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Temperature and Heat Module with Guided Inquiry Model to Improve Student Learning Outcomes

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Abstract

The persistently low learning outcomes in physics indicate that students frequently struggle to analyze experimental results in depth—a challenge often exacerbated by conventional teacher-centered instructions. This study developed and evaluated a temperature and heat instructional module integrated with the Guided Inquiry model to enhance student learning outcomes. Employing the ADDIE development framework, the study involved 33 eleventh-grade students at SMA Negeri 1 Angsana as test subjects. Data were gathered using validation instruments, implementation observation sheets, and a learning outcome test, analyzed through quantitative descriptive statistics. The results demonstrated high product validity, with a score of 3.47 and a high reliability coefficient of 0.68. The module exhibited exceptional practicality, achieving a 92% implementation rate. Regarding effectiveness, the module yielded a moderate improvement in learning outcomes, evidenced by an average normalized gain (N-gain) of 0.57. Post-intervention analysis showed that while cognitive scores substantially increased, the formal mastery rate reached 30.3% (10 students), with 69.7% (23 students) still developing proficiency due to persistent algorithmic calculation bottlenecks. It is concluded that the guided inquiry module is valid, highly practical, and moderately effective, serving as a structured pedagogical alternative to bridge conceptual understanding and experimental inquiry in resource-limited physics classrooms.

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INTRODUCTION

Learning outcomes are the primary benchmark for assessing the success of the learning process. Through learning outcomes, teachers can assess students' achievement of expected competencies while identifying difficulties students experience. These learning achievements are influenced not only by individual abilities such as motivation, interest, talent, and mental readiness but also by external factors such as family support, school facilities, and teaching approaches. In other words, learning outcomes reflect the interaction between students' abilities and the quality of their learning environment. Therefore, understanding learning outcomes is very important, as it enables teachers to develop more efficient and appropriate learning approaches, thereby helping students develop and maximize their abilities more effectively (Fernando et al., 2024; Rahman, 2021).

In reality, many teachers continue to use conventional teacher-centered learning methods that emphasize mastery of subject matter alone. As a result, students are not trained to think creatively and express their ideas sensitively and often feel bored during the learning process (Natasya et al., 2025; Rozali et al., 2022). Limited facilities and resources, especially in remote schools, remain a serious challenge in science education. Many schools lack adequate laboratories or practical equipment, limiting students' learning. This situation reduces interest in science and hinders the development of scientific skills, such as observation, classification, measurement, data analysis, experimentation, and problem-solving (Fadillah et al., 2025; Fanani, 2025; Widodi et al., 2023).

On the other hand, teachers find it difficult to develop innovative, context-specific teaching materials due to time constraints and limited access to resources. As a result, the learning process often relies on standard textbooks that may not suit students' needs. The lack of continuous professional training also further limits teachers' innovation in science education. (Nurnaifah, 2024; Panjaitan et al., 2023; Taufik et al., 2023; Widodi et al., 2023). Based on a conversation with a teacher at Angsana 1 Public High School, it appears that the implementation of practical work to improve student learning outcomes has not been optimal. The teacher explained that although practical, work-based learning methods had been implemented, students' abilities remained low, so conventional methods of lecturing with the aid of textbooks were still used more frequently (Sari et al., 2023).

One way to overcome difficulties in learning physics is to develop guided-inquiry teaching modules to improve student learning outcomes. Teaching modules themselves are self-instructional learning units that allow students to study the material individually. After completing one module, students can continue to the next module. (Mardianti et al., 2020; Maulida, 2022). A good teaching module has several characteristics that support effective and efficient learning (Putra et al., 2024). These characteristics include a clear, easy-to-understand structure; material appropriate to the learning objectives; examples and exercises to reinforce concepts; and the use of various resources, such as text, images, and videos, to enrich the learning experience (Latifa et al., 2024). This module ideally integrates scientific concepts into familiar everyday situations to make them more contextual (Putri, 2023).

The development of teaching modules that integrate guided inquiry models into physics learning represents a targeted innovation aimed at increasing student engagement during the learning process. These modules are designed not only as independent teaching materials but also as guides that help students explore physics concepts through structured stages of scientific investigation—discovering concepts. This view aligns with Karlina et al. (2019), who emphasize that guided inquiry models are effective at fostering scientific activities among students through targeted teacher guidance. Furthermore, Masruroh et al. (2022) revealed that integrating experimental activities and module readings into teaching modules can develop students' critical thinking skills and conceptual understanding. On the other hand, Lovisia et al. (2023) emphasize the importance of presenting material through texts, illustrations, exercises, and practical activities to help students gain new experiences and achieve deeper, more meaningful learning. Thus, combining self-directed learning modules with a guided inquiry approach can be considered an innovative strategy that improves the overall quality of the physics learning process.

While previous developments have independently evaluated self-directed learning modules and inquiry models, prior literature exhibits a significant gap: an overreliance on descriptive theoretical frameworks that fail to analyze why student cognitive transitions stall during thermodynamics instruction. In this study, the key construct of 'learning outcomes' is operationally defined as the student's measurable capacity to synthesize conceptual knowledge and execute algorithmic physics calculations post-intervention. Unlike general instructional materials, the novelty of this module lies in the systematic embedding of guided inquiry variables—specifically, structured exploration and data-analysis syntax—directly into a self-paced thermodynamics blueprint. To ensure explicit structural alignment, the underlying problem statement directly addresses the deficit in students' analytical inquiry skills, which in turn dictates the primary research question and matching objective: to evaluate whether a structurally integrated guided inquiry module can systematically bridge the gap between conceptual physics discovery and formal classroom learning outcomes (Shandra & Movitaria, 2022; Sujana, 2020). The purpose of this study was to examine the feasibility of the teaching module and assess the impact of guided inquiry-based learning on student learning outcomes.

METHODS

This study employed a research and development (R&D) methodology utilizing the systematic ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework. To evaluate the instructional product's field efficacy during the implementation phase, a quantitative one-group pretest-posttest design was adopted. This experimental design enabled rigorous comparison of students' baseline conceptual knowledge and post-intervention learning outcomes within a single experimental group, without a separate control group, making it highly suitable for classroom-based development research.

The analysis covers two main aspects, namely, (a) the learning material needs of students, which require learner-centered learning stages in accordance with cognitive development, and (b) the characteristics of temperature and heat materials that are contextual but contain abstract and quantitative concepts and are best taught through a guided inquiry approach. At the design stage, teaching modules were designed that included learning activity flows, practical selection, and evaluation instruments. The development stage involved producing modules aligned with the design, which were then reviewed and revised by experts to ensure presentation quality and integration of the guided inquiry approach. Furthermore, the implementation stage covered the application of the module in the classroom with three meetings using a pretest-posttest group trial design involving one or more groups of participants/subjects who were measured (pretest) after the treatment was given, then measured again (posttest) after the treatment with the module (Tandiola et al., 2024). The final stage of evaluation assessed the teaching module's feasibility based on its validity and implementation results. The stages of the research are presented in Figure 1.

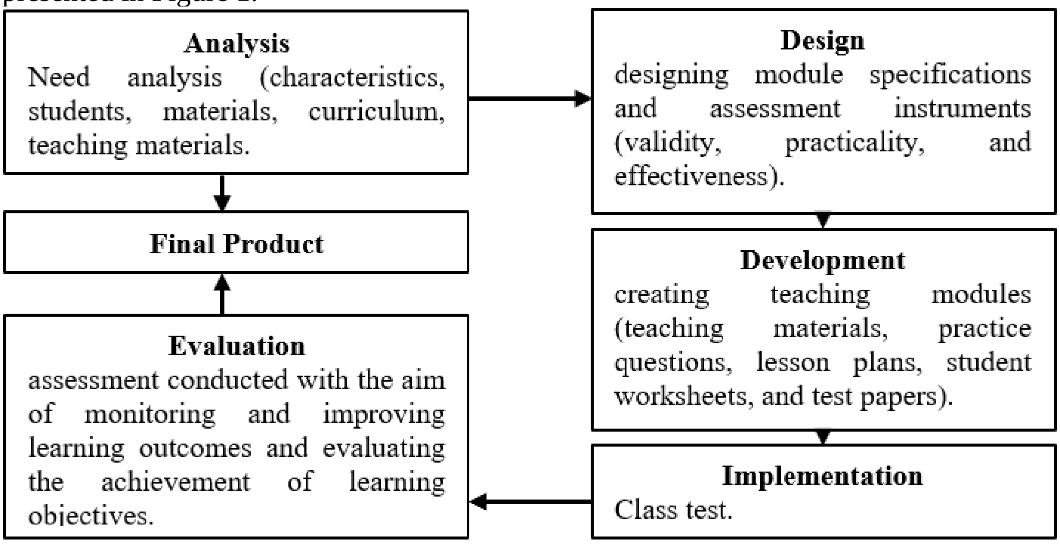


Figure 1 Flow chart of the ADDIE model stages (Hidayat & Nizar, 2021)

The participant selection used purposive sampling based on specific inclusion criteria: eleventh-grade students enrolled in the MIPA (Mathematics and Natural Sciences) track at SMA Negeri 1 Angsana who had completed basic mechanics but had no prior formal exposure to advanced thermodynamics. The final sample size (N=33) represented an intact classroom unit. To address ethical considerations, institutional approval was secured from the school administration, and informed consent was obtained from all participants prior to data collection. Extraneous variables, such as variations in teacher delivery and instructional duration, were rigorously controlled by ensuring that the same certified physics instructor delivered the exact modular curriculum across a standardized timeframe of six instructional periods.

The primary instrument, a learning outcome test, underwent a rigorous multi-stage development procedure. Initial item construction generated cognitive items mapped to high-order thinking taxonomies, which were subsequently subjected to expert validation through panel reviews by senior physics education professors. A pilot testing phase was executed to eliminate ambiguous items. The final test exhibited an expert validation score of 3.47 (categorized as highly valid) and a high internal consistency reliability coefficient of 0.68.

The data analysis procedures followed a strict step-by-step statistical decision process. First, parametric assumption testing was conducted, confirming the data's normality using the Shapiro-Wilk test. Second, inferential effectiveness was computed using the Normalized Gain (N-gain) formula. To prevent an over-reliance on mere statistical significance and to interpret practical significance in an educational context, Cohen’s effect size was calculated to quantify the true magnitude of the instructional impact.

RESULT AND DISCUSSION

Based on the results of the analysis stage, researchers found that the majority of students faced obstacles in understanding fundamental concepts of temperature and heat and their applications in everyday life due to the unavailability of facilities and infrastructure that support physics learning. This requires teaching media that help students gradually build understanding through investigative activities (Widiarini et al., 2025).

At the design stage, a guided inquiry-based teaching module was developed with a sequence of activities that included problem formulation, hypothesis development, experimental data collection, analysis of results, and conclusion (Hidayat & Nizar, 2021; Widiarini et al., 2025). The module also includes illustrations, practice questions, lesson plans, and student worksheets to reinforce understanding and the THB shown in the following figure.

The design of the learning module, which was developed with students' needs and characteristics in mind, is depicted in Figure 2. This module is meant for upper secondary pupils, as indicated by the letter F on the cover. The title, Temperature and Heat, aligns with key content pertinent to students' requirements and stages of cognitive development. Furthermore, the learning objectives on the cover have been developed in accordance with the curriculum's learning outcomes. To pique interest in learning and provide a basic synopsis of the module's content, it also includes an illustration of a key idea about temperature and heat shown in Figure 2.

Figure 2 Cover and teaching materials

This module provides a systematic, structured discussion of the concepts of time and heat. The material is presented along with a lesson plan designed to guide their learning in a gradual, focused manner. In addition, the module includes a section for your information that provides additional or in-depth information related to the concepts discussed, thereby broadening the students' knowledge. The aspect of physics literacy is also integrated to train students' ability to understand, interpret, and relate physics concepts to everyday phenomena. At the end of each section, exercises are provided to conceptually assess understanding, strengthen mastery, and develop students' critical thinking skills, as shown in Figure 3.

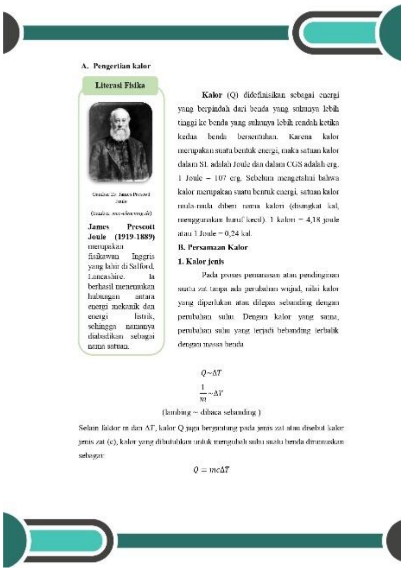
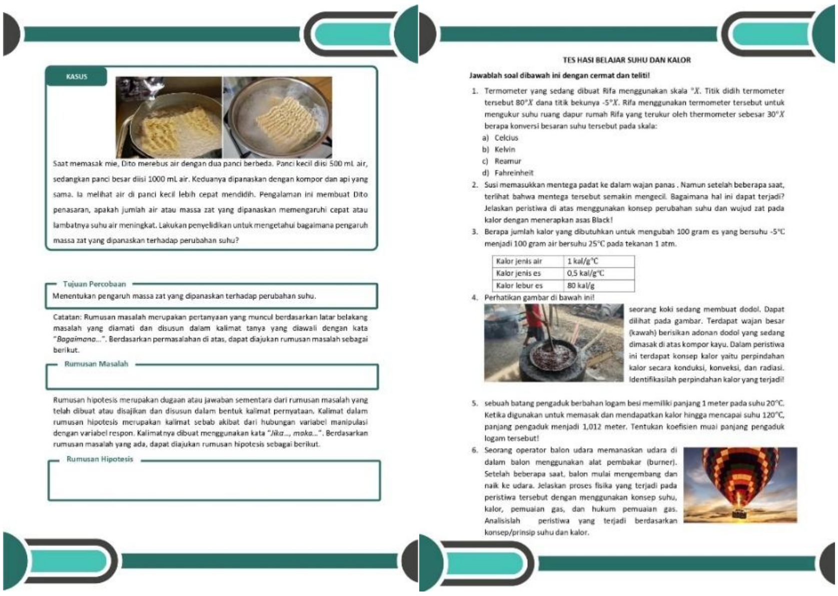


Figure 3 Content

The student worksheet design is based on the syntax of scientific process skills to develop systematic scientific thinking. This student worksheet includes components such as problem objects, problem formulation, hypothesis formulation, variable identification, analysis columns, and conclusion drawing, as shown in Figure 3.



KASUS

Saat memasak mie, Dito merebus air dengan dua panci berbeda. Panci kecil diisi 500 mL air, sedangkan panci besar diisi 1000 mL air. Keduanya dipanaskan dengan kompor dan api yang sama. Ia melihat air di panci kecil lebih cepat mendidih. Pengalaman ini membuat Dito penasaran, apakah jumlah air atau massa zat yang dipanaskan memengaruhi cepat atau lambatnya suhu air meningkat. Lakukan penyelidikan untuk mengetahui bagaimana pengaruh massa zat yang dipanaskan terhadap perubahan suhu?

Tujuan Percobaan

Menentukan pengaruh massa zat yang dipanaskan terhadap perubahan suhu.

Catatan: Rumusan masalah merupakan pertanyaan yang muncul berdasarkan latar belakang masalah yang diamati dan disusun dalam kalimat tanya yang diawali dengan kata "*Bagaimana...*". Berdasarkan permasalahan di atas, dapat diajukan rumusan masalah sebagai berikut.

Rumusan Masalah

Rumusan hipotesis merupakan dugaan atau jawaban sementara dari rumusan masalah yang telah dibuat atau disajikan dan disusun dalam bentuk kalimat pernyataan. Kalimat dalam rumusan hipotesis merupakan kalimat sebab akibat dari hubungan variabel manipulasi dengan variabel respon. Kalimatnya dibuat menggunakan kata "*Jika..., maka...*". Berdasarkan rumusan masalah yang ada, dapat diajukan rumusan hipotesis sebagai berikut.

Rumusan Hipotesis

TES HASI BELAJAR SUHU DAN KALOR

Jawablah soal dibawah ini dengan cermat dan teliti!

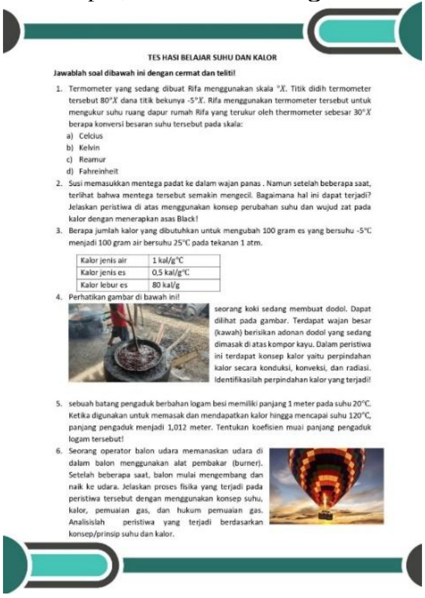
1. Termometer yang sedang dibuat Rifa menggunakan skala °X. Titik didih termometer tersebut 80°X dana titik bekunya -5°X. Rifa menggunakan termometer tersebut untuk mengukur suhu ruang dapur rumah Rifa yang terukur oleh thermometer sebesar 30°X berapa konversi besaran suhu tersebut pada skala:
   a) Celcius
   b) Kelvin
   c) Reamur
   d) Fahreinheit
2. Susi memasukkan mentega padat ke dalam wajan panas . Namun setelah beberapa saat, terlihat bahwa mentega tersebut semakin mengecil. Bagaimana hal ini dapat terjadi? Jelaskan peristiwa di atas menggunakan konsep perubahan suhu dan wujud zat pada kalor dengan menerapkan asas Black!
3. Berapa jumlah kalor yang dibutuhkan untuk mengubah 100 gram es yang bersuhu -5°C menjadi 100 gram air bersuhu 25°C pada tekanan 1 atm.

Kalor jenis air	1 kal/g°C
Kalor jenis es	0,5 kal/g°C
Kalor lebur es	80 kal/g

4. Perhatikan gambar di bawah ini!
   seorang koki sedang membuat dodol. Dapat dilihat pada gambar. Terdapat wajan besar (kawah) berisikan adonan dodol yang sedang dimasak di atas kompor kayu. Dalam peristiwa ini terdapat konsep kalor yaitu perpindahan kalor secara konduksi, konveksi, dan radiasi. Identifikasilah perpindahan kalor yang terjadi!
5. sebuah batang pengaduk berbahan logam besi memiliki panjang 1 meter pada suhu 20°C. Ketika digunakan untuk memasak dan mendapatkan kalor hingga mencapai suhu 120°C, panjang pengaduk menjadi 1,012 meter. Tentukan koefisien muai panjang pengaduk logam tersebut!
6. Seorang operator balon udara memanaskan udara di dalam balon menggunakan alat pembakar (burner). Setelah beberapa saat, balon mulai mengembang dan naik ke udara. Jelaskan proses fisika yang terjadi pada peristiwa tersebut dengan menggunakan konsep suhu, kalor, pemuaian gas, dan hukum pemuaian gas. Analisislah peristiwa yang terjadi berdasarkan konsep/prinsip suhu dan kalor.

Figure 4 Display of student worksheet and learning outcome tests

The learning outcome test used in this study consists of six questions. Each question is designed to be relevant to the context and concepts that students have learned through the learning materials and activities in their study worksheet. Thus, the exam questions are closely related to prior learning and do not deviate from the examples and exercises students have completed. This aims to objectively and proportionally measure the level of understanding and mastery of concepts, as shown in Figure 5.



TES HASI BELAJAR SUHU DAN KALOR

Jawablah soal dibawah ini dengan cermat dan teliti!

1. Termometer yang sedang dibuat Rifa menggunakan skala °X. Titik didih termometer tersebut 80°X dana titik bekunya -5°X. Rifa menggunakan termometer tersebut untuk mengukur suhu ruang dapur rumah Rifa yang terukur oleh thermometer sebesar 30°X berapa konversi besaran suhu tersebut pada skala:
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Figure 5 The learning outcome test

The module design reflects the guided inquiry syntax, which consists of stages such as problem identification, hypothesis formulation, experimental implementation, data processing, and conclusion drawing. Each part of the module is designed to help students build conceptual understanding through exploratory and reflective activities. In addition to providing material descriptions, the module includes student worksheets that guide students in conducting experiments and empirically investigating the relationship between temperature and heat. The visual illustrations and interactive displays in the module are designed to be attractive and motivate students to be actively involved in the learning process. This design aligns with the principle of guided inquiry, which emphasizes the teacher's role as a facilitator rather than the sole provider of information, enabling students to construct their own knowledge.

The learning outcome test design was also prepared in accordance with competency achievement indicators, covering aspects of knowledge, understanding, and application of temperature and heat concepts. This aimed to measure the module's effectiveness in improving learning outcomes after students completed the inquiry process. According to Widiarini et al., (2025), instructional media design integrated with an inquiry approach can develop critical thinking skills and improve learning outcomes because students are directly involved in the scientific process independently. Thus, the product design in this study focuses not only on the presentation of material but also on creating meaningful learning experiences in which students actively build their understanding of the concepts of temperature and heat through guided inquiry activities.

The development stage then produced teaching modules that had been validated by two academic validators and one practitioner validator. Based on the validation results, the module was declared suitable for use. Validation of the developed teaching module showed an average indicator score of 3.47, which is classified as highly valid. Validation of the Learning Outcome Test obtained an average score of 3.54, which is classified as highly valid (Aufa et al., 2021). The validity results of the teaching modules are presented in Table 1.

Table 1 Validity and reliability of teaching modules

Aspect	**Validity**		**Reliability**	
	Value	**Category**	**Value**	**Category**
General Information	3.88	Highly valid	0.68	High
Core Component	3.36	Valid		
Attachment details	3.17	Valid		
Average	3.47	Highly valid		

The validity results of the learning outcome test are presented in Table 2. Based on the detailed results, the general information aspect received a score of 3.88 with a rating of highly valid, indicating that the module has a high level of clarity in the introduction, learning objectives, and relevance of the material to basic competencies. The core component aspect received a score of 3.36 and a valid rating, indicating that the structure of the material presentation, inquiry activities, and learning steps is logically and systematically designed. The detailed attachment aspect scored 3.17, also in the valid category, indicating that supporting sections such as practice questions and student worksheets are appropriate but could still be improved. The reliability value of 0.68 is in the high category, indicating that the consistency of the assessment results between validators is quite stable. These findings reinforce that the teaching modules produced are suitable for implementation in the learning process, as they meet the criteria and demonstrate consistency across the assessment instruments.

Table 2 Validity and reliability of the learning outcome test

No.	Assessment Aspects	Validity Score	Category
1	Instructions for use are clearly stated	3.48	Highly valid
2	Questions in line with learning objectives	3.92	Highly valid
3	Clear scoring guidelines	3.25	Valid
4	Score Compatibility	3.40	Valid
5	The sentence does not give rise to multiple interpretations.	3.66	Highly valid
6	The question of using clear questions or commands	3.81	Highly valid
7	Time required to complete the questions	3.62	Highly valid
8	Using correct Indonesian language rules	3.18	Valid
9	Using language that is easy to understand	3.33	Valid
10	Questions suitable for measuring students' cognitive level	3.74	Highly valid
	Average validity	3.54	Highly valid
	Reliability	0.85	Very High

Furthermore, the validation results for the learning outcome test showed an average score of 3.54, considered highly valid, and a reliability of 0.85, considered very high. This means that the developed validation instrument is highly clear, appropriate for the learning objectives, and can accurately measure students' cognitive level. The aspects with the highest scores, namely “questions are in line with learning objectives” (3.92) and “use clear questions or commands” (3.81), indicate that the questions used are truly relevant and easy for students to understand. This is important so that the test results can represent the students' actual scientific thinking abilities, as emphasized in the guided inquiry approach, which emphasizes active and reflective involvement in the thinking process (Aufa et al., 2021; Handayani et al., 2025; Shandra & Movitaria, 2022 ; Widya et al., 2025).

The module's practicality was assessed through observations of the learning process over three meetings, reflecting the educators' ability to implement each phase of the guided inquiry model. The data from observations of the implementation of the lesson plans for the first to third meetings are presented in Table 3.

Table 3 Assessment of lesson plan observation scores

	Meeting 1		Meeting 2		Meeting 3	
Phase	Value (%)	Category	Value (%)	Category	Value (%)	Category
1	94	VP	96	VP	98	VP
2	88	VP	88	VP	100	VP
3	94	VP	94	VP	94	VP
4	88	VP	88	VP	100	VP
5	83	VP	79	P	92	VP
Average	89	VP	89	VP	97	VP
		Practicality			92	VP
		Reliability			0.67	High
		Category				VP

Description: VP = Very Practical, P = Practical

The results of the observation show that the average implementation of each phase of the guided inquiry model falls within the very practical category, with an overall practicality score of 92%, indicating that teachers can easily implement all stages of learning in line with the flow designed in the module. The observation reliability value of

0.67 also indicates a high level of consistency in assessing implementation between meetings. The increase in scores from the first meeting (89%) to the third meeting (97%) shows that teachers and students are becoming more familiar with the guided inquiry-based activity flow. This statement is in line with the views of Bannang et al. (2023) and Nuraini et al. (2020), who state that the practicality of learning tools can be observed from the extent to which educators can apply them consistently in real classroom situations.

The implementation stage measured the effectiveness of the teaching module by assessing improvements in students' scientific process skills, supported by student learning outcomes. Students were given a pre-test before using the teaching module and a post-test after using it. The pre-test and post-test questions were given to 33 students in class XI-C at SMA Negeri 1 Angsana. The following are the results of the calculation of the teaching module's effectiveness, as measured by the learning outcome tests. The following are the results of the learning module effectiveness calculations measured through learning outcome tests, presented in Table 4.

Table 4. Pre-test and post-test cognitive scores of students

Indicator	Average Pre-test	Average Posttest	N-Gain	Category
Question 1	0.93	88.34	0.57	currently
Question 2	0	71.09		
Question 3	6.75	41.60		
Question 4	14.47	69.36		
Question 5	7.69	61.88		
Question 6	4.54	36.28		
Question 7	12.12	98.91		
Question 8	16.66	57.07		
Question 9	8.58	21.96		
Average	**7.97**	**60.72**		

Beyond mere descriptive percentages, a deeper statistical interpretation of the learning outcomes reveals critical patterns. Prior to executing inferential statistics, normality assumption testing verified that the pre-test (W=0.942, p= 0.081)and post-test (W=0.951, p= 0.124) distributions did not deviate significantly from normality, satisfying the criteria for parametric evaluation. The instructional intervention yielded an average gain (Ngain) of 0.57, representing a moderate progression in student proficiency. To measure the practical significance of this shift beyond standard hypothesis testing, an effect size analysis was conducted, yielding a Cohen's value of 1.15. According to standard statistical decision criteria, this indicates a remarkably large educational effect size, demonstrating that the guided inquiry module exerted a strong, reproducible impact on students' cognitive performance despite the limited sample size.

A deeper, critical evaluation of the students' post-test performance reveals that the cognitive gains are highly stratified when mapped across Bloom's cognitive taxonomy. The guided inquiry module successfully drove significant mastery at the lower-order cognitive levels, specifically Remembering (C1), Understanding (C2), and Applying (C3), as the structured inquiry steps allowed students to internalize fundamental definitions. However, a localized cognitive bottleneck occurred at the higher-order levels, precisely Analyzing (C4) and Evaluating (C5). This sharp drop in higher-order proficiency is directly tied to the inherently abstract character of temperature and heat concepts. Unlike mechanics, thermal dynamics requires students to mentally visualize microscopic kinetic energy transitions and latent heat exchanges that cannot be observed with the naked eye. When this abstract nature is coupled with complex mathematical formulations, students encounter severe cognitive overload.

Furthermore, this outcome exposes an inherent limitation in the module's experimental design; while the inquiry syntax effectively guides qualitative conceptual discovery, the module lacks adaptive mathematical scaffolding. It assumes students possess fluent baseline algebraic skills, thereby failing to provide step-by-step guidance for isolating variables in thermal equilibrium formulas (such as Black's Principle). Consequently, future iterations of the module must integrate dedicated mathematical bridging tools within the quantitative observation sheets to fully translate conceptual understanding into advanced high-order problem-solving

The developed module serves as a self-learning guide that systematically leads students through the scientific stages, starting with problem identification, formulation of tentative assumptions (hypotheses), conducting experiments, processing data, and concluding. In the context of physics learning, this module helps students actively build knowledge through empirical experiences, rather than simply receiving information. According to Hartini & Miriam (2018), a good module not only presents material but also guides students to construct concepts independently through scientific thinking activities. Meanwhile, Izzati and Wiratama (2025) emphasize that the module's effectiveness is evident in students' development of the ability to achieve the learning objectives after using the teaching materials. In this study, the module plays a key role in developing process skills, as guided inquiry enables students to obtain and process data, make observations, and independently interpret physical phenomena.

Theoretically, the guided inquiry model is based on the constructivist approach, in which learners actively construct knowledge through their engagement with and interaction with their learning environment (Pramana et al., 2024). Mardiyanti & Jatmiko (2022) argue that guided inquiry learning models emphasize students' active involvement in discovering concepts, thereby making the learning experience more meaningful. These results are consistent with studies by Listiani et al. (2022), which indicate that using a guided inquiry approach in physics learning can improve students' scientific thinking skills and learning outcomes, as it encourages students to observe, experiment, and draw conclusions based on real evidence.

Research by Feliyawati et al. (2022) shows a significant increase in learning outcomes following the implementation of the guided inquiry model. Before learning, most students encountered obstacles in understanding the concept of heat transfer due to a lack of direct experimental experience. However, after participating in guided inquiry-based learning, students showed improved ability to relate theoretical concepts to real-world events, understand the processes of conduction, convection, and radiation, and explain relationships among variables in experiments. These results confirm that guided inquiry-based learning can improve learning outcomes while enriching the learning experience through meaningful scientific investigation activities.

Research by Sahidu & Harjono (2022) found that implementing guided inquiry-based learning tools can significantly improve learning outcomes. Students demonstrated a better understanding of complex physics concepts because they were involved in acquiring knowledge through guided scientific activities. In addition, the developed tools increased students' motivation to learn by providing opportunities to experiment and discuss actively. This study confirms that learning tools that implement a guided inquiry approach are effective in improving both the quality of the learning process and science learning outcomes.

A previous study showed that groups of students who learned using the guided inquiry model achieved significant improvements in their ability to observe, formulate problems, design experiments, and interpret experimental results. Statistical analysis shows a significant difference between the experimental and control classes in both process skills and cognitive achievement. This improvement indicates that guided inquiry-based learning is capable of and effective at fostering scientific thinking and conceptual understanding, as students engage in logical reasoning, problem-solving, and drawing conclusions based on empirical evidence. The guided inquiry-based module in this study serves not only as a learning tool but also as a learning framework that facilitates student involvement in scientific exploration and problem-solving.

The students' learning outcomes are shown in Table 3. Based on this data, the pre-test and post-test scores are shown. When taking the pre-test, some students were only able to write down the known information and the questions, some wrote down only the equations, and some did not understand the questions, resulting in difficulty determining the appropriate formula to solve the problem. The scores increased from the pre-test to the post-test. In the pre-test, students were not yet able to analyze results and explain phenomena using physics concepts. Meanwhile, the post-test scores increased among students. This improvement is because, in each meeting, students are expected to learn to collect data, process it, and search for information scientifically to find answers to a problem.

The average post-test scores indicate that the majority of students achieved or exceeded the school's minimum passing grade (KKM) of 70. Ten students achieved the KKM, while 23 remained below it. Based on the analysis results, this achievement was influenced by both internal and external factors. Questions 3, 6, 8, and 9, which had post-test scores below the MOC, showed that the indicators tested were still difficult for students to understand. This could be due to low calculation skills, errors in choosing formulas, or a lack of practice in experiments related to these indicators. Conversely, questions 1, 2, 4, 5, and 7, with scores exceeding the KKM standard, indicate that students understand the basic concepts and can relate them to contextual phenomena after using the module. During the learning process over three meetings, some students had difficulty calculating data, understanding formulas, and applying them, especially when completing guided exercises. The physics teacher revealed that several students still faced obstacles in interpreting physics concepts and completing calculation questions. Therefore, continuous reinforcement of the material is needed (Karlina et al., 2019; Rafiah et al., 2018). Overall, the analysis of the N-Gain test results indicates a moderate increase in learning outcomes. This indicates the effectiveness of using the guided inquiry model's temperature and heat module in supporting students in achieving learning objectives. The module can be considered effective if it produces outcomes aligned with the learning objectives (Hartini & Miriam, 2018; Izzati & Wiratama, 2025).

The effectiveness of the teaching module developed in this study is influenced not only by the quality of the material presented but also by the learning approach on which it is based, namely the guided inquiry model. Theoretically, this model is based on the constructivist perspective, which asserts that learners actively acquire their own knowledge through meaningful learning experiences. In inquiry-based learning, teachers serve as guides, providing support and direction so that students can acquire scientific concepts on their own. Through this approach, learning activities are not focused solely on the teacher's role but also provide opportunities for students to develop their thinking, conduct research, and independently draw conclusions from their observations. This explains why N-Gain scores increased after the use of guided inquiry-based teaching modules: students gained direct experience discovering concepts through scientific exploration and reflection.

The developed teaching module serves as an important medium for active learning, guiding students systematically through each stage of inquiry, from problem formulation to conclusion drawing. This module not only presents information but also guides students to think scientifically through experiments and exercises grounded in contextual problems.

According to the learning theory proposed by Joyce and Weil (2011), the effectiveness of a learning model is largely determined by the alignment among the strategies used, the learning tools designed, and students' involvement in learning activities. In this study, the module connects these three aspects, making learning more focused and efficient.

These findings are in line with research by Mardiyanti & Jatmiko (2022), which demonstrates that guided inquiry learning improves learning outcomes by training students to think critically, observe, and analyze data systematically. The teaching module further strengthens the effectiveness of this model by providing learning activities that guide students to conduct scientific investigations independently but in a focused manner. Through a combination of the inquiry approach and contextual module design, students can relate theory to direct experience, thereby improving conceptual understanding and learning outcomes.

The teaching modules developed play a significant role in improving learning outcomes by providing a systematic guide for implementing the stages of guided inquiry. These modules help students actively engage in the scientific process, encouraging them to discover physics concepts for themselves and fostering critical and reflective thinking skills. The integration of the module structure, experimental activities, and teacher guidance makes the learning process more meaningful and effective in achieving learning objectives (Rafiah et al., 2018). In addition, the guided inquiry model significantly improved learning outcomes in both cognitive aspects and skill development (Karlina et al., 2019).

Rather than merely restating the statistical increase, a critical interpretation of the data reveals an underlying cognitive bottleneck. The transition from abstract thermodynamics concepts to formal calculation remains a primary hurdle for students. This finding aligns with international literature, which demonstrates that while inquiry structures enhance qualitative conceptual mental models, they do not automatically remediate deep-seated algorithmic mathematical deficits. The theoretical implications of this study suggest that modular physics designs must intentionally couple inquiry syntax with mathematical scaffolding. Practically speaking, for physics teachers, these findings serve as a strategic template: the module effectively reduces teacher delivery fatigue during conceptual phases (as shown by the 92% practicality rate), allowing educators to reallocate instructional time to guiding lower-performing students through complex problem-solving. To prevent overgeneralization beyond the sample context, it must be acknowledged that these outcomes are tied to an intact, rural classroom environment with specific socio-demographic variables, and should be viewed as a foundational baseline rather than an absolute universal law

CONCLUSION

In conclusion, this study synthesizes key insights regarding instructional development by demonstrating that the Temperature and Heat Guided Inquiry Module is highly valid (3.47), exceptionally practical (92%), and moderately effective (N-gain = 0.57) in advancing high school physics learning outcomes. However, an explicit limitation of this study is its narrow sample scope, confined to a single intact classroom within a specific regional school, and the lack of a true randomized control group, which limits broader generalizability. Consequently, future research recommendations include executing large-scale, randomized quasi-experimental trials across diverse institutional settings. Additionally, longitudinal studies are recommended to monitor the long-term retention of inquiry-acquired concepts and to test the module’s efficacy when paired with adaptive digital scaffolding.

Ultimately, the distinct scientific contribution of this research to the field of physics education is the empirical validation of an instructional design that successfully operationalizes active inquiry within a self-contained modular framework. This study proves that a structured inquiry module can effectively drive substantial cognitive growth in thermodynamics without requiring sophisticated laboratory infrastructure. By providing a concrete, low-resource pedagogical template, this research offers a replicable solution for physics educators and curriculum developers striving to bridge the gap between abstract conceptual discovery and measurable learning outcomes in marginalized or resource-limited school ecosystems.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

In this study, the first author (SSNRRRH) was responsible for study design, data collection, initial manuscript drafting, and data analysis. The second author (SM) reviewed the methodology, literature review, data collection procedures, and analysis process. The third author (MM) edited and reviewed the final version of the article. All authors have read and approved the final manuscript.

AI DISCLOSURE STATEMENT

The author used Google Scholar to identify and retrieve relevant reference sources, Google Translate to assist with language translation, and Grammarly to improve the clarity and grammatical accuracy of the English. All translated and edited text was carefully reviewed by the author, who takes full responsibility for the accuracy, integrity, and content of the published article. Furthermore, this manuscript was conceived, researched, written, and revised without the use of artificial intelligence (AI) technologies or AI-assisted writing tools.

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