

Building an Understanding of the Concept of Heat Through the Implementation of Guided Inquiry Learning with Formative Assessment

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Article Info	Abstract
Article history: Received: January 27, 2026 Accepted: March 27, 2026 Published: May 3, 2026 Keywords: Formative assessment Guided Inquiry Heat Understanding This article is licensed under a Creative Commons Attribution-Share Alike 4.0 International license © 2026 Jurnal Ilmiah Pendidikan Fisika	The students' understanding of temperature, heat, and thermal equilibrium remains inadequate, necessitating an educational strategy to enhance their scientific understanding. This study seeks to enhance students' understanding of concepts by employing guided inquiry learning in conjunction with formative assessment on thermal material. The research employed a mixed methods strategy, utilizing quantitative data from concept understanding exams and qualitative data from interviews. Quantitative analysis encompassed descriptive statistics, normalized gain (N-Gain) computations, and independent samples t-tests, and qualitative data was examined through content analysis methodologies. The study's results indicated a significantly greater enhancement in conceptual understanding in the experimental group relative to the control group. The N-Gain value for the experimental group was 0.69 (moderate category), but the control group attained just 0.25 (low category). The data satisfy the statistical requirements, specifically normal distribution ($\text{Sig} > 0.05$) and homogeneity ($\text{Sig} = 0.406$). The t-test results indicated a significant difference between the two courses ($t = 73.761$; $p < 0.001$), demonstrating that guided inquiry learning with formative evaluation substantially enhances conceptual understanding. This study's theoretical implications suggest that integrating guided inquiry learning with formative assessment can enhance students' conceptual understanding through scientific investigations and ongoing feedback. The finding corroborates the constructivist approach, which underscores the significance of active learning experiences and cognitive interactions in fostering a more precise and comprehensive conceptual understanding.
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INTRODUCTION

Students' understanding of the concepts of temperature, heat, and thermal equilibrium remains inadequate and constitutes a prevalent conceptual challenge in physics teaching. Previous research indicates that students across different educational levels continue to struggle with differentiating between temperature and heat, comprehending the flow of heat energy, and articulating the concept of thermal equilibrium in scientific terms ([Kibirige, 2021](#); [Masara et al., 2024](#); [Robertson et al., 2023](#)). Students' comprehension of thermal equilibrium remains inadequate ([Masara et al., 2024](#)). This indicates that the fundamental concept of heat transport is frequently misconstrued ([Brundage et al., 2024](#)). Students frequently conflate temperature with heat, presuming that items with elevated temperatures possess greater energy ([Brown & Singh, 2021](#); [Muliyani et al., 2024](#)). Challenges in comprehending the notions of heat and temperature are evident not only in junior high and high school but also at the university level ([Erceg et al., 2021](#); [Kotsis et al., 2023](#); [Stylos &](#)

[Kotsis, 2023](#)). At the junior high school level, the prevalence of misconceptions regarding heat and temperature is estimated to be significantly high, ranging from 40% to 93% in terms of comprehension of fundamental concepts related to temperature, heat, and energy transfer ([Kibirige, 2021](#)). This indicates that comprehension of the idea of heat remains extensive and requires a more suitable educational methodology. Field conditions indicate that physics education predominantly emphasizes material completion and lecture-based instruction, leading students to memorize formulas without a profound comprehension of the underlying concepts ([Brundage et al., 2024](#)). Consequently, meaningful conceptual understanding fails to develop.

However, the majority of prior research has predominantly emphasized a singular learning methodology, such as guided inquiry devoid of ongoing formative evaluation or formative assessment lacking organized scientific inquiry activities. This research has not yet concurrently combined both approaches to directly and thoroughly address conceptual misunderstandings. This study effectively combines guided inquiry with formative assessment, enabling students to engage actively in the investigative process while receiving ongoing feedback that aids in rectifying reasoning errors at each learning stage. This combination is anticipated to yield more robust, stable, and enduring conceptual transformations than a singular strategy.

One strategy that might be employed is the implementation of a guided inquiry learning model. This methodology enables students to actively participate in the discovery and construction of concepts through scientific activities, including orientation, conceptualization, investigation, conclusion, and discussion ([Pedaste et al., 2015](#)). Guided inquiry can markedly enhance conceptual comprehension ([Hidayat et al., 2022](#); [Triyanti, 2022](#)). This guided inquiry paradigm enhances students' autonomous conceptual understanding ([Aulia et al., 2022](#)), while inquiry activities promote scientific argumentation abilities ([Septiya et al., 2023](#)). A structured inquiry approach can assist students in comprehending abstract ideas, such as heat and heat energy transmission ([Harefa & Yurnetti, 2023](#); [Puspitasari & Setiaji, 2023](#); [Rahayu et al., 2022](#); [Susilawati et al., 2021](#); [Jacalan & A. Castillo, 2023](#)). The implementation of the inquiry model with reflection can facilitate and enhance profound conceptual comprehension ([Doucette et al., 2022](#)). Moreover, inquiry syntax offers a structural framework that enhances conceptual thinking by integrating educator discourse and student reflection ([Planinic et al., 2024](#)). Consequently, directed inquiry is deemed pertinent for the examination of heat-related subjects necessitating comprehensive research and conceptual analysis.

The educational process requires formative assessment to gauge learners' understanding, identify their deficiencies, and address misconceptions before advancing the lesson ([Ramadhani, 2021](#)). Formative evaluation can markedly enhance comprehension of physics subjects, as students obtain immediate feedback and can progressively rectify their responses. Formative assessment can enhance scientific reasoning and facilitate a more consistent understanding of concepts among students ([Asfiya et al., 2024](#); [Lichtenberger et al., 2024](#); [Nabila & Wahyuni, 2020](#); [Pals et al., 2023](#); [Putri et al., 2021](#)). These findings suggest that combining guided inquiry with formative assessment may enhance students' understanding of heat concepts. Formative assessment assistance in education can enhance students' understanding and guarantee alignment between the concepts acquired and the accurate notions ([Jufriadi et al., 2024](#)). During each inquiry phase, formative assessment is used to identify errors and provide targeted feedback. Through this method, students can progressively rectify flaws in their understanding and connect it with accurate scientific conceptions ([Jufriadi et al., 2025](#)). Learning that integrates these components facilitates an investigative process and provides continual feedback, enabling students to develop a deeper knowledge.

This study seeks to evaluate the efficacy of guided inquiry learning combined with formative assessment on students' comprehension of heat concepts. This study aims to address inadequate conceptual understanding and limited investigative activities in physics education, particularly in the areas of temperature and heat, by implementing inquiry-based learning alongside ongoing feedback. The findings of this study are anticipated to serve as a reference and an alternative educational model that aligns with the requirements of scientific and physics instruction in schools and may be utilized to enhance the quality of the learning process and students' conceptual understanding.

METHODS

This research employs a mixed-methods approach using a convergent parallel design, in which quantitative and qualitative data are concurrently gathered, analyzed independently, and subsequently integrated to achieve a more complete understanding of the impact of guided inquiry and formative assessment on students' conceptual understanding ([Charli et al., 2022](#); [Creswell & Inoue, 2025](#); [Younas et al., 2023](#)). Figure 1 shows the research design.

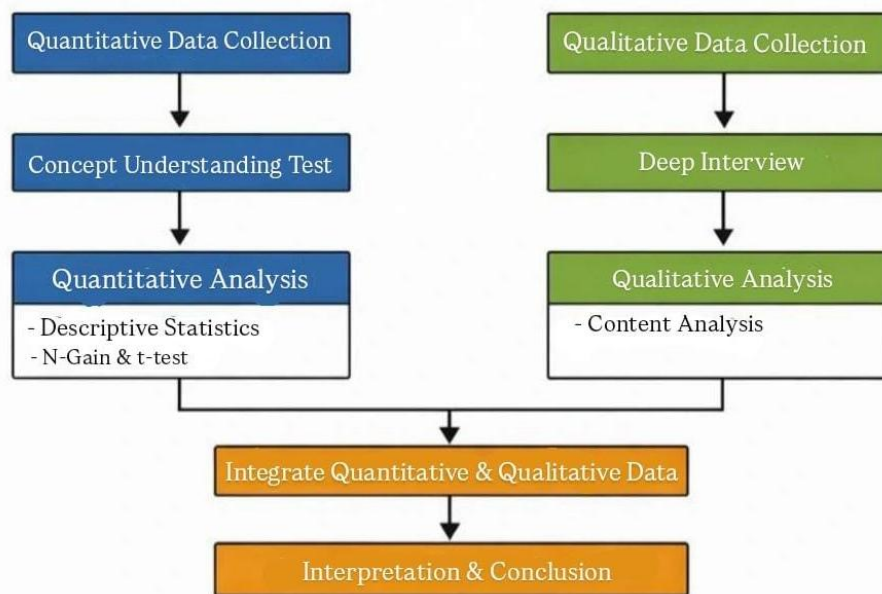


Figure 1 Convergent parallel design

The research was conducted in the seventh grade at SMPN 12 Malang, with 48 students (25 males and 23 females) allocated to the experimental and control groups. The sampling method employed was purposive sampling, predicated on (1) the characteristics of the subjects, specifically the students' preparedness for inquiry-based learning; (2) class attributes, including learning dynamics and levels of student engagement; (3) the accessibility of educational resources, particularly the digital devices required for formative assessments; and (4) the appropriateness of the curriculum, as the chosen classes were engaged in the study of temperature, heat, and Black's Principle, aligning with the research intervention's focus. After evaluating these four factors, the chosen classes were deemed the most representative and pertinent for collecting data aligned with the research aims. The research tools included a concept understanding assessment and in-depth interviews. The assessment was constructed utilizing five indicators of conceptual understanding as per ([Staberg et al., 2023](#)). The instrument comprised 20 questions on temperature and heat. The instrument grid is presented in Table 1.

Table 1 Grid for assessing conceptual comprehension

Concepts measured by the test	Question Number
Conceptual Recognition	1, 2, 11, 12
Conceptual Differentiation	3, 4, 13, 15
Energy-Flow Reasoning	5, 6, 15, 16
Thermal-Equilibrium Analysis	7, 8, 17, 18
Conservation-of-Heat Application	9, 10, 19, 20

This grid guarantees that every item is congruent with the research material and represents the construct being measured.

In several studies on low conceptual understanding among students, the first step was to administer a pretest to the experimental and control classes to assess their initial abilities and identify their understanding of temperature and heat ([Masara et al., 2024](#)). To support the investigative process and provide feedback at every learning level, the experimental class then underwent guided learning in conjunction with formative assessment ([Hidayat et al., 2022](#); [Lichtenberger et al., 2024](#); [Ramadhani, 2021](#); [Triyanti, 2022](#)). Conventional instruction was given to the control group in the meantime. A posttest measuring improvement in conceptual comprehension was administered to both classes following the therapy, and interviews with several students in the experimental class were conducted to support the quantitative findings. To make the research flow understandable and methodical, the full series of processes was condensed into a research procedure chart.

In the quantitative section, this study used a pretest and a posttest in both the experimental and control classes to assess improvement in concept understanding after learning. However, the main design of this study still used a convergent parallel mixed-methods approach, namely the simultaneous collection of quantitative and qualitative data, separate analysis, and their combination at the final stage to obtain a more complete picture of the results. Observations were conducted in four stages: initial interviews, pretests, posttests, and final interviews, with learning treatments administered only to the experimental class. The research design is shown in Figure 2.

Experiment	O ₁	O ₂	X	O ₃	O ₄
Control	O ₁	O ₂	-	O ₃	O ₄

Figure 2 Research design

Description

O₁ = Initial Interview

O₂ = Pretest

X = Treatment (guided inquiry learning with formative assessment)

- = No Treatment

O₃ = Posttest

O₄ = Final Interview

The experimental class's and control class's research designs are shown in Figure 2. While the control group received conventional education, the experimental group received guided inquiry learning combined with formative assessment (X). In addition to pre-tests and post-tests (O₂ and O₃) to measure the growth in conceptual understanding, both the experimental and control groups completed introductory and final interviews (O₁ and O₄) as supporting evidence.

The degree to which each item correlated with the overall instrument score was determined using the corrected item-total correlation to test the validity of the instruments

used in this study. According to [Nunnally's \(1978\)](#) standards, an item is deemed to be of appropriate quality if its item – total correlation value falls within the range of ≥ 0.30 . This implies that the item makes a considerable contribution to the construct being measured. According to Nunnally, an item's suitability for the instrument as a whole is indicated by a correlation value above 0.30, whereas a value below this threshold suggests that the item does not sufficiently represent the construct and tends to have weak measurement power. The original concept comprehension test, consisting of 30 multiple-choice questions, was created using five markers for idea understanding. The instrument's validity was then assessed using corrected item–total correlations. According to the test results, 10 items were eliminated, and 20 items with correlation values ≥ 0.30 were deemed valid. After that, the 20 valid items were used as a study tool, consisting of 10 pretest and 10 posttest questions. The validity test results are shown in Table 2.

Table 2 Summary of instrument validity test results

Total Items	Valid	Invalid	Description
30	20	10	20 Instruments are suitable for use

Additionally, the instrument's reliability was evaluated using 20 valid study items, yielding a Cronbach's alpha value of 0.931. This indicates that the instrument is appropriate for assessing students' conceptual comprehension because every item consistently measures the same construct. Table 3 summarizes the dependability findings.

Table 3 Instrument reliability test

Cronbach' Alpha	Total Items	Category
0.931	20	High internal consistency

Descriptive statistics and normalized gain (N-gain) were used to analyze quantitative data and assess the extent of conceptual knowledge increase in the experimental and control groups. The content analysis procedures of data familiarization, coding, topic identification, theme review, and conclusion drawing ([Elo & Kyngäs, 2008](#)) were used to evaluate qualitative interview data. The quantitative findings were supported by this research, particularly regarding how formative assessment and guided inquiry learning affected students' conceptual understanding.

RESULTS AND DISCUSSION

The study's findings are presented to show how students' conceptual understanding changed following their participation in formative assessment and guided inquiry. Pretest and posttest findings, normalized gain (N-Gain) computations, answer pattern distribution, and interview results were used to examine the data. Following that, an integrated discussion of the quantitative and qualitative results was conducted in compliance with the convergent parallel design, ensuring that each finding enhanced the others. To more succinctly and effectively demonstrate improvements in students' conceptual comprehension, the pretest and posttest results were shown side by side. Table 5 compares the two scores. With an average of 46.25 in the experimental class and 48.75 in the control class, the pretest results for both groups were within a similar range. This condition demonstrates that the beginning abilities of the two classes were comparable and fairly matched.

After the learning process, the experimental class's posttest results showed a significantly greater improvement than those of the control group. The experimental class's average posttest score was 84.58, but the control group's score was only 62.00. This improvement suggests that formative assessment combined with guided inquiry can

correct conceptual errors and enhance students' understanding of heat and temperature. Descriptive statistics are shown in Table 4.

Table 4 Descriptive statistics

Group	Mean	Min	Max	SD
Pretest – Experiment	46.25	20	60	10.55
Posttest – Experiment	84.58	70	100	10.20
Pretest – Control	48.75	20	60	11.90
Posttest – Control	62.00	60	90	8.83

Table 4 indicates that the pretest results reveal a predominantly inadequate foundational comprehension of temperature and heat concepts among students in both groups. The experimental class had an average pretest score of 46.25, whereas the control class achieved an average of 48.75. Both scores fall within the low-medium range and exhibit minimal variance, suggesting that the students' starting competencies are reasonably comparable and can serve as a foundation for comparison. Nonetheless, the scores did not adequately reflect a comprehensive grasp of the topics, as a study of the students' responses revealed a pronounced pattern of misunderstanding. Numerous pupils asserted that temperature and heat were identical amounts, leading them to conclude that hotter items inherently possessed greater heat. One student stated, "Heat is equivalent to temperature." "A high temperature correlates with elevated heat." Comparable assertions were made by other students, who stated that "the higher the temperature of an object, the greater its heat, and if it is cold, it must be diminutive." This misconception has been well documented in prior research and typically arises because students perceive heat as a sensation rather than a quantifiable physical entity ([Masara et al., 2024](#)).

After implementing guided inquiry learning, the experimental class showed a marked improvement in conceptual understanding. The posttest average increased to 84.58, significantly surpassing the control class's average of 62.00. The rise in scores not only indicates that students answered questions accurately but also demonstrates a transition towards enhanced scientific reasoning. In the experimental class, students developed the ability to differentiate between the concepts of temperature and heat, recognizing that heat depends on mass, specific heat, and temperature changes. A student remarked, "Temperature and heat are distinct." Objects possess heat. Additional statements demonstrated advancement in comprehension, exemplified by, "The quantity of heat is discerned not solely through temperature differentials but also through mass and temperature elevation." These quotations indicate a substantial conceptual transformation following the learning process. The enhancement of pupils' conceptual comprehension was evaluated using normalized gain calculations. The experimental group achieved a substantially higher N-Gain than the control group, indicating that guided inquiry learning significantly enhances learning efficacy. The results of the N-Gain analysis are presented in Table 5.

Table 5 N-Gain analysis results

Class	N	N-Gain	Category
Experiment	24	0.69	Moderate
Control	24	0.25	Low

In Table 5, the N-Gain classification for the experimental group was moderate, whereas the control group was classified as low. This indicates that inquiry-based learning methodologies and formative evaluation are successful in promoting conceptual transformation. The results demonstrate that learning using guided inquiry-based digital modules significantly enhances conceptual understanding. Guided inquiry enables

students to engage in a systematic investigation process, commencing with observation, hypothesis formulation, experimentation, and concluding with analysis. Formative assessment is employed at each stage to deliver prompt feedback, enabling students to recognize and rectify their reasoning flaws swiftly ([Asfiya et al., 2024](#); [Hidayat et al., 2022](#)).

Normality tests were performed to verify that the N-Gain data in both the experimental and control groups followed a normal distribution before conducting the t-test. Normality tests employed were the Kolmogorov–Smirnov and Shapiro–Wilk tests. The calculated significance values for both classes exceeded 0.05 in the Kolmogorov–Smirnov and Shapiro–Wilk tests. This indicates that the N-Gain data follow a normal distribution, thereby satisfying the necessary assumption for parametric analysis. The findings of the normalcy test are summarized in Table 6.

Table 6 Results of N-Gain normality test

Class	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Description
Experiment	0.169	0.216	Normal
Control	0.200	0.298	Normal

The homogeneity test assesses whether the variation in N-Gain data across both classes is uniform. The Levene test was employed to test. The study yielded a p-value of 0.406 (> 0.05), indicating that the variance in N-Gain data between the experimental and control classes is homogeneous. Consequently, the data meet the criteria for the independent two-sample t-test. Table 7 displays the outcomes of the homogeneity test.

Table 7 Homogeneity test results (Levene test)

Variable	Levene Statistic	df1	df2	Sig.	Description
N-Gain	0.704	1	46	0.406	Homogen

The independent-samples t-test was used to assess differences in conceptual understanding between the experimental and control groups. Given that the data met the assumptions of normality and homogeneity, the t-test was performed using the equal-variance model. The test findings indicated a t-value of 73.761 with a p-value of $p < 0.001$, indicating a highly significant difference between the two classes. The mean N-Gain value of 0.5746 indicates that guided inquiry learning with formative assessment significantly enhances conceptual understanding compared to conventional learning. Table 8 presents a summary of the t-test.

Table 8 Results of the independent t-test for N-Gain

Variable	t	df	Sig. (2-tailed)	Mean Difference	Description
N-Gain	73.761	46	< 0.001	0.57458	Significant difference

The independent-samples t-test results in Table 6 indicate a highly significant difference in understanding between the experimental and control groups. A t-value of 73.761 with a significance of $p < 0.001$ signifies that this variation is not attributable to chance but is indeed a result of the administered learning treatment. The mean N-Gain difference of 0.57458 indicates that guided inquiry learning, when paired with formative assessment, significantly enhances learners' conceptual understanding compared to traditional learning methods. This finding aligns with the research indicating that the inquiry approach fosters an active scientific exploration process, while formative assessment offers effective ongoing feedback to enhance conceptual frameworks ([Hidayat et al., 2022](#); [Lichtenberger et al., 2024](#)). The t-test results indicate a substantial difference,

suggesting that integrating these two methodologies yields more robust, consistent, and profound conceptual transformations than traditional learning.

This study focuses primarily on the interaction among formative assessment, guided inquiry learning, and conceptual understanding. These two independent variables do not operate in isolation; rather, they collaborate to enhance and fortify students' scientific understanding. Guided inquiry provides a structured framework for exploration, while formative assessment delivers ongoing feedback that guides students' cognition throughout the learning process. The amalgamation of these two methodologies yields profound, concentrated, and enduring conceptual transformation. Figure 3 presents a model that completely illustrates the link between these factors.

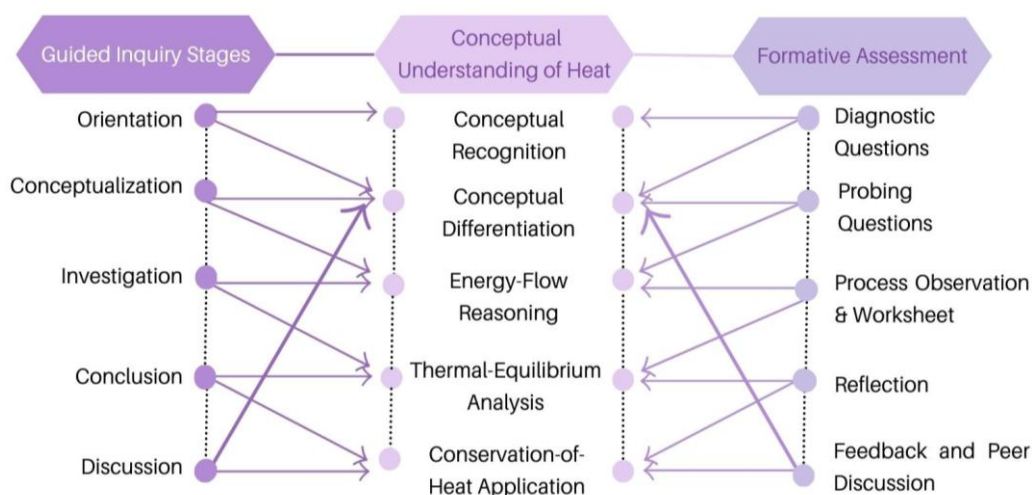


Figure 3 Conceptual framework for integrating guided inquiry and formative assessment in the development of conceptual understanding

Figure 3 illustrates that guided inquiry learning and formative assessment significantly enhance each indication of students' conceptual understanding. The primary pathway employs guided inquiry to facilitate research-based learning experiences encompassing orientation, conceptualization, investigation, conclusion, and discussion activities. These stages assist students in identifying fundamental concepts (conceptual recognition), distinguishing between analogous concepts such as temperature and heat (conceptual differentiation), and comprehending the direction of heat energy transfer through investigative activities (energy-flow reasoning). The inquiry approach helps students study thermal equilibrium phenomena and apply the theory of heat conservation in calculations and practical scenarios (Thermal-Equilibrium Analysis and Conservation-of-Heat Application).

In the supportive structure, formative assessment enhances the learning process by providing ongoing feedback at every step. This feedback helps learners recognize incorrect assumptions, correct reasoning errors, and consolidate the information they have acquired, in alignment with the research indicators. Consequently, formative assessment does not function as an isolated variable; rather, it collaborates with inquiry to ensure that learners' investigative process culminates in accurate understanding.

The amalgamation of these two methodologies subsequently led to a clearer understanding of the idea among students. The N-Gain calculation findings and t-tests indicate substantial differences between the experimental and control groups. This variable relationship model demonstrates that the research's efficacy is rooted in the

integration of guided inquiry with ongoing feedback from formative assessments, which collectively enhance students' conceptual understanding as indicated by the measured criteria. Interviews were undertaken to substantiate the quantitative results and offer a more comprehensive understanding of student cognition. Initially, many students subjectively equated heat with warmth, neglecting the actual variables that influence heat. The stages of guided inquiry, formative assessment, and conceptual findings are listed in Table 9.

Table 9 Stages of guided inquiry, formative assessment, and conceptual findings

Guided inquiry Stages	Formative a Assessment	Concept Findings
Orientation	Diagnostic Questions	Students still equate temperature with heat and associate heat with the amount of heat. <i>"Heat is the same as temperature. If the temperature is high, it means the heat is great."</i>
Conceptualization	Probing Questions	Students begin to realize that temperature and heat are different concepts. <i>"Temperature indicates how hot or cold an object is, whereas heat is different and not the same as temperature."</i> <i>"Temperature indicates how hot or cold an object is, whereas heat is something that transfers."</i>
Investigation	Process Observation & Worksheet	Students discover that heat is energy that transfers and is influenced by mass and temperature changes. <i>"Heat is energy that transfers from a hot object to a cold one, and its amount depends on its mass and temperature increase."</i>
Conclusion	Reflection	Students are able to scientifically conclude the differences between temperature and heat. <i>"Temperature only indicates heat or cold, while heat is energy that is transferred."</i>
Discussion	Feedback & Peer Discussion	Students' understanding becomes more consistent and in line with physics concepts. <i>"An object with a high temperature does not necessarily have a high heat capacity; it depends on its mass."</i>

Table 9 indicates that, during the orientation phase, students continue to conflate the notions of temperature and heat, linking the quantity of heat to the thermal intensity of an object. This preliminary pattern of understanding indicates that students continue to rely on intuitive reasoning derived from everyday experiences and have not yet conceptualized heat as a scientifically quantifiable physical entity, as evidenced by numerous studies addressing incorrect assumptions regarding temperature and heat among students ([Brown & Singh, 2021](#); [Kibirige, 2021](#); [Masara et al., 2024](#)). Subsequent data indicate that using formative assessment-driven guiding questions during the conceptualization phase, students came to recognize that temperature and heat are distinct concepts; this

understanding was not yet entirely consistent. This initial change is in line with research stating that the conceptualization phase in inquiry-based learning plays a role in creating cognitive conflict that drives shifts in students' understanding of physics concepts ([Robertson et al., 2023](#); [Stylos & Kotsis, 2023](#)).

The findings from the investigation phase of the study indicate that students discerned that heat is energy transmitted due to temperature differentials, influenced by variations in mass and temperature, through observational and data analysis activities. This finding corroborates earlier research indicating that guided inquiry learning effectively aids students in developing a scientific understanding of the concept of heat through a systematic investigative process ([Ariza & Widodo, 2022](#); [Hidayat et al., 2022](#); [Puspitasari & Setiaji, 2023](#); [Rahayu et al., 2022](#)). The subsequent study indicates that at the conclusion stage, students can articulate temperature and heat variations with more precision based on the outcomes of the conducted investigation. The reflection process at this stage contributes to the consolidation of conceptual understanding and the stabilization of the students' understanding structure, as highlighted in research regarding the importance of reflection in inquiry learning (Doucette et al., 2022; Planinic et al., 2024). Conceptual understanding is established when students can derive meaning from educational messages, whether presented graphically, orally, or in written form (Ayu et al., 2024). This arises when pupils effectively understand heat as energy that is exchanged, informed by the outcomes of scientific inquiry and discussion.

The research findings at the discussion stage indicate that feedback from educators and peers enhances the understanding of learners, aligning it more consistently with physics ideas, especially concerning the interplay between temperature, heat, mass, and temperature variation. These findings align with research indicating that ongoing formative assessment aids students in rectifying reasoning errors and progressively enhancing their conceptual understanding ([Asfiya et al., 2024](#); [Lichtenberger et al., 2024](#); [Ramadhani, 2021](#)). The findings of this study demonstrate that the amalgamation of guided inquiry learning and formative assessment can transform students' reasoning from intuitive understanding to a more precise and profound scientific understanding, corroborated by research highlighting the significance of inquiry activities and formative feedback in enhancing the grasp of physics concepts ([Jufriadi et al., 2022](#); [Robertson et al., 2023](#); [Staberg et al., 2023](#)).

This study demonstrates that guided inquiry learning significantly enhances students' understanding of concepts related to temperature and heat. The increase in posttest scores, the elevation of N-Gain categories, and alterations in students' responses indicate that the inquiry technique facilitates deeper exploration of concepts. In addition, formative assessment has demonstrated its efficacy in helping students progressively correct their mistakes through feedback delivered at each phase of learning. Formative assessment enables students to develop their understanding more precisely while also allowing for the progressive rectification of conceptual inaccuracies. The alterations in understanding reflected in student quotations and interview findings further substantiate that this methodology enhances cognitive performance and significantly influences the caliber of students' scientific thinking. This study's results reveal a substantial disparity between the experimental and control groups, with the former achieving a superior level of understanding. The implementation of guided inquiry promotes student engagement in the discovery of concepts, leading to a deeper, more enduring comprehension ([Jufriadi et al., 2022](#)). Engaging students as active participants in the inquiry process has been shown to enhance their conceptual understanding substantially. Consequently, guided inquiry learning, when integrated with formative assessment, is a suitable educational option in

junior high school science and physics instruction, particularly for correcting conceptual errors and enhancing understanding of physics concepts.

This study demonstrates considerable improvements in students' conceptual understanding through guided inquiry learning and formative assessment; however, numerous limitations must be acknowledged. The study was conducted at a single school with a restricted sample size; the results cannot be extrapolated to a wider context. Subsequent research should incorporate a greater number of schools with varied student demographics to enhance the external validity of the findings. Secondly, interviews were conducted exclusively with a subset of students from both the experimental and control classes, resulting in qualitative data that does not comprehensively represent the complete population. Future research must increase the participant pool to provide a more comprehensive analysis of conceptual shift patterns and comparisons between the two groups.

Third, time limitations during the learning process precluded an in-depth examination of certain inquiry phases, thereby failing to capitalize on opportunities for broader conceptual development fully. Consequently, subsequent studies should extend the intervention duration or incorporate additional investigative activities to monitor conceptual changes with greater precision. The assessment tools employed were multiple-choice questions focused on the outcomes, which did not fully reflect students' scientific reasoning and argumentation processes. Future research may integrate authentic assessments, including project-based assignments, portfolios, and performance assessments, to achieve a more holistic understanding of students' learning processes. Given these constraints, further study may yield more robust findings and significantly advance guided inquiry learning and formative assessment in physics education.

CONCLUSION

This study demonstrates that integrating guided inquiry learning with formative evaluation effectively enhances students' conceptual understanding of temperature and heat. The quantitative analysis results indicate that the experimental group demonstrated greater improvement than the control group, as evidenced by the N-Gain score and an independent-samples t-test, which revealed a significant difference between the two groups. Qualitative data from interviews with both experimental and control course participants corroborated these findings, demonstrating an enhancement in students' comprehension of the ideas following their engagement in the learning process.

The research objective of assessing the efficacy of integrating guided inquiry learning and formative assessment in enhancing learners' conceptual understanding has been met. This study theoretically enhances the understanding of how structured inquiry activities and ongoing formative feedback facilitate the formation and development of conceptual understanding within the constructivist framework. These findings underscore that combining these two methodologies can help students construct a more precise and coherent conceptual framework. Consequently, guided inquiry learning, supplemented by formative assessment, is a pertinent methodology for implementation in junior high school physics education, particularly for content that requires robust, profound conceptual understanding.

Even though this study shows how well guided inquiry learning and formative assessment work together to enhance students' conceptual understanding, there is still an opportunity for more research. This study was carried out in a particular educational setting, offering a targeted viewpoint on physics instruction in junior high school. To improve comparative viewpoints, future studies might expand the application of this strategy to more varied contexts and educational levels. Furthermore, in order to better investigate

students' thought processes and the durability of conceptual understanding over extended periods of time, future research may use more types of assessment styles.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The first author conceived the research. All authors collaboratively designed the methodology, data collection, and analysis. The primary author composed the initial draft of the piece, whereas the secondary and tertiary authors evaluated, revised, and polished the manuscript to its final form. All authors have reviewed and endorsed the final manuscript.

AI DISCLOSURE STATEMENT

The authors state that the only purpose of the artificial intelligence (AI) tools was to help with grammar checking, language editing, and making academic writing more readable. The writers carried out all conceptual formulation, data analysis, result interpretation, and final conclusions on their own. The integrity and content of this manuscript are entirely the authors' responsibility.

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