

Improving Senior High School Students' Cognitive Learning Outcomes through the Group Investigation (GI) Cooperative Learning Model Supported by a Simple Physics Kit

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Abstract

Low cognitive learning outcomes and the prevalence of teacher-centred instruction demand serious attention from physics educators. This study aims to examine the empirical reliability and effectiveness of implementing the Group Investigation (GI) cooperative learning model, supported by a simple KIT, in improving the cognitive learning outcomes of Year 10 students at a state senior secondary school in Kerinci on the topic of Temperature and Heat. This research employed a Classroom Action Research (CAR) approach, utilizing the Kemmis and McTaggart cyclical model implemented across three instructional cycles. The research subjects comprised 19 tenth-grade students selected through purposive sampling. Data were collected using cognitive tests and instructional observations, which were subsequently analysed using descriptive quantitative methods. The findings revealed a linear escalation in cognitive achievement. Classical learning completeness in Cycle I reached 57.89% with a mean academic score of 70.26. In Cycle II, completeness increased to 78.95% (mean score of 75.53) and ultimately achieved the targeted success criterion in Cycle III at 94.74% with a mean score of 82.63. The effective utilization of the GI model, synergized with simple KIT media, significantly enhances students' comprehension of physical concepts and their cognitive abilities. Future research could expand upon this study by applying the GI model to physics topics with higher levels of abstraction to evaluate the consistency of its effectiveness. Furthermore, integrating 21st-century skills and modern KIT with the GI model presents a promising avenue for instructional integration in subsequent studies.

Keywords: group investigation; simple physics kit; classroom action research (car); cognitive learning outcomes.

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Introduction

Physics is one of the fundamental branches of science that inherently integrates a body of knowledge, a way of thinking, and a way of investigating. Ideally, physics instruction should emphasize the development of comprehensive scientific literacy (Chi, 2009; Hambali et al., 2025). Such instruction is designed to equip students with critical, analytical, and applied thinking skills through a series of contextualized learning experiences (Rosa et al., 2025; Susanti et al., 2023). Mastering physics concepts requires students' active cognitive engagement in observing natural phenomena, formulating hypotheses, and conducting empirical verification.

In physics education, the abstract nature of topics such as Temperature and Heat presents considerable challenges for learners. Fundamental concepts, including mechanisms of heat transfer, thermal heat capacity, and the Black Principle, are frequently presented in purely theoretical and mathematical forms (Masara et al., 2024; Mustari &

Sari, 2017). Consequently, many tenth-grade students experience cognitive overload and persistent misconceptions because they are unable to visualize the underlying physical mechanisms of invisible energy transfer (Rosa et al., 2025). The absence of appropriate visual representations further limits students' working memory capacity when processing complex scientific information.

In physics instruction, the ability to simplify abstract concepts into observable learning experiences can enhance students' direct interaction with the physical phenomena under investigation. This requires a paradigm shift from traditional, teacher-centered knowledge transmission toward structured collaborative inquiry (Guo et al., 2020; Hmelo-Silver et al., 2007; Kozanitis & Nenciovici, 2023). Physics classrooms should therefore be transformed into social learning laboratories where students actively collaborate in small groups to investigate scientific problems (Bjørke & Mordal Moen, 2020; Kurniawan et al., 2019). Furthermore, instruction should incorporate empirical manipulative learning media that enable students to construct meaningful understanding and independently validate physical principles through experimentation (Masara et al., 2024; Syaqiqoh et al., 2025; Wan Hussin et al., 2019).

However, classroom realities continue to reveal a discrepancy between theoretical expectations and actual instructional practice. Based on a preliminary study and classroom observations conducted among tenth-grade students at a public senior high school in Kerinci, physics instruction remains predominantly characterized by conventional teacher-centered learning. The limited availability of adequate laboratory equipment compels teachers to rely primarily on lecture-based instruction. The consequences of this instructional gap are clearly reflected in students' learning outcomes: the classical learning mastery rate for the Temperature and Heat topic reached only 36.84%, with a mean score of 64.73. These results fall substantially below the institutional Minimum Mastery Criterion (MMC) of 70. These preliminary findings indicate that students have not yet achieved adequate cognitive understanding of the concepts of temperature and heat.

To address these instructional challenges through a strategic and evidence-based approach, this study proposes the implementation of the Group Investigation (GI) cooperative learning model integrated with the use of a Simple Physics Kit. The principal strength of the GI model lies in its foundation in social constructivist learning theory (Fadilurrahman et al., 2019; Kozanitis & Nenciovici, 2023). The model provides students with autonomy throughout a systematic investigative process encompassing group planning, multidimensional investigation, data synthesis, analytical presentation, and interactive evaluation (Fadilurrahman et al., 2019; Hmelo-Silver et al., 2007). The integration of the Simple Physics Kit into the GI instructional framework provides essential material scaffolding, enabling students to manipulate variables related to temperature and heat directly through practical, cost-effective experimentation (Anselmo, 2024; Narayanan et al., 2023).

This study accommodates the integration of collaborative social inquiry with the development of low-cost experimental learning media through the use of a Simple Physics Kit. Such integration is designed to align with the capacity of schools to provide accessible

and feasible instructional resources (Syaqiqoh et al., 2025; Zhang et al., 2025). Rather than relying on expensive virtual reality technologies or sophisticated laboratory instrumentation, this study investigates how everyday materials can be engineered into precise thermodynamics inquiry tools within the Group Investigation learning environment (Arinda et al., 2019; Mira, 2024). This instructional synergy is intended not only to reduce students' extraneous cognitive load when learning abstract concepts but also to model an inclusive and adaptive science pedagogy suitable for schools with limited laboratory facilities.

Based on the research background presented above, this study aims to examine the empirical effectiveness and reliability of implementing the Group Investigation (GI) cooperative learning model supported by a Simple Physics Kit in improving the cognitive physics learning outcomes of tenth-grade students at public senior high schools in Kerinci on the topic of Temperature and Heat.

Methods

This study employed a Classroom Action Research (CAR) design conducted through a collaborative and participatory approach. Conceptually, Classroom Action Research is defined as a reflective, critical, and systematic approach undertaken by educators to improve instructional practices, gain a deeper understanding of classroom dynamics, and implement measurable positive changes in the teaching and learning process (Arikunto et al., 2015; Burns, 2007; Kemmis, McTaggart, & Nixon, 2014; Setiawan & Indriwati, 2018; Siregar, 2025; Syaqiqoh et al., 2025). This approach requires teachers to systematically investigate their own classrooms by identifying specific instructional problems, implementing pedagogical interventions—in this study, the Group Investigation (GI) learning model supported by a Simple Physics Kit—and evaluating their effects on students' learning outcomes (Siregar, 2025).

The operational design of this study systematically adopted the cyclical (spiral) model of Classroom Action Research, which involves four interrelated stages: planning, acting, observing, and reflecting (Arikunto et al., 2015; Burns, 2007). The study was conducted over two action cycles. The transition from Cycle I to Cycle II, including the refinement of instructional strategies, was based entirely on the findings derived from critical reflection and a comprehensive analysis of students' cognitive learning outcomes obtained during the preceding cycle.

The population of this Classroom Action Research comprised all tenth-grade students of SMAN 11 Kerinci, distributed across several classes, with a total population of 117 students. The research participants were selected using a purposive sampling technique, whereby Class X Science was chosen as the target sample based on academic considerations, specifically its relatively low average score on the pre-intervention physics achievement test. The study involved 19 students representing heterogeneous academic ability levels.

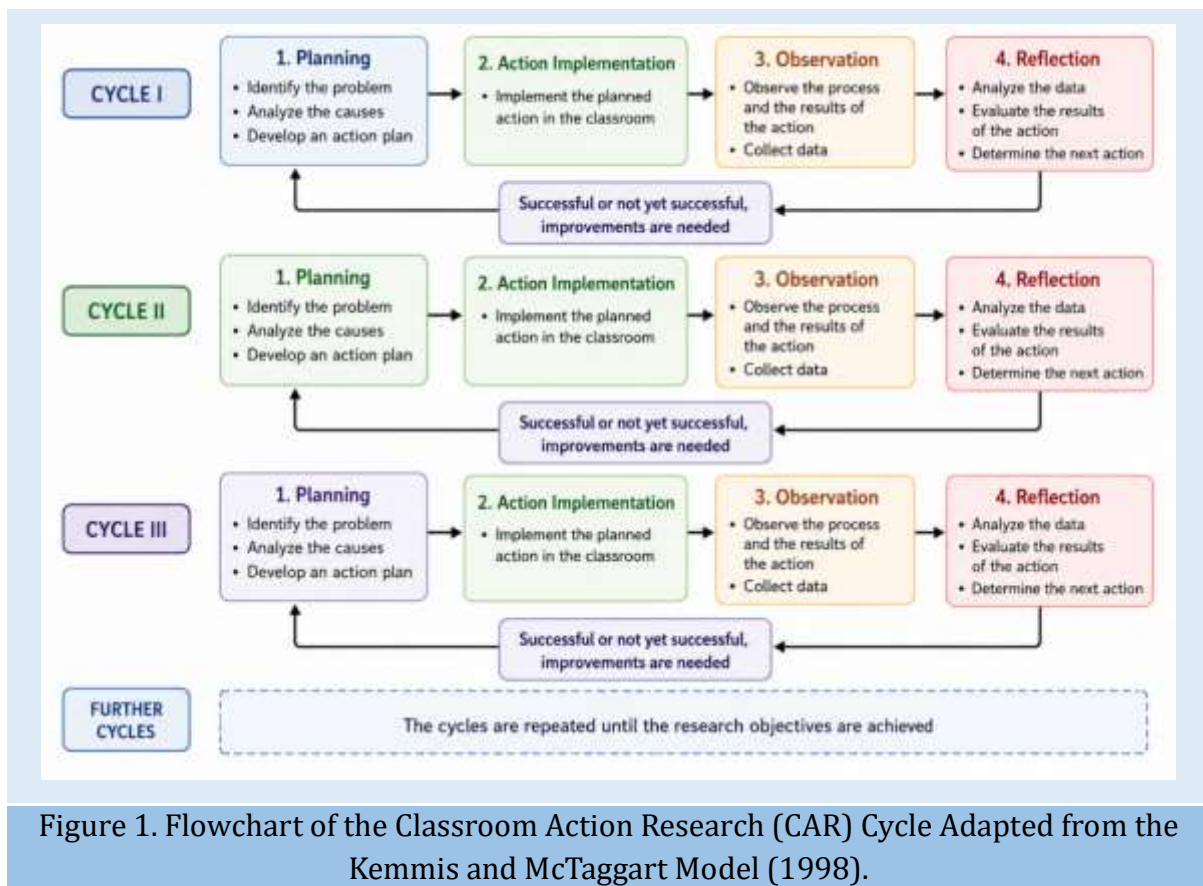


Figure 1. Flowchart of the Classroom Action Research (CAR) Cycle Adapted from the Kemmis and McTaggart Model (1998).

As illustrated in Figure 1, the overall research procedure consisted of four sequential stages: (1) planning, (2) action implementation, (3) observation and evaluation, and (4) analysis and reflection. The study was conducted through several action cycles, each comprising the following stages.

A. Cycle I

1. Planning

During the planning stage, several preparatory activities were undertaken to facilitate the implementation of the instructional intervention, including:

- Preparing the lesson plan (LP).
- Preparing instructional materials, learning media, and equipment required to support the planned learning activities.
- Developing an observation sheet for monitoring teacher activities.
- Developing an observation sheet for monitoring students' learning activities.
- Preparing the evaluation instrument, including the achievement test and its scoring rubric (answer key).

2. Action Implementation

The instructional intervention was implemented in accordance with the prepared lesson plan. The activities conducted during this stage included:

- Creating a conducive learning environment.
- Motivating and encouraging students throughout the learning process.

- c) Implementing the instructional activities according to the prepared lesson plan.
- d) Conducting learning assessments to measure students' achievement.
- e) Reflecting on the implementation of the instructional process to identify areas for improvement in the subsequent cycle.

3. Observation and Evaluation

Observation was conducted systematically throughout the instructional process using student activity observation sheets and instructional implementation observation sheets. The observational data served as the basis for determining the necessary instructional improvements in the subsequent cycle.

Evaluation was conducted to determine students' learning achievement following the implementation of the instructional intervention. At the end of each cycle, students completed a post-cycle achievement test to assess the extent of their cognitive learning outcomes.

4. Analysis and Reflection

The data obtained from both observation and evaluation were analyzed at the end of each cycle. The findings from the analysis and reflection were used to evaluate the effectiveness of the implemented intervention in addressing the identified instructional problems. If the intervention had not yet produced satisfactory improvements, appropriate revisions and instructional modifications were incorporated into the subsequent cycle.

B. Cycle II and Cycle III

The implementation of Cycle II was based on the findings obtained from the reflection and evaluation of Cycle I. Similarly, Cycle III was conducted following the reflection and revisions derived from Cycle II. Therefore, the procedures employed in Cycles II and III were fundamentally identical to those implemented in Cycle I, consisting of four iterative stages: planning, action implementation, observation and evaluation, and analysis and reflection.

The class average was then calculated (Daryanto, 2012) using the following formula:

$$\bar{X} = \frac{\sum X}{N}$$

Notes:

\bar{X} = the class mean.

$\sum X$ = the sum of all pupils' marks.

N = the number of pupils.

C. Calculating the Percentage of Learning Outcome Achievement

Finally, the percentage of student learning achievement is calculated using the following formula:

$$P = \frac{\text{Number of pupils who have completed the course}}{\text{Total number of pupils}} \times 100\%$$

Notes:

P = percentage of learning achievement.

Number of pupils who have achieved the required standard = the number of pupils who have obtained a mark equal to or above the Minimum Pass Mark (KKM).

Total number of pupils = the total number of pupils taking part in the learning

Results and Discussions

Cycle I

The implementation of the Group Investigation (GI) learning model supported by a Simple Physics Kit in the Temperature and Heat unit demonstrated a consistent positive trend across successive action cycles. This section presents a detailed quantitative analysis of students' cognitive learning outcomes in Cycles I, II, and III based on post-intervention objective achievement tests. The results obtained in Cycle I are presented in Table 1.

Table 1. Students' Cognitive Learning Outcomes in Cycle I

No	Student Initials	Cognitive Score	Mastery Status (MMC \geq 70)
1	AV	65	Not Achieved (-)
2	AS	50	Not Achieved (-)
3	AH	80	Achieved (\checkmark)
4	AS	60	Not Achieved (-)
5	AA	65	Not Achieved (-)
6	AW	75	Achieved (\checkmark)
7	AP	60	Not Achieved (-)
8	BP	75	Achieved (\checkmark)
9	DDF	70	Achieved (\checkmark)
10	DR	85	Achieved (\checkmark)
11	FAW	65	Not Achieved (-)
12	M	80	Achieved (\checkmark)
13	MJ	75	Achieved (\checkmark)
14	MS	60	Not Achieved (-)
15	MW	70	Achieved (\checkmark)
16	MAW	90	Achieved (\checkmark)
17	MT	75	Achieved (\checkmark)
18	MR	65	Not Achieved (-)
19	RS	70	Achieved (\checkmark)
Total Score		1.335	11
Class Mean Score		70.26	-
Classical Mastery		57.89	

Based on the cognitive achievement test results in Cycle I, the total score obtained by the class was 1,335, with a mean score of 70.26. Of the 19 participating students, 11 students (57.89%) achieved the Minimum Mastery Criterion (MMC \geq 70), whereas 8 students (42.11%) had not yet reached the required level of mastery. These findings indicate that the instructional intervention implemented during Cycle I positively influenced students' learning achievement; however, the level of classical learning mastery had not yet met the predetermined success criterion.

The initial improvement observed in Cycle I suggests that the instructional intervention successfully enhanced students' conceptual understanding of the learning material. This finding is consistent with the study conducted by Syaqiqoh et al. (2025), which demonstrated that Classroom Action Research (CAR) based on the Kemmis and McTaggart model gradually improves both student participation and learning outcomes across successive cycles. Likewise, previous studies have reported that iterative instructional improvements implemented through CAR contribute significantly to students' academic achievement (Fadilurrahman et al., 2019; Rosa et al., 2025; Setiawan et al., 2023).

Despite these encouraging findings, the classical mastery rate of 57.89% indicates that the intervention in Cycle I had not yet achieved the expected level of effectiveness. Eight students still obtained scores below the MMC, ranging from 50 to 65, suggesting that students' conceptual understanding remained uneven and that several learners continued to experience difficulties in comprehending the instructional content. These findings imply that further refinement of the instructional strategy was necessary to better accommodate the diverse learning needs of all students (Fania et al., 2021; Hof, 2021).

From a theoretical perspective, instructional approaches that actively engage students and promote meaningful interaction have consistently been shown to improve academic achievement. Previous meta-analytical evidence indicates that active learning yields significantly better academic outcomes than conventional lecture-based instruction. Furthermore, Arinda et al. (2019) reported that the Group Investigation learning model effectively enhances students' scientific learning skills.

The observation and evaluation conducted during Cycle I also revealed several instructional challenges, including limited participation among some students, uneven conceptual understanding, and insufficient learning motivation. These findings are consistent with the systematic review conducted by Sari et al. (2025), which concluded that active student engagement is a key determinant of successful learning and improved academic performance.

According to the Classroom Action Research framework proposed by Kemmis and McTaggart (Arikunto et al., 2015), each action cycle consists of four interconnected stages: planning, action implementation, observation, and reflection. The reflection stage is intended to identify shortcomings in the instructional process and formulate appropriate improvements for the subsequent cycle. Since the classical mastery level achieved in Cycle I reached only 57.89%, the intervention was considered insufficient to meet the research objectives, thereby necessitating further instructional refinement in Cycle II. This iterative

process reflects the spiral nature of the Kemmis and McTaggart model, in which reflective evaluation serves as the foundation for continuous instructional improvement.

Overall, the findings from Cycle I demonstrate that the intervention successfully improved students' learning outcomes but had not yet fulfilled the predetermined criteria for classical learning mastery. Therefore, based on the reflective evaluation, the study proceeded to Cycle II by strengthening student engagement, providing additional academic support to students who had not yet achieved mastery, and optimizing the implementation of the instructional model.

Cycle II

The reflection conducted after Cycle I identified several major instructional issues, including limited student participation, uneven conceptual understanding, and difficulties experienced by some students in adapting to the instructional procedures. Accordingly, several improvements were implemented during Cycle II, including strengthening students' learning motivation, providing more intensive guidance for students experiencing learning difficulties, and optimizing the implementation of the instructional model to promote greater and more equitable student participation.

These improvements were expected to enhance both the class average score and the overall level of classical learning mastery. The cognitive achievement test results obtained in Cycle II are presented in Table 2.

Table 2. Cognitive Learning Outcomes of Students in Cycle II

No	Student Initials	Cognitive Score	Mastery Status (MMC \geq 70)
1	AV	75	Achieved (√)
2	AS	65	Not Achieved (-)
3	AH	80	Achieved (√)
4	AS	65	Not Achieved (-)
5	AA	70	Achieved (√)
6	AW	65	Not Achieved (-)
7	AP	80	Achieved (√)
8	BP	70	Achieved (√)
9	DDF	75	Achieved (√)
10	DR	85	Achieved (√)
11	FAW	70	Achieved (√)
12	M	90	Achieved (√)
13	MJ	85	Achieved (√)
14	MS	75	Achieved (√)
15	MW	60	Not Achieved (-)
16	MAW	90	Achieved (√)
17	MT	80	Achieved (√)
18	MR	75	Achieved (√)
19	RS	80	Achieved (√)
Total Score		1.435	15
Class Mean Score		75.53	-
Classical Mastery		78.95	

Based on the results presented in Table 2, the class obtained a total score of 1,435, with a mean achievement score of 75.53. Among the 19 participating students, 15 (78.95%) met the Minimum Mastery Criterion, while 4 (21.05%) did not. Compared with Cycle I, substantial improvement was observed. The class means increased from 70.26 to 75.53, representing an improvement of 5.27 points, while the classical mastery level increased from 57.89% to 78.95%, corresponding to an increase of 21.06 percentage points.

These improvements demonstrate that the instructional revisions implemented following the reflective evaluation of Cycle I had a positive impact on students' academic performance. The additional motivational strategies, individualized guidance, and optimization of the Group Investigation learning process enabled students to develop a more comprehensive understanding of the Temperature and Heat concepts.

The improvement observed between Cycles I and II is fully consistent with the theoretical principles of the Kemmis and McTaggart Classroom Action Research model, in which planning, implementation, observation, and reflection are continuously repeated to facilitate sustainable instructional improvement. Consequently, the enhanced learning outcomes achieved in Cycle II can be regarded as the direct result of systematic reflection and instructional revision based on the findings obtained in Cycle I.

These findings are supported by previous empirical studies. Mira (2024) reported that iterative instructional interventions implemented across two action cycles increased students' learning mastery from 78% in Cycle I to 94% in Cycle II. Similarly, international research has consistently demonstrated that student-centred instructional approaches significantly improve academic achievement. Chen and Yang (2019) reported that active and project-based learning exert moderate to large positive effects on students' academic performance, while Kozanitis and Nenciovici (2023) concluded that active learning approaches are more effective than conventional instruction in improving students' academic achievement.

Nevertheless, although Cycle II demonstrated substantial improvement, the classical mastery rate of **78.95%** remained slightly below the predetermined success criterion of **80%**. Consequently, according to the reflective principles of the Kemmis and McTaggart model, additional instructional refinement was required in Cycle III to ensure that the research objectives were fully achieved.

Cycle III

Based on the cognitive achievement test results presented in Table 3, the class obtained a total score of 1,570, with a mean score of 82.63. Of the 19 participating students, 18 students (94.74%) successfully achieved the Minimum Mastery Criterion, whereas only one student (5.26%) remained below the required standard.

The substantial improvement achieved in Cycle III indicates that the instructional refinements implemented during this cycle were highly effective in enhancing students' learning outcomes. Strengthening individualized academic support, increasing students' learning motivation, and optimizing active participation throughout the learning process enabled nearly all students to achieve the expected level of mastery. These findings further demonstrate that the continuous process of reflection and instructional improvement,

which constitutes the core principle of the Kemmis and McTaggart Classroom Action Research model, was successfully implemented and resulted in progressively improved instructional quality across successive cycles.

Table 3. Students' Cognitive Learning Outcomes in Cycle III

No	Student Initials	Cognitive Score	Mastery Status (MMC \geq 70)
1	AV	85	Achieved (√)
2	AS	80	Achieved (√)
3	AH	85	Achieved (√)
4	AS	80	Achieved (√)
5	AA	90	Achieved (√)
6	AW	85	Achieved (√)
7	AP	90	Achieved (√)
8	BP	80	Achieved (√)
9	DDF	80	Achieved (√)
10	DR	85	Achieved (√)
11	FAW	80	Achieved (√)
12	M	90	Achieved (√)
13	MJ	85	Achieved (√)
14	MS	80	Achieved (√)
15	MW	65	Not Achieved (-)
16	MAW	90	Achieved (√)
17	MT	85	Achieved (√)
18	MR	75	Achieved (√)
19	RS	80	Achieved (√)
Total Score		1.570	18
Class Mean Score		82.63	
Classical Mastery		94.74	

The substantial improvement achieved in Cycle III indicates that the instructional refinements implemented during this cycle were highly effective in enhancing students' learning outcomes. Strengthening individualized academic support, increasing students' learning motivation, and optimizing active participation throughout the learning process enabled nearly all students to achieve the expected level of mastery. These findings further demonstrate that the continuous process of reflection and instructional improvement, which constitutes the core principle of the Kemmis and McTaggart Classroom Action Research model, was successfully implemented and resulted in progressively improved instructional quality across successive cycles.

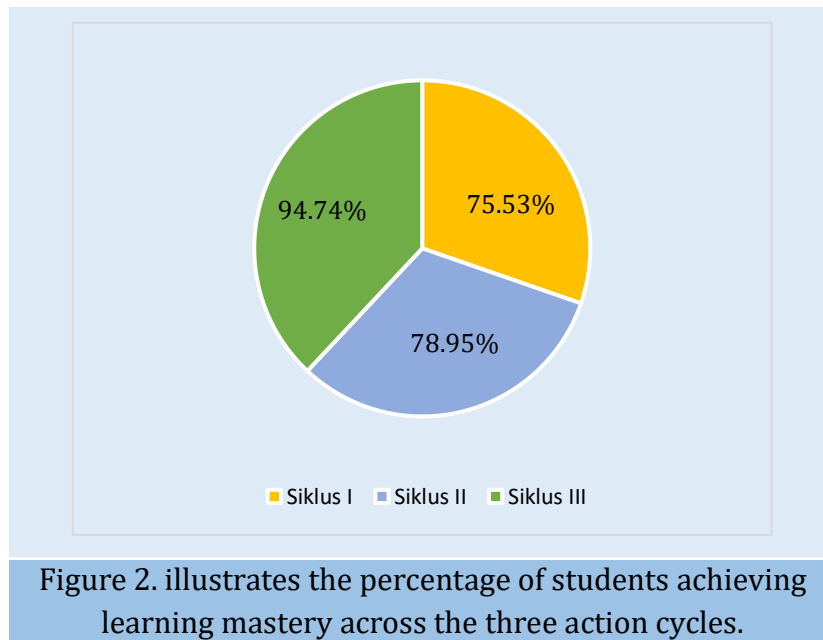


Figure 2. illustrates the percentage of students achieving learning mastery across the three action cycles.

Overall, the results of Cycle III indicate that the predetermined research success criteria were successfully achieved. Although one student had not yet attained the Minimum Mastery Criterion, the overall level of classical learning mastery (94.74%) demonstrates that the implementation of the Group Investigation learning model supported by a Simple Physics Kit was highly effective in improving the cognitive physics learning outcomes of tenth-grade students studying the topic of Temperature and Heat.

Conclusion

Based on the findings of this Classroom Action Research conducted over three iterative cycles, the implementation of the Group Investigation (GI) learning model supported by a Simple Physics Kit effectively and consistently improved students' cognitive learning outcomes. The synthesized findings revealed a progressive increase in the mean achievement score from 70.26 in Cycle I to 75.53 in Cycle II and 82.63 in Cycle III. Similarly, the level of classical learning mastery increased substantially from 57.89% to 78.95%, ultimately reaching 94.74% in the final cycle. These improvements indicate that a cyclical instructional process characterized by systematic reflection and continuous refinement effectively enhanced students' conceptual understanding of Temperature and Heat. Therefore, the research objective of improving students' cognitive learning outcomes through the implementation of the Group Investigation learning model supported by a Simple Physics Kit was successfully achieved by the end of Cycle III.

An important finding of this study is that the observed improvements extended beyond quantitative learning outcomes to include meaningful enhancements in the quality of the learning process. Students became more actively engaged in collaborative investigations, demonstrated greater independence in constructing scientific knowledge, and exhibited stronger collaborative skills when solving abstract physics problems. Furthermore, the use of the Simple Physics Kit effectively reduced students' cognitive load and facilitated the visualization of abstract concepts related to temperature and heat that

had previously been difficult to comprehend. These findings provide further evidence that integrating an inquiry-oriented cooperative learning model with contextual, low-cost instructional media constitutes an effective pedagogical alternative for physics instruction, particularly in schools with limited laboratory facilities.

Future research is recommended to extend the present study in several directions. First, subsequent studies should investigate the effectiveness of the Group Investigation model supported by a Simple Physics Kit in developing other twenty-first-century competencies, including critical thinking, problem-solving, and scientific creativity. Second, comparative studies involving other student-centred instructional approaches, such as Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL), would provide a more comprehensive understanding of their relative effectiveness. Third, future research should examine the applicability of this instructional approach to other highly abstract physics topics and across different educational levels to evaluate the consistency and generalizability of its effectiveness. Accordingly, this study not only contributes practical evidence regarding the improvement of students' cognitive learning outcomes but also provides a foundation for future research on inquiry-based innovations in physics education.

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Authors' Contribution

WP (Wilda Purnawati) was responsible for the conceptualization and design of the study, planning and implementing Classroom Action Research, and collecting data through classroom instructional activities. WP also conducted data analysis, interpreted the research findings, prepared the original manuscript, and carried out the review and revision process until the final version of the manuscript was completed and approved for publication.

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