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# Investigating Strategies and Best Practices in Teaching Heat and Temperature: a Systematic Review in Science and Physics Education

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**Abstract:** Teaching heat and temperature is a fundamental aspect of science and physics education. This systematic review investigates the strategies and best practices employed in science education and physics education to effectively teach heat and temperature concepts. A comprehensive search was conducted in reputable databases, resulting in the identification of relevant publications published between 2018 and 2023. Content analysis techniques were applied to analyze the selected publications, focusing on the techniques, outcomes, and conclusions presented. The review highlights a diverse range of instructional strategies, such as in-class demonstrations, virtual methods, and computer simulations, utilized to teach temperature and heat concepts. Educators are encouraged to consider these strategies to enhance student understanding. Furthermore, the review provides a valuable compilation of effective teaching practices, serving as a practical resource for educators and researchers in the field of temperature and heat education. Overall, the review emphasizes the necessity for further research on successful teaching approaches in temperature and heat education, offering valuable insights for both researchers and educators.

**Keywords:** Heat and temperature; Strategy and best practices; Systematic review

## Introduction

Teaching heat and temperature holds significant importance in science and physics education as it serves as a foundational knowledge base for understanding thermodynamics and the behavior of matter (Zanoletti & Godard, 2022). Heat and temperature concepts provide essential insights into the transfer of energy, changes in states of matter, and the functioning of various natural phenomena. By comprehending these fundamental principles, students can grasp key scientific principles, such as the laws of thermodynamics, and apply them to real-world scenarios (Kleine et al., 2019; Lai, 2020; Lee, 2018). Furthermore, a solid understanding of heat and temperature is crucial for students who wish to pursue further studies or careers in fields like engineering, chemistry, and environmental science.

The significance of evidence-based teaching strategies cannot be overstated when it comes to enhancing student learning outcomes. Instructional methods play a pivotal role in promoting conceptual understanding among students (Bumbacher et al., 2018; Kurniawan, 2018). By employing evidence-based strategies, educators can effectively engage students and facilitate the acquisition of deep and meaningful knowledge. These approaches are designed to align with cognitive processes and learning principles, ensuring that students are actively involved in constructing their understanding of complex concepts, such as those related to heat and temperature (Banda & Nzabahimana, 2023; Sun & Looi, 2019; Vyas et al., 2021).

Evidence-based teaching approaches have demonstrated a significant impact on student achievement. Research studies have shown that when educators utilize instructional methods grounded in

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evidence, students exhibit higher levels of engagement, improved retention of information, and enhanced problem-solving skills. For instance, inquiry-based learning encourages students to explore and investigate concepts through hands-on activities and inquiry-based questions, fostering a deeper understanding of heat and temperature (Deniş-Çeliker & Dere, 2022). Similarly, the use of interactive simulations and multimedia resources allows students to visualize abstract concepts and make meaningful connections to real-world applications (Ballesta-Claver et al., 2021).

By embracing evidence-based teaching strategies, educators can create an optimal learning environment that supports the diverse needs and learning styles of students (Yousaf et al., 2021). These approaches leverage research and empirical evidence to inform instructional decision-making, ensuring that teaching methods are based on sound pedagogical principles. This not only enhances student learning outcomes in the immediate context but also equips students with the necessary skills and knowledge to succeed in their future academic pursuits and careers (Yavich & Rotnitsky, 2020). Thus, the adoption of evidence-based teaching strategies is crucial for promoting conceptual understanding and achieving positive student learning outcomes in the domain of heat and temperature education (Teig et al., 2020; Vanbecelaere et al., 2020).

The rationale for conducting a systematic review on teaching strategies for heat and temperature stems from the need to identify gaps and inconsistencies in the existing literature. While there have been various studies conducted on heat and temperature education, there may be a lack of comprehensive and cohesive analysis that systematically evaluates the effectiveness of different teaching strategies. By conducting a systematic review, researchers can identify areas where the current literature falls short and where further investigation is needed (Nugraha et al., 2023). This allows for a more comprehensive understanding of the strengths and limitations of existing approaches and provides valuable insights for future research and instructional practices.

Additionally, there is a need for a comprehensive analysis of the effectiveness of different teaching strategies for heat and temperature. While individual studies may have explored specific methods or interventions, a systematic review allows for a broader perspective by synthesizing findings across multiple studies (Chong et al., 2022; Nyirahabimana et al., 2022). By examining a wide range of research articles and publications, researchers can evaluate the overall impact and effectiveness of various teaching strategies (Sibgatullin et al., 2022; Sokhanvar et al., 2021). This comprehensive analysis provides a more robust understanding of which strategies are most effective in enhancing student learning outcomes in the context of heat and temperature education. Moreover, it helps to identify gaps in the research and areas where further investigation is required, thus informing future directions for instructional design and practice in this field.

*Theoretical Framework*

*Constructivism*

This theoretical framework emphasizes that learning is an active process where students construct their own understanding of concepts based on their prior knowledge and experiences (Bakar et al., 2019; Barari et al., 2020). In the context of teaching heat and temperature, constructivism suggests that effective teaching strategies should encourage students to actively engage in the learning process, make connections to their existing knowledge, and construct meaning through hands-on activities, discussions, and problem-solving tasks.

*Cognitive Load Theory*

This framework focuses on the cognitive resources and limitations of learners. It suggests that effective teaching strategies should consider the cognitive load imposed on students' working memory (Zu et al., 2021). In the context of teaching heat and temperature, instructors should aim to present information in a way that minimizes extraneous cognitive load and optimizes germane load (Ardayeni et al., 2019), allowing students to focus on understanding the core concepts without being overwhelmed by irrelevant information or complex instructional design.

*Socio-Constructivism*

This theoretical framework emphasizes the social and collaborative nature of learning. It suggests that knowledge is co-constructed through social interactions and dialogue (Homayouni, 2022). In the context of teaching heat and temperature, socio-constructivism highlights the importance of collaborative learning activities, such as group discussions, peer interactions, and cooperative problem-solving, where students can share their ideas, challenge each other's thinking, and collectively construct a deeper understanding of the subject matter.

*Multimedia Learning Theory*

This framework focuses on the design and use of multimedia materials to enhance learning. It suggests that effective teaching strategies should utilize various media (Dervić et al., 2019), such as visual aids, animations, simulations, and videos, to present information in multiple modalities, promote active engagement (Dervić et al., 2019; Liew et al., 2020), and

facilitate the visualization of abstract concepts related to heat and temperature (Moon & Ryu, 2021).

*Model-Based Instruction*

This theoretical framework emphasizes the use of models as cognitive tools to facilitate understanding (Malone et al., 2018; Wirzberger et al., 2020). It suggests that teaching strategies should involve the use of visual representations, diagrams, and conceptual models to help students develop mental models of heat and temperature phenomena (Batlolona et al., 2020). Model-based instruction encourages students to actively interact with and manipulate the models to make sense of complex concepts and enhance their understanding (Firdaus et al., 2019). By employing these theoretical frameworks in the systematic review, researchers can analyze and interpret the effectiveness of different teaching strategies and best practices in teaching heat and temperature, providing a theoretical lens through which the findings can be understood and contextualized.

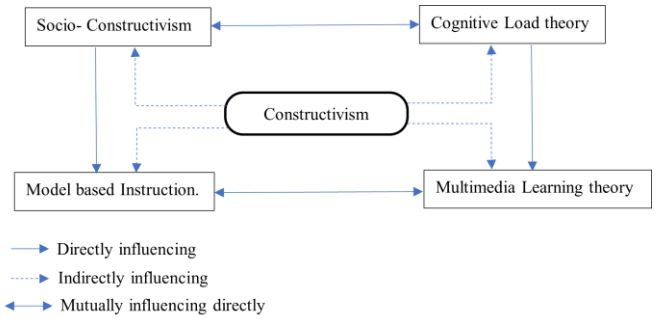


**Figure 1.** Theoretical framework of best practice in teaching

This review investigates the strategies and best practices utilized in science education and physics education intended for imparting heat and temperature concepts effectively.

To facilitate this research, the outcome of studies underway between 2018 and 2023 will serve as the focal point. The data to be discussed include details concerning teaching strategies and best practices utilized in science and physics education for teaching heat and temperature, current developments in the development of research on heat and temperature instructions, and the results and conclusions that were drawn from the reviewed literature in regard to the relationship between different teaching strategies and students' understanding of heat and temperature concepts.

## Method

The present study, which was a systematic review, examined articles from around the globe on the subject of heat and temperature education. The ability to map and summarize the current corpus of knowledge regarding primary research on a particular topic is one of the potential contributions of systematic reviews to the field of research. In systematic reviews, a systematic search strategy may or may not be employed. In this research, it is preferable to employ a systematic review approach. Developing a conceptual framework and formulating research questions are the first two stages in a systematic review.

*The Searching Technique*

The author used terms or combinations of them associated with heat and temperature to search for pertinent literature in the two most prominent databases, Scopus and Web of Science. The document search was restricted to journal articles published between 2018 and 2023 and to journal articles alone.

*The Selection Criteria*

The sources for this article came from Scopus and Web of Science. The 48 documents discovered appeared to be duplicates (see Figure 2). Then, five inclusion criteria were used to evaluate the abstracts and collect relevant studies for this study. First, only journal-published publications were processed. The second focus of the study was on heat, temperature, and their related concepts. The research utilized data from quantitative, qualitative, and mixed method investigations. In addition, the research included an examination of heat and temperature concepts in any subject. The research was carried out within the context of science education and applied science programs.

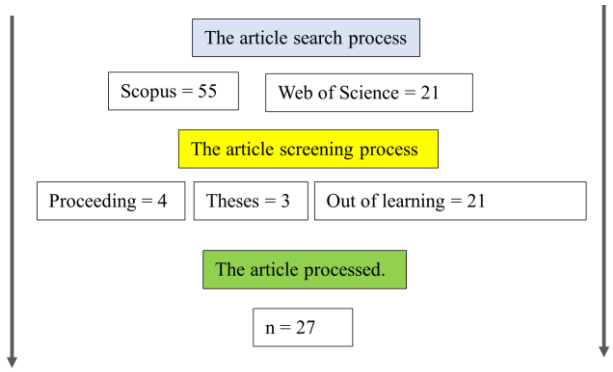


**Figure 2**. The process of determining articles to be reviewed

*Data Analysis*

The author summarized common concerns and themes, then coded and extracted them into a categorization matrix using Microsoft Excel software. In order to fulfill the requirements of the study, the articles were coded and classified according to the following criteria. The analysis began by taking into account the

article's identification details, such as the author's name, country of origin, publication year, and the specific topic addressed. During the article's synthesis, the approach utilized in the learning process was given careful consideration. During the synthesizing process, the research methodology employed in the studies was also considered. These categorizations and considerations were implemented to ensure a thorough analysis of the study's articles.

## Result and Discussion

The results and discussion of this article focus on the learning process in terms of learning models, teaching methods, and learning approaches that are commonly used in teaching the concept of temperature and heat. The discussion will be written in accordance with the order of the research questions presented at the beginning of this article. Table 1 provides an overview of what models are widely used in teaching the concepts of temperature and heat. These models are used at various levels from elementary school to university level.

**Table 1.** The Various Instruction for Heat and Temperature Concept 2018-2023

| Heat and temperature learning model |
|---|
| Model of Assure, Relevance, Interest, Assessment |
| HINT |
| Peer interaction learning |
| Science learning + Islamic values |
| Script laboratory exercise |
| Physics Holo Lab |
| Activity Based Instruction |
| 7E |
| 5E |
| Inquiry Learning |
| Laboratory learning |
| Collaborative learning |
| Virtual laboratory |
| Inquiry based representation |
| POEE |
| Modified Teaching Learning-based Optimization |
| Experimental learning |
| e-learning |
| Game- based learning |
| Research learning |

To answer the trend of using what learning model is most often used by teachers in conveying the concept of temperature and heat, the researchers obtained data in general, the learning trend is divided into five namely inquiry-based learning, laboratory-based, learning cycle-based, virtual learning and collaborative learning. Table 2 shows the 2018-2023 temperature and heat learning trends.

**Table 2.** Trend of Heat and Temperature Instruction 2018-2023

| Type of approach | F | Range of Learning Model Occurrence | | | |
|---|---|---|---|---|---|
| Inquiry | 4 | 2020 | 2020 | 2021 | 2022 |
| Laboratory | 4 | 2018 | 2020 | 2022 | 2023 |
| Teaching learning sequences | 4 | 2019 | 2020 | 2022 | 2023 |
| Virtual | 2 | 2018 | 2021 | - | - |
| Collaborative | 2 | 2018 | 2019 | - | - |

F = frequency

In the 2018-2023 period, there are findings that show some of the most frequently appearing learning models are inquiry (4 times), laboratory (4 times), teaching learning sequences (4 times), virtual (2 times), and collaborative (2 times). This confirms that inquiry-based approaches, laboratory practicum, as well as learning involving collaboration and the use of virtual technology have become significant trends in learning during the period.

These findings provide confirmation that students who are active in constructing their knowledge and experiences will be more effective in any learning (Sri Asmorowati et al., 2021). Furthermore, collaborative learning provides many advantages for students. They feel more involved in the learning process as they can share ideas, discuss and work together in achieving a common goal, which in turn increases learning motivation (Widodo et al., 2020).

In addition, the collaborative learning approach is also in line with socio-constructivism theory, where students interact with peers and learn to work in teams. During this collaborative process, they learn to appreciate others' perspectives, communicate effectively, work together, and manage conflict (Widodo et al., 2020; Wongta et al., 2021). Thus, collaborative learning also helps students develop social skills that are important in everyday life. Given these findings, inquiry-based learning approaches, laboratory practical and collaborative learning are strong options in promoting effective student interaction, engagement, and knowledge building. The use of virtual technology also provides new opportunities to enrich the learning experience and facilitate collaboration between students.

## Conclusion

In conclusion, the findings presented show that in the period 2018-2023, the most frequently appearing learning models are inquiry, laboratory, teaching learning sequences, virtual, and collaborative. This leads to one main conclusion: learning that actively involves students in building their knowledge and experience is proven to be more effective in the learning process of temperature and heat. In addition, the collaborative

approach brings many benefits, such as increased student engagement and motivation, development of social skills, and preparation for the real world. Thus, it is important for educators and educational institutions to consider using learning models such as inquiry, laboratory practicum, and collaborative learning. The use of virtual technology can also be a valuable resource in enriching the learning experience. The limitations of this study include generalization of the findings of temperature and heat learning trends only in 2018-2023, limited number of samples reviewed, and subjective interpretation of the researcher in interpreting the research results and in selecting the articles processed in this review.

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Riski Muliyani; conceptualization, writing original draft preparation, Eka Cahya Prima; supervision, methodology, and consulting draft, and Andi Suhandi; supervision.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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