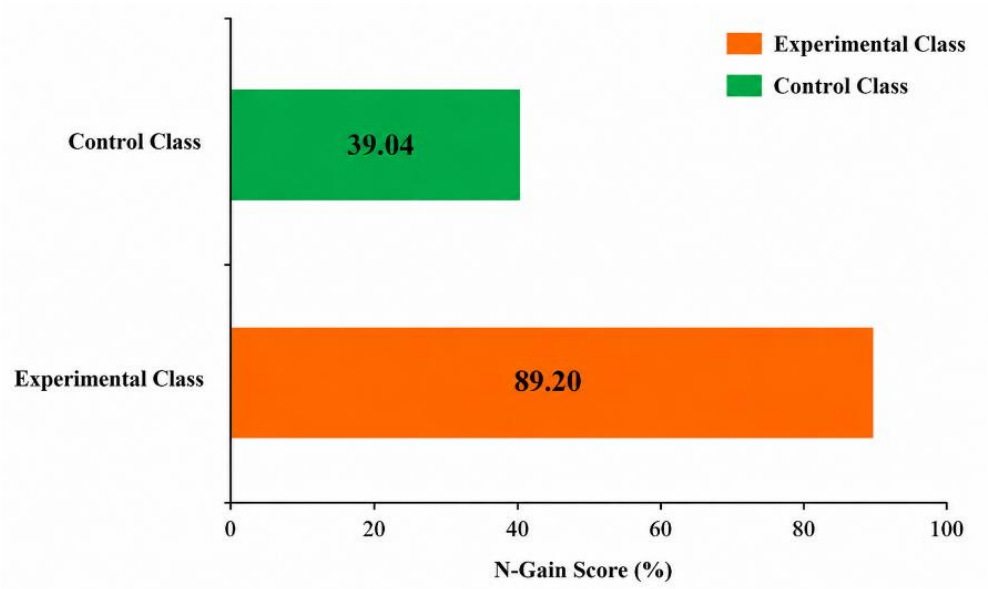


Figure 1. Diagram Uji *N-Gain Score*

Based on Figure 3, the average N-Gain Score for the experimental group using the collaborative learning model was 89.20, which falls into the high category. Meanwhile, the control class that implemented the Direct Instruction learning model had an average N-Gain Score of 39.04, which falls into the moderate category. This difference in average N-Gain Scores indicates that the improvement in students' problem-solving skills in the experimental class was higher than in the control class. This suggests that the implementation of the collaborative learning model has a more effective impact on improving students' problem-solving skills regarding temperature and heat.

The improvement in students' problem-solving skills can be attributed to the learning activities implemented during the collaborative learning process. Throughout the lessons, students worked in small groups to discuss physics problems, exchange ideas, compare different solution strategies, and evaluate each other's reasoning. These collaborative activities encouraged active participation and enabled students to construct knowledge through social interaction rather than relying solely on teacher explanations. As a result, students developed a deeper understanding of temperature and heat concepts and became more systematic in solving physics problems.

Among the collaborative learning activities, group discussion played the most significant role in improving students' problem-solving skills. During discussions, students were encouraged to identify the given information, formulate appropriate solution strategies, and justify their reasoning to other group members. Peer feedback also helped students recognize misconceptions and improve their solutions before presenting the final answers. Furthermore, group presentations provided opportunities for students to explain their reasoning and receive constructive feedback from both peers and the teacher, thereby strengthening their conceptual understanding and problem-solving abilities.

The results of this study encompass four stages: understanding the problem, planning a solution, implementing the solution, and evaluating the results. These four stages were evident throughout the collaborative learning process. Students first understood the given problem, then discussed to determine a solution strategy, implemented the planned solution steps, and reviewed the results obtained. Thus, the collaborative learning model is able to facilitate students in developing problem-solving skills systematically.

Based on the problem-solving indicators, the planning solution indicator demonstrated the greatest improvement after the implementation of collaborative learning. This finding indicates that collaborative discussions enabled students to identify appropriate strategies before solving physics problems. Through the exchange of ideas and collaborative reasoning, students became more confident in selecting suitable solution procedures.

Although all four indicators improved, the implementing the solution indicator remained relatively lower than the others. This may be because solving physics problems requires not only conceptual understanding but also procedural and mathematical skills. Some students still experienced difficulties when applying equations accurately and performing calculations independently. Nevertheless, collaborative learning helped reduce these difficulties by allowing students to learn from their peers during the problem-solving process.

This study aligns with social constructivism theory, which states that knowledge is constructed through social interaction and shared learning experiences. In collaborative learning, students have the opportunity to construct knowledge through discussions, sharing experiences, and expressing opinions (Zuliyanti, 2025). Thus, the social interactions that occur during collaborative learning provide students with the opportunity to develop a deeper conceptual understanding, thereby enhancing their problem-solving skills.

These findings demonstrate that the principles of social constructivism were reflected throughout the collaborative learning process. Students did not simply receive information from the teacher but actively constructed knowledge through interaction, discussion, and shared problem-solving experiences. The exchange of ideas among group members enabled students to refine their understanding of physics concepts and develop more effective strategies for solving temperature and heat problems. Therefore, collaborative learning provided meaningful learning experiences that promoted both conceptual understanding and problem-solving skills.

The results of this study are consistent with research conducted by (Setiawan, 2024) which showed that collaborative learning models can improve students' problem-solving skills. Collaborative learning allows students to exchange information, provide feedback, and develop various alternative solutions to the problems they face. Another study by (Nurdiansyah, 2024) also found that group collaboration can improve students' ability to analyze and solve problems systematically. These findings reinforce the results of this study that collaborative learning models influence students problem-solving skills.

These findings are supported by the research of (Safitri et al., 2024), which states that Collaborative Problem Solving is effective in improving students' problem-solving skills through

active interaction and group collaboration. Through collaborative activities, students have the opportunity to think critically, express their opinions, and integrate various ideas to find solutions to the problems they face. Similarly, (Safriana, 2025) through a systematic literature review, concluded that collaborative learning positively affects students' critical thinking, creativity, collaboration, communication, and problem-solving skills in science education. Collaborative learning encourages students to actively participate in discussions, exchange ideas, evaluate alternative solutions, and construct knowledge collectively, leading to improved learning outcomes.

In addition, (Wilujeng et al., 2024) found that the implementation of the Process-Oriented Guided Inquiry Learning (POGIL) model significantly improved students' problem-solving abilities in thermodynamics learning. The study emphasized that learning activities centered on students' active participation enable learners to analyze problems more effectively, develop appropriate solution strategies, and evaluate the results obtained. Therefore, these previous findings strengthen the results of the present study, indicating that collaborative learning has a significant effect on improving students' problem-solving skills in physics learning, particularly on temperature and heat topics.

Compared with previous studies, the present research provides additional evidence by analyzing students' problem-solving skills based on four structured indicators, namely understanding the problem, planning a solution, implementing the solution, and evaluating the results. This approach not only demonstrates that collaborative learning improves students' overall problem-solving skills but also explains how each stage of the problem-solving process develops through collaborative learning activities. Therefore, this study contributes more detailed pedagogical evidence regarding the implementation of collaborative learning in physics education, particularly on the topic of temperature and heat.

Based on the results of the hypothesis testing, it can be concluded that the collaborative learning model has a significant effect on students' problem-solving skills. These results indicate that learning that involves cooperation, communication, and active student participation provides a more meaningful learning experience than teacher-centered learning. Thus, the collaborative learning model can serve as an effective alternative for improving students' problem-solving skills in physics.

The findings of this study suggest that the collaborative learning model implies that teachers need to provide students with more opportunities to actively engage in the learning process. This collaborative model not only influences students' understanding of physics concepts but also fosters the development of 21st-century skills such as critical thinking, communication, collaboration, and problem-solving.

4. CONCLUSION

Based on the research findings, it can be concluded that the collaborative learning model has an effect on students' problem-solving skills regarding temperature and heat at MAS Syamsuddhuha. This was demonstrated through an independent samples t-test with a significance level of $0.000 < 0.05$, leading to the rejection of H_0. Furthermore, the posttest mean and N-Gain scores for the experimental class were higher than those for the control class. Thus, the collaborative learning model has a significant effect on improving students' problem-solving skills.

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