



Evaluating the Efficacy of 5E Learning Cycle-Based Interactive Multimedia in Enhancing Conceptual Mastery of Thermal Physics

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Abstract

Many studies have been conducted to address students' conceptual mastery of temperature and heat topics, but many students still encounter difficulties. This study offers a solution in the form of the implementation of interactive multimedia combined with the 5E model to address this issue. Through this interactive multimedia, students can represent phenomena and receive scaffolding based on constructivist theory via the 5E model. Therefore, the purpose of this study is to determine the effectiveness of interactive multimedia based on the 5E model to address students' conceptual mastery of temperature and heat topics. This study used a pretest-posttest control group design. The experimental class consisted of 33 students, while the control class consisted of 34 students. Data were collected through a multiple-choice test comprising 11 items with a reliability coefficient of 0.71 and interviews. Data analysis was conducted using the paired t-test, t-test, normalized gain (n-gain), and effect size. The results showed that the n-gain value of the experimental class (0.41) differed significantly from that of the control class (0.31) at a significance level of 0.05 and an effect size of 0.713. From the students' perspective, the components of the interactive multimedia that can help improve students' conceptual mastery are worksheets, animated videos, phenomena, and simulations. These elements are used in the engagement, exploration, and explanation phases of the 5E model, and thus significantly influence the improvement of students' conceptual mastery during those phases.

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INTRODUCTION

Temperature and heat are among the most challenging topics in physics. Numerous studies have revealed that many students still struggle to master the concepts related to temperature and heat (Hariyanto, 2021; Nurul, 2022; Yuliana et al., 2019). For example, regarding thermal expansion, many students still believe that a hollow ball expands faster than a solid ball when heated to the same temperature increase (Laili et al., 2021). Regarding the concept of heat and its effects, students are still unable to accurately analyze the relationship between heat and temperature, particularly as it relates to the specific heat of an object (Laili et al., 2021), and they still believe that the size of an object can affect the change in its own temperature (Maunah, 2014; Yuliana et al., 2019). In the concept of the Black principle, temperature change is determined by the temperature difference between the object releasing and receiving heat without considering the mixed temperature of the two objects (Etikamurni, 2019).

These various difficulties indicate that students' conceptual understanding has not yet been coherently integrated (Hsara et al., 2023; Laili et al., 2021). One of the causes is that textbooks place greater emphasis on presenting formulas (Aminulloh & Ristiana, 2020; Argaw et al., 2016; Manuel Almudi et al., 2016; Simbolon et al., 2024). Furthermore, learning remains conventional and tends to be teacher-centered, which often results in students' weak conceptual understanding of temperature and heat (Ahmad & Salleh, 2021), consequently, students are not yet accustomed to developing critical thinking skills when solving problems (Simbolon et al., 2024).

From a constructivist perspective, knowledge cannot be transferred directly from teacher to student; rather, it is actively constructed by students through the process of linking prior knowledge with new learning experiences in a contextual manner (Fosnot, 2013) and scientifically validated (Banda & Nzabahimana, 2021). If this connection does not occur, concepts will be understood through rote memorization and in isolation, thus failing to form a coherent conceptual understanding (Mayer, 1992). To address this issue, instruction is needed that can coherently integrate students' prior knowledge with new knowledge. One such approach is the 5E learning cycle model.

The 5E learning cycle model consists of five stages: engagement, exploration, explanation, elaboration, and evaluation. The 5E learning cycle model is believed to help students actively construct knowledge and deepen their conceptual understanding (Ramadhani et al., 2025). Through the engagement stage, students can activate their prior knowledge and connect it to new learning experiences through exploration, thereby achieving coherent conceptual mastery. Furthermore, to strengthen conceptual mastery, during the elaboration stage, students can apply physics concepts to new situations (Bybee et al., 2006).

One of the challenges encountered in implementing the 5E learning cycle model has been a lack of time to complete all phases of the 5E model, particularly the exploration phase (Larasati, 2025; Nalansari & Winarni, 2020). To ensure that learning is carried out perfectly and thoroughly, a medium is needed to visualize phenomena related to the concept so that they are easy to understand (Dwiyanti et al., 2023; Ilahi et al., 2021) and do not take too much time to demonstrate during the exploration phase (Nalansari &

Winarni, 2020). Furthermore, without visualization during the engagement phase in the 5E model, it is very difficult to activate students' prior knowledge. Previous research, supported by studies (Cylindrica & Dasna, 2021; Puspaningrum, 2017) indicates that during the exploration and elaboration phases, the availability of adequate learning media is a crucial factor in assisting students with both the construction of concepts and their application in problem-solving. Therefore, the media used in this study consists of interactive multimedia to support the implementation of this learning process.

The visualization of physical phenomena presented through interactive multimedia—such as demonstrations, videos, graphs, images, and modeling—is a crucial element in learning that enhances students' conceptual understanding (Pamangin, 2025). Although other interactive media, such as PhET simulations, are already available to improve students' conceptual mastery, the quality of materials on temperature and heat at the high school level remains inadequate. This is because they do not fully optimize students' ability to analyze concepts in depth; they merely visualize the phenomena. Visual and interactive learning allows students to understand physics concepts more intuitively, particularly in abstract and complex topics, which often pose challenges in conventional teaching (Mayer, 2011; Wieman et al., 2008). Instruction begins with the presentation of contextual phenomena to activate students' prior knowledge as an engagement phase (Ramadhani et al., 2025). Research on integrating the 5E learning cycle model with interactive multimedia to enhance students' conceptual mastery has not been published, particularly regarding the topics of temperature and heat.

The integration of interactive multimedia with the 5E learning cycle model in this study was carried out as follows: through the engagement stage, students' conceptual understanding was developed with the aid of various interactive media, such as images/phenomena, videos, and/or PhET simulations, in which students were asked to analyze the physics concepts underlying these phenomena, guided by structured questions. This brief activity is designed to stimulate curiosity, draw upon prior knowledge, and connect it to new knowledge through challenging questions, thereby fostering students' cognitive readiness (Bybee et al., 2006). Next, during the exploration stage, students can develop problem-solving skills, as this stage presents problems leading to mathematical solutions, prompting them to investigate, explore, and generate new ideas for resolution (Bybee et al., 2006; Santhalia et al., 2019). During the exploration phase, students' conceptual mastery also develops because conceptual mastery has a positive relationship with problem-solving ability (Priyadi, et al., 2019; Saputra, 2022; Taqwa, et al., 2019). Students' conceptual understanding is automatically developed in a structured manner. The multimedia formats used in this stage include text (exploring everyday experiences), hands-on experiments, and exploration through short videos and images, with some use of worksheets. Next, in the explanation stage, the observable aspect is conceptual mastery, as indicated by the students' ability to explain. The multimedia formats presented in this stage include text, images, graphs, videos, and animations (to demonstrate particle movement during expansion and the process of heat transfer when heating water or iron). The subsequent elaboration stage is conducted by administering concept mastery quizzes and problem-solving tasks. Some quiz formats include formative feedback. Formative feedback quizzes are created using the navigation buttons within the multimedia. Finally, in the evaluation stage, the teacher reviews students' knowledge at

the end of each session, and assessment tests are administered before and after the final learning session to determine students' conceptual mastery and problem-solving skills.

Based on the above discussion, previous studies have generally examined the effects of the 5E Learning Cycle model or interactive multimedia separately. Therefore, it is necessary to conduct research that combines both to assess their effectiveness in improving students' conceptual understanding of temperature and heat. Through this approach, students are not merely recipients of information but actively observe, explore, and draw conclusions from phenomena presented visually and interactively. Based on this, the purpose of this study is to determine the effectiveness of using interactive multimedia based on the 5E Learning Cycle model in improving students' conceptual understanding of temperature and heat.

METHOD

Research Design and Procedures

This research is quantitative research with a pre-test and post-test control group design. This design was chosen because there were two classes (experimental and control) in the study, and only the experimental class received treatment (Creswell & Creswell, 2017). The experimental class used interactive multimedia learning based on the 5E learning cycle model, while the control class used conventional learning.

Population and Sample

This study was conducted in grade XI of SMAN 3 Pamekasan, which consists of five physics specialization classes in the Merdeka Curriculum. The sample consisted of 67 students selected by random sampling and divided into two classes. The experimental class had 33 samples and the control class had 34.

Data Collection and Instrument

Data collection was conducted using tests administered before and after the learning process. The tests consisted of 11 multiple-choice questions. Table 1 describes the questions used to measure students' initial and final mastery of the concepts. The questions were analyzed using classical parameters, and the data is presented in Table 1.

Table 1. Description of Questions on Mastery of Temperature and Heat Concepts

Topic	Question Content	Item	D	<i>p</i>	<i>r_{pbi}</i>
Temperature & Expansion	Distinguishing between the expansion of solid and hollow balls when subjected to the same temperature change	1	0.2	0.41	0.277
	Explaining the process of opening metal bottle caps through heating	2	0.409	0.49	0.491
Heat and its relationship to changes in temperature	Explaining the relationship between the amount of heat energy absorbed by an object and the specific heat capacity of that object.	3	0.387	0.53	0.471
	Determining the specific heat of two objects with different properties based on the	4	0.563	0.41	0.629

and the state of matter	comparison of the rate of temperature increase of two objects heated simultaneously.				
	Explaining the effect of pressure on the boiling point of water based on cooking with a pressure cooker	5	0.2	0.31	0.270
Asaz Black	Explaining the main idea of the black principle (two objects with different temperatures are mixed)	6	0.344	0.47	0.431
	Applying the black principle to determine the final temperature of different substances	7	0.473	0.52	0.550
Heat transfer	Explaining the structure of a thermos bottle to prevent rapid temperature drop	8	0.521	0.25	0.583
	Explaining the reason for placing the air conditioner at the top of the room based on the principle of heat transfer by convection	9	0.413	0.67	0.491
	Explaining the cause of temperature increase on asphalt surfaces exposed to sunlight based on the process of heat transfer by radiation	10	0.452	0.50	0.530
	Explaining the function of thick curtains in inhibiting heat transfer through conduction and radiation to maintain stable room temperature	11	0.427	0.82	0.489

The research instruments were analyzed using classical test parameters, which included the biserial point correlation coefficient (r_{pbi}), discrimination index (D), and difficulty index (p) for each item. In addition, the overall reliability test results of the instrument as seen from Cronbach's Alpha is 0.71. An item is considered good if it has a discrimination index $D \geq 0.2$ (Mitra et al., 2009; Rahim, 2010; Taib & Yusoff, 2014), a difficulty index between 0.2 and 0.8, and a biserial coefficient (r_{pbi}) ≥ 0.2 (Ding & Beichner, 2009; Kubiszyn & Borich, 2003; Tongchai et al., 2009). If the difficulty index value is less than 0.2, it means the item is too difficult, so only a few participants can answer it correctly. Conversely, if the value is greater than 0.8, the item is too easy. Based on Table 2, it can be seen that these 11 items are suitable for use as an instrument to measure students' conceptual mastery. The number of items in the instrument, totaling 11 questions, is considered adequate because all items were developed based on a blueprint that adequately represents each learning objective indicator (Kurniawan, 2022). Thus, each question represents the conceptual competencies intended to be measured, ensuring that the instrument's content validity is maintained.

Data Analysis

The main data used to distinguish between the two classes was analysis using Ngain (g). However, to determine significant differences, a t-test was used. The procedure was as follows.

$$\langle g \rangle = \frac{\% Post - \% Pre}{100 - \% Pre}$$

In addition to analyzing class n-gains, individual n-gains are also analyzed. If any sample has a negative (-) n-gain, it must be excluded because it is highly illogical for a person or

subject to retain no knowledge after receiving instruction. It is possible that students were merely guessing during the test (Coletta & Steinert, 2020). The n-gain interpretation for determining hypotheses is divided into three categories: $\langle g \rangle \geq 0.7$ is categorized as high, $0.7 > \langle g \rangle \geq 0.3$ is categorized as moderate, and $\langle g \rangle < 0.3$ is categorized as low (Hake, 1998).

However, it is also necessary to determine whether there is a significant difference between initial and final abilities using a t-test. Before conducting the t-test, the data must first be verified to ensure it is normally distributed. This prerequisite test determines the type of t-test to be used for comparing the research results between the two classes. To assess data normality, skewness is examined. If skewness falls within the range of -1 to +1, the data is considered normally distributed (Morgan et al., 2004). The skewness of all data, as shown in Table 2, indicates that the data is normally distributed; therefore, the tests of difference used are the paired t-test and the independent t-test to distinguish the significance between the two classes. As additional data to determine the effectiveness of the 5E-model-based MMI, an effect size analysis is required.

RESULT AND DISCUSSION

Initially, the data were analyzed descriptively and n-gain with a sample size (N) of 33 in the experimental class and 34 in the control class. After analysis, it was found that three students in the experimental class and one student in the control class had negative n-gain (-), so the four samples were discarded and the analysis was repeated. The results of the analysis after removing the 4 samples showed that the pretest-posttest data for the control and experimental classes were presented in a descriptive table. The results of the analysis are shown in Table 2.

Table 2. Pretest, Posttest, & N-gain of the Experiment-Control class

Description	Experimental Class		N-Gain	Control Class		N-Gain
	Pretest	Posttest		Pretest	Posttest	
N	30	30	30	33	33	33
Minimum	27	55	0.0	9	55	0.0
Maximum	73	82	75	73	73	70
Mean	47	71	0.41	49.8	68.1	0.31
Std. Deviation	13.6	9.1	0.2	15.8	5.1	0.2
Skewness	0.04	-0.36	-0.46	-0.35	-0.37	-0.39

*Pretest and posttest scoring using a scale (0-100)

Table 2 presents a description of the pretest and posttest results regarding students' conceptual mastery in the control and experimental classes. The pretest data for both the experimental and control classes had nearly identical means of 47 and 49.8, respectively, indicating that both classes started with the same prior knowledge. In the posttest, the scores of both classes improved, with a mean of 71 in the experimental class and 68.1 in the control class. Both classes experienced an increase in conceptual mastery, but the difference in improvement indicates that the treatment in the experimental class had a greater impact. However, to ensure that this difference is truly statistically significant, inferential analysis is required.

he primary data for this study is the n-gain, as the n-gain is derived from the students' pretest and posttest scores. However, before that, a difference test must first be conducted to determine the difference between the pretest and posttest scores (paired data) in both classes. Based on the results of the paired t-test analysis in the experimental class, there was a significant difference of 0.000 between the pretest and posttest scores, indicating that the use of interactive multimedia based on the 5E learning cycle model significantly influenced the improvement in students' conceptual mastery of temperature and heat. Similarly, in the control class, the paired t-test revealed a significant difference of $0.000 < 0.05$. This indicates that both the use of interactive multimedia in the experimental class and conventional instruction in the control class have an effect on improving students' conceptual mastery.

The difference in normalized gains between the two classes was 0.41 in the experimental class and 0.31 in the control class. Based on these findings, it can be concluded that students in the experimental class showed a moderate increase in conceptual mastery after receiving instruction using interactive multimedia based on the 5E learning cycle model to deepen their understanding of temperature and heat. Meanwhile, the control class, which received conventional instruction, also showed a moderate improvement in conceptual mastery. Although there was a significant difference between the two classes, the performance of the experimental class still fell short of our expectations. These results indicate that the implemented instructional program has not yet fully addressed all the issues that arose.

Meanwhile, the independent-samples t-test on the posttest data showed a significant difference between the experimental class and the control class, with a p-value of $0.004 < 0.05$. In contrast, the pretest data showed a p-value of 0.454 at a significance level of $\alpha = 0.05$, indicating that there was no significant difference between the two groups, as they started from the same baseline knowledge. To determine the extent to which the use of interactive multimedia based on the 5E learning cycle model influences or affects students' conceptual mastery, the effect size yielded an interpretation of 0.713, indicating a fairly strong effect.

The findings demonstrate that the use of interactive multimedia based on the 5E learning cycle model has been effective in improving students' conceptual understanding, as evidenced by a significant difference between the experimental and control classes. These findings are further supported by research (Husein et al., 2015) which indicates that interactive multimedia can enhance conceptual understanding and that there is a difference between the two classes. Furthermore, this is supported by research (Naf'atuzzahrah et al., 2022) which states that there is a significant difference and indicates that classes using the 5E learning cycle model perform better than conventional classes in improving students' conceptual understanding. These findings reinforce previous findings that the use of interactive multimedia and the 5E learning cycle model can significantly improve students' conceptual mastery. These findings are further supported by student interview results, in which respondents overall stated that the use of interactive multimedia based on the 5E model was very helpful and effective in improving conceptual mastery because the learning process was engaging and not boring. Furthermore, according to one of the interviewed students, this interactive multimedia made the material on temperature and heat interesting, engaging, and easy to understand. This student's statement is supported by research (Lestari & Wirasty, 2019), which

indicates that the implementation of interactive multimedia can enhance students' interest in learning.

The elements found in the 5E-model-based MMI include text, phenomena, images and videos, worksheets (LKPD) and e-worksheets (e-LKPD), animations, PhET simulations, and formative feedback quizzes, all of which contribute to effective learning. This is reinforced by student interview results stating that the 5E-model-based MMI elements that greatly assist students' conceptual mastery are the e-worksheets, animated videos, phenomena, and simulations. The elements mentioned are those used in the engagement, exploration, and explanation phases of the 5E model; thus, these phases of the 5E model also significantly aid in enhancing students' conceptual mastery. These findings align with previous research (Fitri, 2022), which found that the use of a virtual laboratory in the form of the PhET application—even when supplemented with worksheets—can improve students' conceptual understanding of dynamic electricity. Similarly, learning that incorporates or is based on phenomena can enhance students' conceptual understanding (Akhir & Habibi, 2015).

Next, an in-depth analysis to determine students' conceptual changes is shown by the average pretest-posttest scores for each item. When the pretest-posttest for each item is shown, the findings related to where the weaknesses lie and the improvement in high conceptual mastery become clearer.

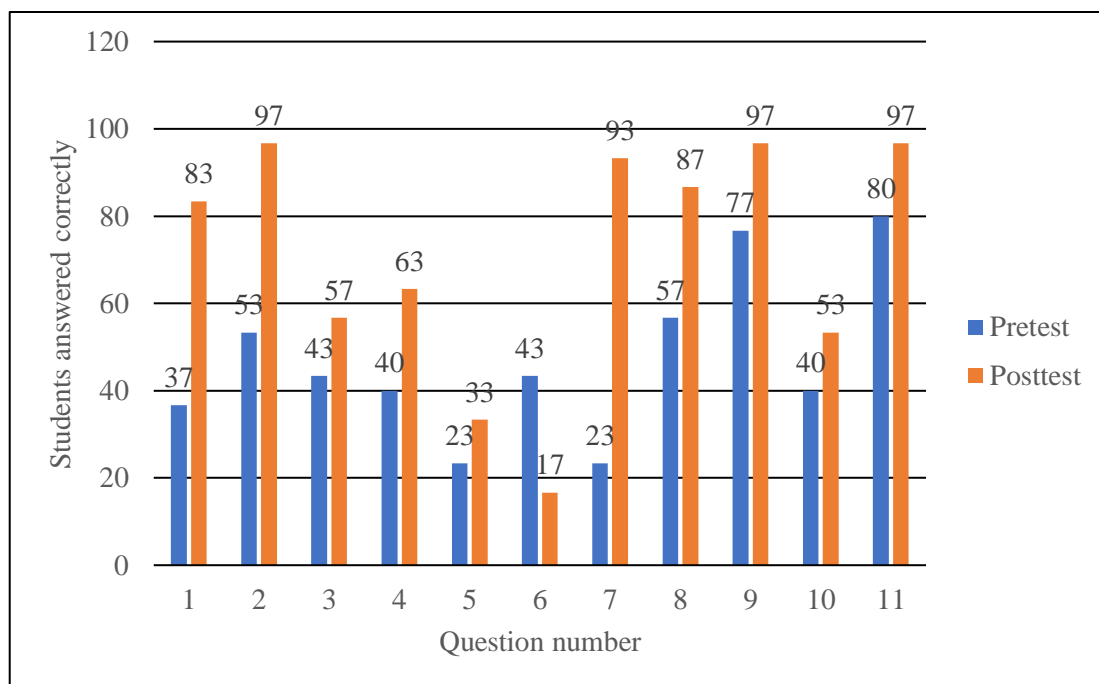


Figure 1. Percentage of pretest-posttest data for each item in the experimental class

Figure 1 shows the percentage of correct answers on the pretest and posttest for each question in the experimental class. The findings show that mastery of concepts is still low for questions 5 & 6. These two questions represent the subtopics of the effect of heat on changes in temperature and the state of matter, and Black's law. The following is an explanation of the two questions that students found most difficult to master the concepts:

5. Ron knows that cooking soup in a pressure cooker is faster than in a regular pot, but he doesn't know why. (Pressure cookers have tightly sealed lids so that the air pressure inside can rise far above atmospheric pressure). Which of the following explanations do you agree with most ?
- A. High pressure causes water to boil above 100°C.
 - B. High pressure generates extra heat.
 - C. The steam from the soup has a higher temperature than the soup itself when it is boiling.
 - D. Pressure cookers distribute heat more evenly throughout the food.
- A. {pre = 23,3% | post = 33,3%}
 B. {pre = 26,7% | post = 56,7%}
 C. {pre = 13,3% | post = 0%}
 D. {pre = 36,7% | post = 10%}

Figure 2. Question number 5

Question number 5 discusses heat and its effects. This time, we will discuss the students' answer patterns in detail. In this question, the experimental class students' mastery of the concept improved slightly. The pretest results of 30 students showed answers spread across all answer choices. There were 23.3% who consistently answered A from the pretest to the posttest, even increasing to 33.3%. The remaining 56.7% of students who answered B, C, or D in the pretest switched to option B, and the remaining 10% remained consistent in their answer of D. This indicates that many students still have difficulty with the concept of the effect of heat on changes in the form of objects. Based on the students' answers, this difficulty arose because they still assumed that what made the soup cook faster was high heat, which produced extra heat. A small number also assumed that it was the pressure cooker that distributed heat evenly to the food/soup so that it cooked faster.

6. The following statement is true regarding the process that occurs when two objects of different temperatures are mixed together
- A. Energy is released by objects with high temperatures
 - B. There is a transfer of heat from hot objects to cold objects
 - C. Energy is absorbed by objects with high temperatures
 - D. There is a decrease in temperature in both objects
- A. {pre = 43,3% | post = 16,7%}
 B. {pre = 23,3% | post = 73,3%}
 C. {pre = 3,3% | post = 0%}
 D. {pre = 30% | post = 10%}

Figure 3. Question number 6

Next, we will discuss students' response patterns to question number 6 regarding the concept of Black's principle. In this question, students' mastery of the concept showed a decline. 16.7% of students consistently selected option A. The remaining 26.6% of students, who initially answered correctly (A), switched to a different option on the posttest. The dominant answer among students in the posttest was option B. This indicates that many students still struggle with the concept of the Black principle. Based on the students' answers, this difficulty arises because they still believe that when two objects

of different temperatures are mixed, the heat transfers from the hotter object to the cooler one. A small portion also believes that both objects experience a decrease in temperature.

Based on the findings shown in Figure 2, for question 5 there was only a slight improvement, and for question 6, students' scores decreased from the pretest to the posttest. Some of the problems or difficulties identified in Chapter 1 (background) namely regarding thermal expansion, the relationship and effect of heat on temperature, and Black's law suggest that the concept of Black's law has not yet been fully mastered. On average, students' conceptual mastery of the Black's law subtopic improved from the pretest to the posttest. However, upon closer examination of each individual question item, differing patterns of improvement are evident. The indicators for mastery of the Black's Law concept are found in questions 6 and 7. Specifically, for question 6 alone, students' conceptual mastery declined. Additionally, a new finding in this study is that students struggled with the effect of heat on changes in the state of matter, as measured by the indicator in question 5.

In question number 5, although students' scores improved from the pretest to the posttest, 66.7% of students still struggled. The majority of students still believe that high pressure causes heat to increase even more, and that the pressure cooker is what distributes the heat, allowing the soup to cook evenly. Therefore, it can be concluded that students still do not fully understand the relationship between heat and changes in the state of matter. Meanwhile, question number 6 reflects students' weak mastery of the principle of heat transfer regarding the process of heat transfer in objects with different temperatures. This is because students still believe that when two objects with different temperatures are mixed, what happens is a transfer of heat from the hotter object to the cooler one. Additionally, they believe that what occurs between the two substances is a decrease in temperature. This indicates that students are still struggling; they still believe that temperature change is determined by the temperature difference between the object releasing heat and the one receiving it, without considering the temperature of the mixture of the two objects (Etikamurni, 2019).

Based on the difficulties identified, there are several factors that cause students to struggle and prevent them from fully mastering the concept. These contributing factors include a mismatch between students' prior knowledge and the scientific concepts being studied (Etikamurni, 2019; Laili et al., 2021); students' tendency to provide answers based on pre-existing alternative conceptions students actually store their knowledge about the concepts of temperature and heat in long-term memory, but this knowledge has not yet been effectively activated into their working memory (Laili et al., 2021). Nevertheless, overall, students' conceptual mastery showed a positive increase from the pretest to the posttest. This result can be seen from the *n*-gain findings of the two classes (0.41 in the experimental class and 0.31 in the control class); although the difference is not very striking, there is still a significant difference of 0.004. This still indicates that students' conceptual mastery increased with learning using the 5E model-based MMI.

This relatively minor difference may be attributed to several factors. Based on interviews with the students, they stated that they lacked focus while working on the questions; some also mentioned that they were in a hurry while answering the multiple-choice questions; and others felt that many of the answer choices were similar, causing them to feel confused when answering. This is further supported by the statement (Coletta & Steinert,

2020) that it is possible that during the post-instructional test, students answered the questions by guessing. Additionally, the interactive multimedia-based learning using the 5E learning cycle model was delivered over a relatively short duration, and the instruction took place during the final school hours under the Full Day School system, which tended to exhaust students and resulted in limited impact on learning outcomes. Similarly, the posttest was administered during the final school hours. This finding aligns with research conducted by (Diantari et al., 2024) which indicates that the intensity of the school schedule, such as in a full-day school system, leads to student academic burnout, with even high levels of academic burnout reported (Maiyun & Imamah, 2023). Similarly, in a study (Pratiwi & Rahmi, 2023), this leads to physical, mental, and emotional fatigue among students. Student fatigue has a negative correlation with academic performance and concentration levels. Classes held from noon until the afternoon cause brain performance to decline, thereby weakening students' concentration levels (Nurshifa et al., 2025), especially when working on problems that require deep thinking.

Based on the findings above, another reason why the *n*-gain in the experimental class was not particularly high is that, upon analyzing the students' answers to each question, it was found that there were two questions that many students still struggled to answer. These two questions addressed the concept of the effect of heat on changes in the state of matter and the main idea of Black's principle. Many previous studies have also revealed that, even with different teaching methods, many students still have difficulty understanding the concepts of the effect of heat on changes in the state of matter and Black's principle (Azizah et al., 2019; Etikamurni, 2019; Yuliana et al., 2019). Students often struggle with Black's principle, particularly regarding heat released and heat absorbed (Yuliana et al., 2019). This finding is consistent with the findings of previous studies, which revealed that students often assume that when two objects with different temperatures are mixed, it is the temperature that transfers, not the energy (Amalia et al., 2016; Etikamurni, 2019).

In fact, during the learning process, in the exploration phase, students conducted a hands-on experiment to see what happens when water at a higher temperature is mixed with water at a lower temperature. Furthermore, students were able to apply equations to solve problems involving the mixing of water at different temperatures, and they were able to explain the factors that cause the results of the Black's Law experiment to differ from or fall short of the mathematical calculations. Meanwhile, regarding the concept of the effect of heat on changes in the state of matter, it was already explained in the explanation phase what kind of state changes occur when water is continuously heated and what the consequences are. Furthermore, during the engagement phase, a brief simulation was conducted to demonstrate that heating and cooling water produces steam.

CONCLUSION

The use of interactive multimedia based on the 5E Learning Cycle model significantly improved students' conceptual understanding and outperformed conventional instruction. This significant difference is evidenced by a *p*-value of 0.000 in the pre-test and post-test scores of both classes and ($p = 0.000 < 0.05$) between the *n*-gain of the experimental class (0.41) and the control class (0.31), with an effect size of 0.713. Additionally, an in-depth analysis was conducted by examining the percentage of correct student responses on each test item to identify the specific areas where students struggled in understanding the topics of temperature and heat in detail. The analysis results showed that students still

experienced significant difficulties in understanding the concepts of the effect of heat on changes in the state of matter and the principle of black body radiation. Nevertheless, overall, the results of this study indicate that interactive multimedia based on the 5E learning cycle model can improve students' conceptual mastery of temperature and heat.

However, overall, the results of this study showed that interactive multimedia based on the 5E learning cycle model could improve students' mastery of concepts in temperature and heat material. However, this study has limitations, including the fact that conducting lessons during the last few hours of the day resulted in less than optimal learning, and time constraints also greatly affected learning outcomes. In addition, not all cycles of the 5E learning cycle model were applied in interactive multimedia, such as in the evaluation phase. In the evaluation phase, the researchers only reviewed the learning outcomes at each meeting with light questions. Therefore, the recommendation that can be conveyed for future research is the need to retest the use of interactive multimedia based on the 5E learning cycle model with all learning cycle models fully integrated. It is also necessary to conduct a more in-depth study of the difficulties faced by students that were not successfully resolved in this study so that these difficulties can be properly addressed. In addition, it is necessary to conduct further research using interactive multimedia based on the 5E learning cycle model on other physics topics to broaden the scope and determine the reliability of this multimedia comprehensively.

REFERENCES

- Ahmad, S. R., & Salleh, S. (2021). Effects of conceptual change-based teaching on the understanding of heat and temperature concepts among technical and vocational education and training (TVET) students with different demographic background. *International Journal of Academic Research in Business and Social Sciences*, 11(3), 59–75. <https://doi.org/10.6007/IJARBS/v11-i3/8918>
- Akhir, R., & Habibi, H. (2015). Pengaruh model pembelajaran berbasis fenomena terhadap pemahaman konsep siswa SMAN 1 Kopang. *Lensa: Jurnal Kependidikan Fisika*, 3(1), 248–252. <https://doi.org/10.33394/j-lkf.v3i1.377>
- Amalia, R., Sinaga, P., Sari, I. M., & Saepuzaman, D. (2016). Identifikasi Miskonsepsi Siswa SMA di Kota Bandung pada Konsep Suhu dan Kalor. *Prosiding Semnas IPA Pascasarjana UM*, 1.
- Aminulloh, R., & Ristiana, M. G. (2020). Improvement mathematical problem's solving ability of junior high school students by using inquiry models with everyone is a teacher here strategy. *Journal of Physics: Conference Series*, 1657(1), 12028. <https://doi.org/10.1088/1742-6596/1657/1/012028>
- Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2016). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(3), 857–871. <https://doi.org/10.12973/eurasia.2017.00647a>
- Azizah, U., Parno, P., & Supriana, E. (2019). Identifikasi Penguasaan Konsep Fisika Siswa SMA Kelas XI dan XII pada Materi Suhu dan Kalor. *State University of Malang*. <https://doi.org/10.17977/jptpp.v4i4.12284>

- Banda, H. J., & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students' conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research*, 17(2), 23108. <https://doi.org/10.1103/PhysRevPhysEducRes.17.023108>
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs, Co: BSCS, 5(88–98).
- Coletta, V. P., & Steinert, J. J. (2020). Why normalized gain should continue to be used in analyzing preinstruction and postinstruction scores on concept inventories. *Physical Review Physics Education Research*, 16(1), 10108. <https://doi.org/10.1103/PhysRevPhysEducRes.16.010108>
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Cylindrica, V. B., & Dasna, I. W. (2021). Pengaruh Model Pembelajaran Learning Cycle 5E berbantuan E-scaffolding pada Materi Laju Reaksi terhadap Pemahaman Konsep Siswa dengan Motivasi Berprestasi Berbeda. 1115–1133. <https://doi.org/10.17977/jptpp.v6i7.14934>
- Diantari, D. A. D., Devi, N. L. P. S., & Puspita, L. M. P. (2024). Community of Publishing in Nursing (COPING), p-ISSN 2303-1298, e-ISSN 2715-1980. *Community of Publishing in Nursing (COPING)*, 12, 498–506.
- Ding, L., & Beichner, R. (2009). Approaches to data analysis of multiple-choice questions. *Physical Review Special Topics - Physics Education Research*, 5(2), 1–17. <https://doi.org/10.1103/PhysRevSTPER.5.020103>
- Dwiyanti, U., Makhrus, M., & ... (2023). Studi Pendahuluan: Pengembangan Multimedia Pembelajaran Interaktif Berbasis PBL Guna Meningkatkan KPM Fisika Peserta Didik. ... Seminar Nasional Fisika. <http://proceedings2.upi.edu/index.php/sinafi/article/view/3349>
- Etikamurni, D. P. (2019). Peningkatan Penguasaan Konsep Siswa Kelas XI IPA pada Materi Suhu dan Kalor melalui Modeling Instruction. 172–177. <https://doi.org/10.17977/jptpp.v4i2.11935>
- Fitri, A. (2022). Laboratorium virtual dengan aplikasi PheT untuk memperkuat penguasaan konsep listrik dinamis siswa pada pembelajaran online. *Jurnal Eksakta Pendidikan (JEP)*, 6(1), 52–60. <https://doi.org/10.24036/jep/vol6-iss1/624>
- Fosnot, C. T. (2013). *Constructivism: Theory, perspectives, and practice*. Teachers College Press.
- Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. <https://doi.org/10.1119/1.18809>
- Hara, A. K., Astiti, K. A., & Lantik, V. (2023). Analisis Penguasaan Konsep Fisika pada Materi Suhu dan Kalor Pasca Pembelajaran Online di Kelas XI SMA Negeri 12 Kota Kupang. *Jurnal Ilmu Pendidikan (JIP) STKIP Kusuma Negara*, 14(2), 118–126. <https://doi.org/10.37640/jip.v14i2.1548>

- Hariyanto, H. (2021). Kesulitan pemecahan masalah fisika pada siswa man 3 jember. *AS-SUNNIYYAH*, 1(02), 58–67. <https://ejournal.uas.ac.id/index.php/assunniyyah/article/view/1064>
- Husein, S., Herayanti, L., & Gunawan, G. (2015). Pengaruh penggunaan multimedia interaktif terhadap penguasaan konsep dan keterampilan berpikir kritis siswa pada materi suhu dan kalor. *Jurnal Pendidikan Fisika Dan Teknologi*, 1(3), 221–225. <https://doi.org/10.29303/jpft.v1i3.262>
- Ilahi, T. D. W., Mufit, F., Hidayati, H., & Afrizon, R. (2021). Disain dan Validitas Multimedia Interaktif Berbasis Konflik Kognitif pada Materi Vektor untuk Kelas X SMA/MA. *Jurnal Penelitian Pembelajaran Fisika*, 12(2), 182–195. <https://doi.org/10.26877/jp2f.v12i2.9324>
- Kubiszyn, T., & Borich, G. D. (2003). *Educational testing and measurement*. John Wiley & Sons.
- Laili, A. N., Sutopo, & Diantoro, M. (2021). Ragam Kesulitan Siswa SMA dalam Menguasai Suhu dan Kalor. *Jurnal Riset Pendidikan Fisika (JRPF)*, 6(1), 20–26.
- Larasati, F. (2025). Learning Cycle 5E Model and Junior High School Students ' Scientific Literacy : Model Siklus Pembelajaran 5E dan Literasi Ilmiah Siswa Sekolah Menengah Pertama. 20(4), 1–12. <https://doi.org/10.21070/ijemd.v20i4.916>
- Lestari, N., & Wirasty, R. (2019). Pemanfaatan multimedia dalam media pembelajaran interaktif untuk meningkatkan minat belajar siswa. *Amaliah: Jurnal Pengabdian Kepada Masyarakat*, 3(2), 349–353. <https://doi.org/10.32696/ajpkm.v3i2.289>
- Maiyun, N. P., & Imamah, I. N. (2023). Tingkat Stress Pada Siswa Dalam Mengikuti Full Day School. *Journal Keperawatan*, 2(2), 160–167.
- Manuel Almudi, J., Zuza, K., & Guisasola, J. (2016). Learning of electromagnetic induction theory in general physics university courses. A teaching based on guided problem solving. *Ensenanza de Las Ciencias*, 34(2), 7–24.
- Maunah, N. (2014). Pengembangan Two-Tier Multiple Choice Diagnostic Test untuk Menganalisis Kesulitan Belajar Siswa Kelas X pada Materi Suhu dan Kalor. *IPF: Inovasi Pendidikan Fisika*, 3(2).
- Mayer, R. E. (1992). Cognition and instruction: Their historic meeting within educational psychology. *Journal of Educational Psychology*, 84(4), 405. <https://psycnet.apa.org/buy/1993-15331-001>
- Mayer, R. E. (2011). Applying the science of learning to multimedia instruction. In *Psychology of learning and motivation* (Vol. 55, pp. 77–108). Elsevier. <https://doi.org/10.1016/B978-0-12-387691-1.00003-X>
- Mitra, N. K., Nagaraja, H. S., Ponnudurai, G., & Judson, J. P. (2009). The levels of difficulty and discrimination indices in type A multiple choice questions of pre-clinical semester 1 multidisciplinary summative tests. *IeJSME*, 3(1), 2–7.
- Naf'atuzzahrah, N., Taufik, M., Gunawan, G., & Sahidu, H. (2022). Pengembangan perangkat pembelajaran model learning cycle 5E untuk meningkatkan penguasaan konsep fisika peserta didik. *Jurnal Pendidikan Fisika Dan Teknologi*, 8(SpecialIssue), 23–30. <https://doi.org/10.29303/jpft.v8iSpecialIssue.3393>

- Nalansari, I. F., & Winarni, E. W. (2020). Pengaruh Model Learning Cycle 5E Berbantuan Mind map Terhadap Pengetahuan Faktual Dan Konseptual Pada Pembelajaran IPA Siswa Kelas V Sekolah Dasar. 3(2), 171–181.
- Nurshifa, C. S., Fahmi, I., & Faizin, M. (2025). Tantangan dan Solusi Dalam Implementasi Full Day School Di Smpit At-Taubah Karawang. *Jurnal Ilmu Pendidikan Islam*, 23(2), 877–885. <https://doi.org/10.36835/jipi.v23i2.70>
- Nurul, D. (2022). Analisis Kesulitan Kemampuan Pemecahan Masalah Pada Peserta Didik Dalam Pembelajaran Fisika. *Jurnal Inovasi Dan Teknologi Pendidikan*, 1(1), 20–30. <https://doi.org/10.46306/jurinotep.v1i1.2>
- Pamangin, W. (2025). Pengaruh Penggunaan Multimedia Interaktif Terhadap Pemahaman Konsep Fisika Peserta Didik. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, 10(02), 303–312.
- Pratiwi, R. A., & Rahmi, A. (2023). Dampak Full Day School Terhadap Konsetrasi Belajar Siswa Di Sma Negeri 4 Pariaman. *Jurnal Kajian Penelitian Pendidikan Dan Kebudayaan*, 1(1), 105–112. <https://doi.org/10.59031/jkppk.v1i1.66>
- Puspaningrum, Y. (2017). Pengaruh pembelajaran learning cycle 5E berbantuan e-scaffolding terhadap hasil belajar kognitif dan keterampilan berpikir kritis mahasiwa pada materi unsur golongan 11 dan 12. Universitas Negeri Malang.
- Rahim, Af. (2010). *What those number mean?* Kubang Kerian: KKMED Publications.
- Ramadhani, C., Sholihah, A., & Sukmawati, A. (2025). Model Learning Cycle 5E untuk Meningkatkan Keterampilan Berpikir Kritis dan Penguasaan Materi PAI. *MA'ALIM: Jurnal Pendidikan Islam*, 6(1), 78–92. <https://doi.org/10.21154/maalim.v6i1.10848>
- Santhalia, P. W., Yuliati, L., & Wisodo, H. (2019). Kemampuan Pemecahan Masalah Siswa pada Materi Suhu dan Kalor melalui Experiential Learning Berbasis Fenomena. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, 4(2), 164. <https://doi.org/10.17977/jptpp.v4i2.11934>
- Saputra, B. H. (2022). Kemampuan pemecahan masalah dan berpikir kritis siswa Kelas XI dengan model problem based learning berbasis stem melalui hybrid learning disertai asesmen formatif pada materi suhu dan kalor. Universitas Negeri Malang.
- Simbolon, M., Jua, S. K., & Simatupang, D. F. (2024). Analisis tingkat kemampuan pemecahan masalah peserta didik kelas X SMA pada materi suhu dan kalor. *Jurnal Review Pendidikan Dan Pengajaran*, 7(2), 3898.
- Taib, F., & Yusoff, M. S. B. (2014). Difficulty index, discrimination index, sensitivity and specificity of long case and multiple choice questions to predict medical students' examination performance. *Journal of Taibah University Medical Sciences*, 9(2), 110–114. <https://doi.org/10.1016/j.jtumed.2013.12.002>
- Tongchai, A., Sharma, M. D., Johnston, I. D., Arayathanitkul, K., & Soankwan, C. (2009). Developing, evaluating and demonstrating the use of a conceptual survey in mechanical waves. *International Journal of Science Education*, 31(18), 2437–2457. <https://doi.org/10.1080/09500690802389605>

- Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science*, 322(5902), 682–683. <https://www.science.org/doi/abs/10.1126/science.1161948>
- Yuliana, I., Kusairi, S., & Taufiq, A. (2019). Profil Penguasaan Konsep Siswa SMA pada Materi Suhu dan Kalor. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, 4(5), 572. <https://doi.org/10.17977/jptpp.v4i5.12384>