Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM
ISSN 1907-1744 (Cetak)
ISSN 2460-1500 (Daring)

Effect of Using the Hydrostatics and Heat Kit on High School Students Conceptual Change in the Heat Topic

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Received: December 8, 2025. Accepted: January 28, 2026. Published: February 11, 2026

Abstract: This research is motivated by the fact that students frequently experience misconceptions, particularly in distinguishing between temperature and heat, understanding the direction of heat transfer, and analyzing the relationship between heat and phase changes. This study aims to analyze the effect of using the Hydrostatics and Heat Kit on senior high school students' conceptual change in the topic of heat. The use of the Hydrostatics and Heat Kit in heat instruction is expected to facilitate students' conceptual understanding through concrete and direct experimental activities. This study employed an experimental method with a one-group pretest–posttest design conducted at SMA Negeri 1 Bolangitang. The research subjects consisted of two classes: an experimental class and a replication class, each with 30 students. A Three-Tier Diagnostic Test was used as the research instrument to identify students' conceptual status, which was classified into Guessing (MB), Lack of Conceptual Understanding (TPK), Misconception (M), and Scientific Understanding (PK). Data were analyzed using descriptive quantitative analysis by comparing pretest and posttest results to identify patterns of students' conceptual change. These patterns were represented by red arrows (↑) indicating improvement from misconception to scientific understanding, blue arrows (↓) indicating a decline in conceptual understanding, and yellow circles (O) indicating no conceptual change. The results showed that students in both classes experienced conceptual changes toward more scientific understanding, as indicated by the dominance of red arrows (↑). The most significant improvements occurred in differentiating between temperature and heat and in analyzing the relationship between heat and temperature changes during phase transitions. These findings support the Constructivism Conceptual Change theory, which emphasizes learning as a process of reconstructing initial conceptions into more accurate scientific concepts. Overall, the use of the Hydrostatics and Heat Kit within an Inquiry-Based Learning framework was effective in improving students' conceptual understanding and reducing misconceptions about heat.

Keywords: Conceptual Change; Heat; Hydrostatics and Heat KIT.

Introduction

Misconceptions among senior high school students regarding the concept of heat remain a common problem in physics learning. Identification results using a three-tier diagnostic test indicate that most students still experience misconceptions in the topic of heat, particularly in the concepts of temperature, heat, and mechanisms of heat transfer [1]. A misconception is an incorrect understanding of a concept or one that does not correspond to the scientifically accepted meaning [2].

Previous studies have shown that students still hold various misconceptions about heat. In the concept of heat [3]Students often equate heat with temperature and perceive heat as energy that can be stored in an object [4]. In the context of latent heat, students often assume that water's temperature continues to increase during boiling. pendidihan [5] and they assume that ice releases heat when it melts. In the concept of heat transfer, students believe that low temperature moves toward high temperature [7], that cold water releases heat while hot water absorbs it [8], that conduction occurs through air [9], and they view the heating of a metal spoon in a cup of coffee as radiation rather than conduction [10].

The emergence of these misconceptions is closely related to physics learning processes in schools that are still dominated by lecture-based instruction and routine problem-solving, causing students to be passive and experience difficulties in connecting physics concepts with real-world phenomena [11]. In addition to instructional factors, internal student factors such as incorrect prior knowledge, limited reasoning ability, and suboptimal cognitive development also contribute to the formation of misconceptions [12].

To overcome these obstacles, a learning approach is needed that can help students construct conceptual understanding through empirical experiences. One alternative is the use of the Hydrostatics and Heat KIT. The Integrated Instrument KIT is a set of tools designed as an integrated learning [13]. Through the use of the KIT, students can directly observe heat-related phenomena, allowing concepts to be constructed not only abstractly but also through real experiences [14].

The use of the Hydrostatics and Heat KIT is also aligned with the Inquiry-Based Learning (IBL) approach, a learning model that encourages students to think analytically, critically, and creatively through scientific processes such as observing, questioning, formulating

How ti Cite:
Y. Baks, A. Arbie, and T. J. Buhungo, "Effect of Using the Hydrostatics and Heat Kit on High School Students Conceptual Change in the Heat Topic", *J. Pijar.MIPA*, vol. 21, no. 1, pp. 97–102, Feb. 2026. https://doi.org/10.29303/jpm.v21i1.10957

hypotheses, conducting experiments, collecting data, and drawing conclusions [15] [16].

Through inquiry-based learning, students are actively involved in scientific investigations, enabling them to construct their own conceptual understanding based on empirical evidence obtained from observations and experimental data [17]. Consequently, integrating the Hydrostatics and Heat KIT with inquiry-based learning has the potential to facilitate conceptual reconstruction from initial misconceptions toward scientific understanding.

Several studies have reported that experiment-based learning using KIT integrated with Inquiry-Based Learning can improve students' conceptual understanding while simultaneously reducing misconceptions [18]. However, most of these studies emphasize improvements in learning outcomes or general conceptual understanding a nd do not specifically focus on analyzing students' concept ual change in detail. Studies that specifically investigate the impact of the Hydrostatics and Heat KIT on senior high school students' conceptual change in the topic of heat within an inquiry-based learning framework are still limited [19]. Based on this research gap, the present study aims to examine the extent to which the use of the Hydrostatics and Heat KIT can support students in transforming their initial conceptions into a more scientific understanding through inquiry-based learning. The novelty of this study lies in its focus on systematically analyzing the direction of students' conceptual change, rather than merely measuring learning outcomes [20].

Research Methods

This study employed a One-Group pretest–posttest experimental design to examine the effect of using the Hydrostatics and Heat KIT on high school students' conceptual change regarding heat. This design allows for measuring changes in students' conceptions within the same group before and after the treatment.

The subtopics examined in this study include: (1) analyzing changes in temperature and heat during changes in the state of matter, (2) distinguishing between temperature and heat, (3) differentiating the types of heat transfer, (4) analyzing heat transfer during changes in the state of matter, (5) examining the difference between heat as transferred energy and energy stored in an object, and (6) analyzing how thermal energy transfer occurs through heat, (7) assessing how heat transfer reaches thermal equilibrium, (8) analyzing how convection currents cause fluid movement, and (9) analyzing the mechanisms of heat transfer through conduction.

The study was conducted at SMA Negeri 1 Bolangitang and involved two classes: an experimental class and a replication class. The total sample consisted of 60 students, selected using a total sampling technique.

The variables in this study consisted of the independent variable, namely the use of the Hydrostatics and Heat KIT, and the dependent variable, namely students' conceptual change on the topic of heat, which was measured based on the categories (MB, TPK, M, PK).

The use of the Hydrostatics and Heat KIT was implemented through exploratory experimentation, recording observational results, reflecting on initial predictions, group discussions to examine differences between predictions and experimental data, and presentations of group work. This series of activities was designed to stimulate the integration of new concepts with prior knowledge, promote higher-order thinking, and reconstruct students' conceptions so that learning not only focuses on laboratory procedures but also fosters deep conceptual understanding.

This study employed a three-tier diagnostic test consisting of 10 multiple-choice items, administered as a pretest before the treatment and a posttest after the treatment. Each item comprised: Tier 1: a multiple-choice conceptual answer, Tier 2: a reason or explanation (structured according to the provided options), and Tier 3: a confidence level. The classification of students' responses followed the categories: Conceptual Understanding (PK), Misconception (M), Lack of Conceptual Understanding (TPK), and Guessing (MB).

Validitas The validity of the learning instrument, including worksheets (LKPD), modules, instructional materials, and test items, was assessed by subject-matter experts and physics education practitioners. The validity coefficient scores ranged from 90.27 to 97.72, indicating that the instruments were classified as valid to very valid.

To clarify the results of data analysis from the three-tier diagnostic test, this study presents a visualization of the direction of students' conceptual change using arrow and circle symbols as part of descriptive quantitative statistics. This visualization is used to represent students' conceptual changes based on the results of cross-tabulation between the pretest and posttest in a more concrete manner. An upward arrow (↑) indicates conceptual improvement, namely a shift from a lower level of understanding to a more scientific category (for example, from Misconception to Scientific Understanding). In contrast, a downward arrow (↓) indicates conceptual decline, referring to a change from scientific understanding to a lower conceptual category (for example, from Scientific Understanding to Lack of Conceptual Understanding or Misconception). A circle symbol (O) indicates no conceptual change, meaning that students' conceptual categories remain the same in the pretest and posttest. The criteria for the symbolic representation of students' conceptual change are summarized in Table 1.

Table 1. Symbolic Criteria for Students' Conceptual Change

Symbol	Meaning	Criteria
↑	Conceptual improvement	Shift from lower-level understanding (MB, TPK, M) to scientific understanding (PK)
↓	Conceptual decline	Shift from scientific understanding (PK) to lower-level categories (TPK or M)
O	No conceptual change	Same conceptual category in pretest and posttest

In addition, students' responses in the three-tier diagnostic test are represented using three-letter codes that describe the correctness of the answer, the reasoning, and the level of confidence. The first letter indicates the conceptual answer (B = Correct, S = Incorrect), the second letter represents the reasoning or explanation (B = Correct, S = Incorrect), and the third letter indicates the student's confidence level (Y = Confident, TY = Not Confident). The meaning of each code is explained in detail in Table 2, which serves as the basis for grouping students' conceptual categories.

Table 2. Answer Codes and Student Conception Categories

No.	Answer Code	Conception Category	Description
1.	BBY	Conceptual Understanding (PK)	Correct answer, correct reasoning, and confident in the chosen response.
2.	BSY	Misconception (M)	Correct answer, incorrect reasoning, and confident in the chosen response.
3.	SBY	Misconception (M)	Incorrect answer, correct reasoning, and confident in the chosen response.
4.	SSY	Misconception (M)	Incorrect answer, incorrect reasoning, and confident in the chosen response.
5.	BBT	Guessing (M)	Correct answer, correct reasoning, but not confident in the chosen response.
6.	BST	Lack of Conceptual Understanding (TPK)	Correct answer, incorrect reasoning, and not confident in the chosen response.
7.	SBT	Lack of Conceptual Understanding (TPK)	Incorrect answer, correct reasoning, and not confident in the chosen response.
8.	SST	Lack of Conceptual Understanding (TPK)	Incorrect answer, incorrect reasoning, and not confident in the chosen response.

Using coloured arrow symbols and three-letter codes, the direction and changes in students' conceptions can be observed more clearly, allowing the analysis to describe not only quantitative score changes but also the dynamics of students' conceptual understanding throughout the learning process using the Hydrostatics and Heat KIT.

The data analysis in this study was conducted quantitatively to examine the effect of using the Hydrostatics and Heat KIT on high school students' conceptual changes regarding heat. Data were obtained through a three-tier diagnostic test administered before (pretest) and after (posttest) the treatment. The analysis focused on changes in students' conception categories, namely Conceptual Understanding (PK), Lack of Conceptual Understanding (TPK), Misconception (M), and Guessing (MB). Conceptual changes were analyzed by comparing the percentage of each category in the pretest and posttest to identify the direction of students' conceptual shifts after participating in learning using the Hydrostatics and Heat KIT.

Through this analysis, a more comprehensive picture of students' conceptual changes was obtained, specifically the shift from less accurate conception categories toward more scientific understanding as a result of using the Hydrostatics and Heat KIT.

Results and Discussion

The research results are presented as quantitative data showing changes in the frequency of each conception category, namely Conceptual Understanding (PK), Misconception (M), Guessing (MB), and Lack of Conceptual Understanding (TPK). Students' conceptual changes are indicated by the symbols (↑) for improvement, (↓) for decline, and (O) for no change. These data are used to illustrate the pattern of students' conceptual changes following the implementation of learning using the Hydrostatics and Heat KIT.

Table 3. Distribution of Conceptual Change in the Experimental Class

Category of Conceptual Change	Frequency (f)	Percentage (%)
(↑) Improvement of Conceptual Understanding	215	71.67
(↓) Conceptual Decline	34	11.33
(O) No Conceptual Change	51	17.00
Total	300	100

Table 3 shows the distribution of students' conceptual change in the experimental class based on item-level analysis. Out of 300 analyzed responses, 215 responses (71.67%) indicate conceptual improvement, as represented by upward arrows (↑). Meanwhile, 34 responses (11.33%) show conceptual decline (↓), and 51 responses (17.00%) indicate no conceptual change (O). These results suggest that the implementation of the Hydrostatics and Heat KIT predominantly facilitated students' conceptual improvement across the analyzed test items.

Table 4 presents the percentage of students' conceptual change across different heat subtopics in the experimental class. The highest conceptual improvement was observed in Subtopic 2 (Item 3) and Subtopic 6 (Item 7), each showing an improvement rate of 83.33%. In contrast, Subtopic 8 (Item 9) showed the lowest conceptual improvement (46.67%) and the highest proportion of conceptual decline (26.67%). These findings indicate that the effectiveness of the Hydrostatics and Heat KIT varied across subtopics, with certain heat concepts remaining more challenging for students.

Table 4. Percentage of Students' Conceptual Change in the Experimental Class by Subtopic (Per-Item Analysis)

Subtopic of Heat	↑ (%)	↓ (%)	O (%)
Subtopic 1 (Items 1–2)	76.67	11.67	11.67
Subtopic 2 (Item 3)	83.33	10.00	6.67
Subtopic 3 (Item 4)	73.33	10.00	16.67
Subtopic 4 (Item 5)	63.33	13.33	23.33
Subtopic 5 (Item 6)	70.00	3.33	26.67
Subtopic 6 (Item 7)	83.33	6.67	10.00
Subtopic 7 (Item 8)	80.00	3.33	16.67
Subtopic 8 (Item 9)	46.67	46.67	26.67
Subtopic 9 (Item 10)	63.33	16.67	20.00

Table 5. Distribution of Conceptual Change in the Replication Class

Category of Conceptual Change	Frequency (f)	Percentage (%)
(↑) Improvement of Conceptual Understanding	233	77.67
(↓) Conceptual Decline	21	7.00
(O) No Conceptual Change	46	15.33
Total	300	100

Table 5 presents the distribution of students' conceptual change in the replication class based on item-level analysis. Of the 300 analyzed responses, 233 responses (77.67%) indicate conceptual improvement, while 21 responses (7.00%) show conceptual decline and 46 responses (15.33%) indicate no conceptual change.

Table 6. Percentage of Students' Conceptual Change in the Replication Class by Subtopic (Per-Item Analysis)

Subtopic of Heat	↑ (%)	↓ (%)	O (%)
Subtopic 1 (Items 1–2)	80.00	6.67	13.33
Subtopic 2 (Item 3)	76.67	6.67	16.67
Subtopic 3 (Item 4)	73.33	6.67	20.00
Subtopic 4 (Item 5)	70.00	13.33	16.67
Subtopic 5 (Item 6)	73.33	6.67	20.00
Subtopic 6 (Item 7)	80.00	3.33	16.67
Subtopic 7 (Item 8)	70.00	3.33	26.67
Subtopic 8 (Item 9)	63.33	10.00	26.67
Subtopic 9 (Item 10)	76.67	6.67	16.67

Table 6 shows the percentage of conceptual change across heat subtopics in the replication class. High levels of conceptual improvement were observed across most subtopics, particularly in Subtopics 1 and 6. These findings indicate that the learning pattern observed in the experimental class was consistently replicated, supporting the robustness of the instructional intervention.

From a broader perspective, the results from the replication class indicate that integrating the Hydrostatics and Heat KIT with Inquiry-Based Learning effectively promotes students' conceptual change toward a more scientifically accurate understanding. This improvement demonstrates that students not only acquire new information but also reconstruct their initial misconceptions through meaningful learning experiences. These findings are consistent with the Constructivist Conceptual Change theory, which states that conceptual change occurs when students experience dissatisfaction with their initial understanding and subsequently encounter new concepts that are more intelligible, plausible, and useful [21]. Through experimental activities using the KIT, students are directly confronted with heat-related phenomena that contradict their prior conceptions, thereby encouraging gradual conceptual restructuring.

The use of the Hydrostatics and Heat KIT also creates a learning environment that supports exploration, reflection, and scientific discussion. Visual representations and hands-on experimental experiences help students understand abstract concepts such as the distinction between temperature and heat, thermal equilibrium, and mechanisms of heat transfer. These conditions strengthen conceptual change by actively engaging students in higher-order cognitive processes and direct interaction with the studied phenomena [22-23]. Furthermore, the results of this study are consistent with previous findings reporting that experiment-based learning and the use of physics laboratory tools can enhance conceptual understanding while simultaneously reducing students' misconceptions. The integration of inquiry-based learning with experimental media has been shown to significantly support students' conceptual change in physics learning [24-25]. Thus, the findings of this study reinforce empirical evidence that the use of the Hydrostatics and Heat KIT within an Inquiry-Based Learning framework is an effective strategy for reducing misconceptions and improving students' conceptual understanding.

Overall, the findings of this study confirm that learning using the Hydrostatics and Heat KIT not only improves learning outcomes but also plays a crucial role in facilitating deep and sustained conceptual change. The implications of these findings suggest that physics teachers should further optimize experiment-based and inquiry-oriented learning as a systematic approach to addressing students' misconceptions, particularly in the topic of heat.

Conclusion

Based on the study's results, it can be concluded that the use of the Hydrostatics and Heat KIT can promote students' conceptual change in the topic of heat. The observed conceptual changes indicate a positive direction, with most students shifting from the categories of Guessing (MB), Lack of Conceptual Understanding (TPK), and Misconception (M) to Conceptual Understanding (PK). The dominance of the red arrow symbol (↑) in the analysis of each table demonstrates consistent conceptual changes across both the experimental and replication classes. The most prominent conceptual changes occurred in the concepts of heat, latent heat, and heat transfer, while the fewest changes were observed in the concept of heat transfer through convection. These results indicate that learning using the Hydrostatics and Heat KIT is effective in helping students overcome misconceptions and strengthen their conceptual understanding through exploration, reflection, and empirical verification. This finding also supports the Constructivist Conceptual Change theory, which posits that learning occurs through the transformation of students' initial understanding toward more scientifically accurate concepts. Therefore, this approach is recommended for implementation in physics education to enhance students' conceptual understanding.

Author Contributions

Y. Baks: contributed to the development of the research design, data collection, data analysis, and manuscript writing; A. Arbie: served as the primary supervisor, providing scientific guidance, methodological direction, and substantive corrections to the article. Both authors have read and approved the final manuscript for publication.

Acknowledgments

The authors would like to express their sincere gratitude to Mr. Asrie Arbie, as the first supervisor, and Mrs. Trisnawaty Junus Buhungo, as the second supervisor, for their guidance and direction throughout the research process. Thanks are also extended to the Principal of SMA Negeri 1 Bolangitang, the physics teachers, and all Class XI Physics students who participated enthusiastically as research partners. The authors deeply appreciate the validators for their valuable input in refining the learning instruments, as well as all parties who have assisted, directly or indirectly, in completing this research. Special thanks are also extended to the author's beloved mother for her endless prayers, support, and motivation.

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