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# Technology as the Key to Overcoming Physics Misconceptions: Exploring the Concepts of Temperature and Heat through a Digital Approach

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**Abstract:** This study explores the role of technology in addressing misconceptions related to temperature and heat concepts in high school physics education. Misconceptions in physics, particularly on abstract topics like temperature and heat, can significantly hinder students' understanding of core scientific principles. The research focuses on identifying common misconceptions among high school students and examining how digital tools, such as interactive simulations and augmented reality (AR), can be used to clarify these misconceptions. Data was collected through interviews and classroom observations of 23 students from a high school in Tasikmalaya, Indonesia. The findings reveal that many students hold misconceptions, such as believing that water temperature will continuously rise with added heat without considering phase changes. Additionally, the study highlights how digital tools can provide a more interactive and visual learning experience, enhancing students' comprehension of complex concepts. The use of technology in physics education is shown to be effective in correcting misconceptions and improving overall understanding. The study concludes that integrating technology into the classroom can offer significant benefits in addressing misconceptions, but challenges such as limited access to resources and teacher training must be overcome to maximize its potential.

**Keywords:** Augmented Reality, Digital Tools, Misconceptions, Physics Education, Simulations, Temperature, Heat.

## Introduction

Physics is a natural science that examines physical phenomena through in-depth concepts and theories (Alfiansyah et al., 2022; Maolani et al., 2025; Nurdini et al., 2025). At the secondary education level, physics learning often encounters challenges, particularly in teaching abstract concepts such as temperature and heat (Irvani et al., 2017; Sari et al., 2023; Septianti et al., 2023; Shrestha et al., 2023). These concepts frequently confuse students because they are not directly observable and require a deeper understanding of fundamental physical principles. Misconceptions surrounding these concepts represent one of the main obstacles in the learning process, ultimately affecting students' ability to achieve comprehensive understanding of the subject matter (Assem et al., 2023; Guerra-Reyes et al., 2024; Soeharto & Csapó, 2021).

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The difficulties students face in understanding temperature and heat are also influenced by their intuitive knowledge, which does not always align with the scientific concepts taught in class. Research has shown that students often perceive temperature and heat as the same entity, whereas they are fundamentally distinct concepts (Argyropoulos & Yfantis, 2021; Duruk et al., 2021; Yeo et al., 2021). One of the main causes of this misconception is students' inability to differentiate between thermal energy, temperature, and heat, each of which possesses unique characteristics within the context of physics. The majority of students still hold misconceptions regarding these fundamental concepts (Assem et al., 2023; Machová & Ehler, 2023).

To address these challenges, more innovative and interactive learning approaches need to be developed. One effective method that has been proven is the use of instructional materials based on active learning methods, such as Predict-Observe-Explain (POE), which provides students with the opportunity to directly engage with physics concepts (Assafuah-Drokow, 2023; Qolbi et al., 2024; Wang & Wang, 2023). With this approach, students can observe physical phenomena, predict the outcomes, and then explain their observations, which can deepen their understanding of the concepts of temperature and heat. The use of interactive e-books based on POE can help reduce misconceptions and enhance students' understanding of these complex concepts (Afriwardani et al., 2023; Çırakoğlu et al., 2022).

Misconceptions are one of the major challenges in physics education, where students have an understanding that is incorrect or inconsistent with the scientifically accurate concepts (Henukh et al., 2024; Smart et al., 2024). These misconceptions often stem from everyday experiences that are not entirely accurate or from improper interpretations of the physical phenomena being studied. In the context of learning temperature and heat, many students are unable to differentiate between the processes of heating and the phase changes of a substance (Baydere, 2021; Inaltekin & Akcay, 2021). For example, they often assume that the temperature of water will continuously rise during heating, without considering the fact that phase changes, such as from liquid to gas, can occur at a certain point without a significant temperature change. This misunderstanding may hinder a deeper understanding of the actual concepts of heat and temperature changes.

Research on misconceptions in physics education shows that this is very common, especially in topics involving thermal concepts. One form of misconception frequently encountered is the idea that temperature and heat have the same meaning (Stefanou et al., 2024; Susanti, 2021). In fact, temperature is a measure of the average kinetic energy of particles in a substance, while heat is the energy transferred between systems due to a temperature difference. If not addressed properly, this misconception can lead to difficulties in understanding other more complex foundational concepts, such as the laws of thermodynamics or physical processes involving energy transfer. Therefore, it is crucial to identify and address these misconceptions early on so that students can build a more accurate and structured understanding.

Various studies have identified effective strategies for reducing misconceptions in physics education. One such strategy is providing more detailed explanations of the differences between temperature and heat, as well as teaching the concept of phase changes in the context of heating (Baydere, 2021; Matuszek et al., 2022). The use of visual aids, such as diagrams or animations depicting temperature and heat changes during heating, can help students understand these processes more clearly. Additionally, an experimental-based learning approach can provide students with hands-on experience of the phenomena occurring during heating, allowing them to observe and experience the difference between temperature increase and phase changes in a tangible way. Therefore, these strategies can help reduce misconceptions and improve students' understanding of basic physics concepts.

Educational technology has opened up significant opportunities for transforming the way learning takes place, particularly in addressing misconceptions that often occur in physics topics (Irvani et al., 2024; Maolani et al., 2025; Shrestha et al., 2023). By utilizing digital media, physics education can be presented in a more interactive and visual manner, allowing students to see and directly interact with abstract physics concepts. For example, the use of computer-based physics simulations can help students understand physical phenomena, such as temperature and heat changes, in a more concrete way. Through these simulations, students can directly observe how temperature changes occur in a substance being heated or how thermal conductivity affects the rate of heating, which is difficult to grasp through verbal explanations or static images (Illene et al., 2023).

One effective example of technology use is augmented reality (AR)-based applications that allow students to interact with 3D models of physics concepts. AR applications enable students to "see" particles at the microscopic level, such as how water molecules move during heating or how heat flows through materials with different thermal conductivities. By observing these phenomena directly, students can correct their misconceptions about physical processes, such as confusion regarding phase changes at specific temperatures. Previous research shows that the use of AR can enhance students' understanding of challenging physics concepts by providing in-depth and interactive visualizations (Sisman et al., 2024; Vidak et al., 2024).

The use of simulation software, such as PhET Interactive Simulations, has proven effective in helping students understand the concepts of temperature and heat. With features that allow students to change variables such as the amount of heat applied or the type of material being heated, this software provides an opportunity for students to directly explore physical phenomena. This supports the constructivist learning theory, which states that students achieve a better understanding when they are actively engaged in the learning process and can relate new concepts to their own experiences (Mishra, 2023; Zajda & Zajda, 2021). With the right educational technology, students can not only correct their misconceptions but also develop a deeper and more applied understanding of complex physics concepts.

The main objective of this study is to analyze misconceptions that occur among students regarding the topics of temperature and heat, and to explore how technology can play a role in addressing these misconceptions. Misconceptions in physics, particularly in abstract concepts such as temperature and heat, often become barriers to achieving a correct understanding of the material. Therefore, it is important to delve deeply into the types of misconceptions present among students and understand the factors causing them. This study focuses on identifying misconceptions among 11th-grade students at a high school in Tasikmalaya, with the goal of providing a clearer picture of the common misunderstandings that arise in physics education, particularly concerning the topics of temperature and heat.

This study also aims to explore the use of technology as a tool to address the misconceptions identified. Technology, with its various educational tools and applications, has great potential to present physics material in a more visual and interactive form. Therefore, it is expected that technology can facilitate students in understanding abstract and complex concepts, such as temperature, heat, and phase changes. This study also aims to examine how the application of technology, such as physics simulations or digital-based applications, can help students correct their misconceptions and deepen their understanding of the material taught. Through this analysis, it is hoped that empirical evidence can be found regarding the effectiveness of technology in enhancing physics understanding and reducing misconceptions among students.

## Method

This study employs a descriptive-analytical research design, aimed at analyzing misconceptions that occur among students in physics education, particularly concerning the topics of temperature and heat. This design allows the researcher to explore and describe the phenomenon of misconceptions among students, as well as identify the factors influencing their understanding of physics concepts (Amarulloh & Irvani, 2025; Klassen et al., 2012). With this approach, the researcher can detail the types of misconceptions found and the relationships between the concepts misunderstood by students. The descriptive-analytical approach enables the study to present deeper data on how misconceptions arise and develop during the learning process.

This study was conducted with 23 students from class XI MIPA 7 at a high school in Tasikmalaya. From this group, 3 students were selected as samples for in-depth interviews to further explore the misconceptions they had regarding the topics of temperature and heat. The sample selection was purposively done to obtain more specific and detailed information about the students' understanding of the concepts being taught. These interviews allowed the researcher to explore the students' understanding directly and gain a clearer picture of their comprehension, as well as the types of misconceptions that might arise.

To collect data, the researcher used two main methods: interviews and direct classroom observation. The interviews were conducted with the 3 selected students to explore their understanding in more depth. During the interviews, students were asked to explain their understanding of the concepts of temperature and heat, as well as related phenomena. Direct classroom observation was carried out to observe how students interacted with the physics material being taught and to identify potential misconceptions that might arise during the learning process. Data collection through these two methods provides a more comprehensive understanding of the misconceptions emerging among students.

As part of this study, educational technology was also integrated to support the identification of misconceptions and assess students' understanding. Technology was used in the form of learning applications and digital platforms that allowed the researcher to measure students' understanding in a more interactive manner. These applications or platforms provide tests or quizzes that can give immediate feedback to students, as well as enable automatic data analysis to identify areas where students experience misconceptions. Thus, technology not only serves as a tool for data collection but also as a means to enhance students' understanding through a more engaging and effective approach.

## Result and Discussion

### Identification of Misconceptions

The results of the observation show several misconceptions, which can be seen in Figure 1 below.

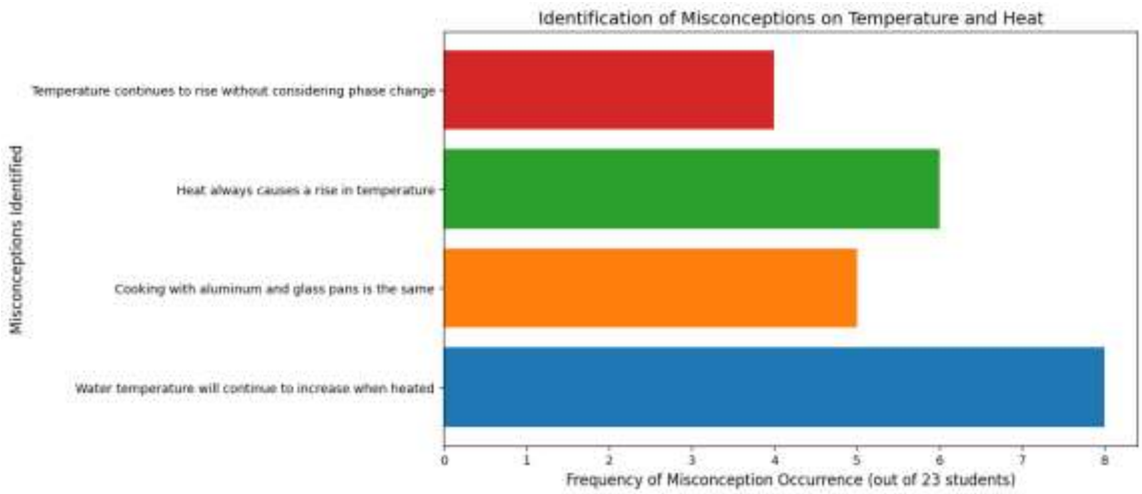


**Figure 1.** Frequency of Misconceptions in Temperature and Heat Concepts Among 23 Students

The graph in Figure 1 above shows several common misconceptions held by students regarding the topics of temperature and heat. The most frequent misconception found is the understanding that the temperature of water will continuously increase during heating, as understood by 8 students. This reflects students' difficulty in understanding phase changes, such as when water boils, where the temperature remains constant despite the continuous addition of heat. As a result, students often fail to distinguish between temperature increase and phase changes (Bhamare et al., 2021; Lanzante, 2021; Savasci-Acikalin, 2021). Additionally, five students assumed that cooking with aluminum and glass pots is the same, indicating a lack of understanding of thermal conductivity. A more detailed explanation of how the physical properties of materials affect the heating process is necessary for students to understand the influence of material properties in heating (Boswell et al., 2021).

Another misconception identified is that the heat added always causes a temperature increase, found in six students, as well as the belief that temperature always increases without considering phase changes, found in four students. These misconceptions reflect confusion between the concepts of heat and temperature, particularly in phase changes, where heat is not always used to increase temperature but also to change the phase of a substance. This highlights the need for more interactive and visual teaching approaches, such as the use of physics simulations, to help students better understand the difference between temperature change and phase change. The use of educational technology can facilitate a deeper understanding of abstract physics concepts.

The results of the interviews with students revealed several significant misconceptions regarding the topics of temperature and heat. One of the most common misconceptions found was the incorrect understanding of the relationship between temperature and heat addition. Many students assumed that the temperature of water would continuously increase as heat was added, without considering phase changes in the heated substance. In this case, students believed that if water was heated longer or more intensely, the temperature would keep rising. However, at the boiling point, even though heat is continuously added, the water temperature remains constant until all the water turns into steam. This phenomenon, known as phase change, is often overlooked by students who lack a deep understanding of the concept of heat and phase transitions (Susman, 2024; Zhang et al., 2022).

Another misconception found relates to thermal conductivity and the way heat works in the heating process. Many students assume that cooking with an aluminum pot is similar to cooking with a glass pot. They fail to realize that these two materials have different thermal conductivities. Aluminum, which has a higher thermal conductivity, transfers heat more quickly than glass, leading to a faster heating process in the aluminum pot. This misconception causes students difficulty in understanding the basic physics concept of how heat transfers from a heat source to an object and how thermal conductivity affects the rate of heating of a material. This misconception arises because students often view cooking as a simple process, without considering the physical properties of the materials used in the process (Alagappan, 2023; Knorr & Augustin, 2021; Spreafico & Landi, 2022).

In the interviews, it was found that some students also had an incorrect understanding of the amount of heat required to heat a substance. They often assumed that the heat added is always directly proportional to the temperature increase, without realizing that heat is also used for phase changes, such as from liquid to gas. Students with this misconception tend to struggle in explaining the difference between the heat required to raise temperature and the heat needed for phase changes, as seen in the heating process of water to boiling point (Stefanou et al., 2024). This indicates a misunderstanding of the role of heat in the energy changes of the heated substance.

These misconceptions reflect a significant gap between the knowledge students possess and the scientifically accurate understanding. The main cause of these misconceptions is likely related to the lack of teaching that deeply addresses foundational concepts and the limitations of the teaching methods used by instructors. Many physics teachers focus more on delivering theory verbally or through assignments that are more memorization-based, without providing students the opportunity to explore and interact directly with these concepts through discussions or hands-on experiments. Therefore, there is a need for a more applied and interactive approach in teaching to help students build a deeper understanding and reduce the occurrence of misconceptions.

**Impact of Technology in Addressing Misconceptions**

The application of technology in physics education can have a significant impact in addressing misconceptions among students, particularly in the topics of temperature and heat. Educational technology, such as computer-based physics simulations, can present abstract physical phenomena in a visual and interactive form, making it easier for students to understand challenging concepts. For example, an interactive simulation showing temperature changes as a substance is heated and the phase change from liquid to gas can help students more clearly understand how these physical processes occur (Al Mamun & Lawrie, 2024; Łach & Svyetlichnyy, 2024; Tsvetkova et al., 2023). With detailed visualizations, students can observe how temperature remains constant when water boils, even as heat is continuously added, helping them overcome the misconception that temperature always increases with added heat.

The use of technology also enables students to understand the phenomenon of thermal conductivity through simulations that demonstrate how heat transfers through different materials with varying conductivity levels. For example, through digital-based simulations, students can see how aluminum, with a higher thermal conductivity, heats up faster compared to glass. Such simulations give students the opportunity to observe and directly explore how materials with different physical properties affect the rate of heating, allowing them to better understand these differences (Banda & Nzabahimana, 2021; Kade et al., 2024; Sadidah & Irvani, 2021). Technology also enables students to conduct virtual experiments that might be difficult to perform in a physical classroom, such as altering variables like material type or the amount of heat applied to directly observe the results.

Augmented reality (AR)-based applications also offer an innovative approach in addressing misconceptions. With AR technology, students can directly interact with 3D models of physics concepts, such as temperature, heat, and phase changes. For example, by using an AR application, students can observe water molecules moving as they are heated and even witness the phase change from liquid to gas in a more dynamic way. This approach provides a more interactive learning experience and allows students to develop a stronger understanding of previously abstract physics concepts (Banda & Nzabahimana, 2021; Georgiou et al., 2021). This aligns with the principles of constructivist learning, where students learn more effectively through hands-on experiences and active exploration.

With the integration of technology in education, students are not only introduced to physics concepts in a more engaging and understandable way but also given the opportunity to correct the misconceptions they have. Educational technology provides space for students to learn through visual and hands-on experiences that facilitate their understanding, which is not always achieved through traditional methods. Therefore, the application of technology in physics education can enhance the overall quality of learning, correct students' misconceptions, and equip them with deeper skills in understanding physical phenomena.

**Comparison of Traditional vs. Digital Approaches**

A comparison between traditional learning methods and technology-based approaches shows significant differences in how students interact with physics learning materials, particularly in addressing misconceptions. Traditional methods, which typically rely on lectures and verbal explanations from teachers, often do not provide sufficient opportunities for students to actively engage with the material. Lecture-based learning tends to be one-way, where students listen to explanations without many opportunities for exploration or deep understanding (Ssemugenyi, 2023). This results in many students merely memorizing physics concepts without truly understanding the underlying principles, which in turn can lead to misconceptions.

Technology-based approaches, such as the use of interactive applications and computer-based simulations, allow students to directly interact with physics concepts. For example, by using simulations that demonstrate changes in temperature and heat in a heated substance, students can see and directly experience how these phenomena occur, rather than just hearing theoretical explanations from the teacher. This interactivity allows students to test various scenarios, such as changing the amount of heat applied or switching the material being heated, and directly observe the effects on temperature or phase changes (Illene et al., 2023; Xing et al., 2023). This approach provides a more concrete learning experience and enables students to better understand the relationship between theory and real-world applications, which is difficult to achieve with traditional teaching methods.

Educational technology allows students to receive faster and more specific feedback. In computer-based simulations or interactive applications, students can immediately see the results of the virtual experiments they conduct and quickly determine whether their understanding is correct or incorrect. This rapid feedback is highly beneficial in correcting misconceptions, as students can promptly identify their mistakes and learn from the experience. This contrasts with traditional methods, where feedback is often delayed or limited to results from periodically administered exams (Guntani et al., 2025; McCue et al., 2025; Yang et al., 2021). The use of technology also provides students with the opportunity to learn independently and explore concepts further outside the classroom, which is not always possible with lecture-based approaches.

One of the main advantages of the digital approach is its ability to visualize abstract physical phenomena in a way that is easy to understand. Many physics concepts, such as temperature changes during heating or differences in thermal conductivity, can be very difficult to comprehend if explained only with words or static images. Digital simulations or animations can depict these concepts dynamically and interactively, allowing students to see and understand the processes occurring at a microscopic level. In this way, educational technology can help reduce misconceptions caused by students' limited visual understanding of physics material.

Although traditional methods still play an important role in teaching, particularly in providing foundational theoretical knowledge, technology-based approaches offer greater benefits in terms of interactivity, visualization, and understanding of physics concepts. By providing students the opportunity to interact directly with learning materials and receive quick feedback, technology can help reduce misconceptions and enhance a deeper understanding of complex physics concepts. Therefore, the integration of technology in physics education not only increases student engagement but also supports them in building a stronger and more accurate understanding.

**Challenges and Limitations**

Although educational technology offers great potential to enhance the quality of physics education and address misconceptions, its implementation is not without challenges. One of the main obstacles in applying technology is the lack of technical readiness in many schools. Many schools, especially those in resource-limited areas, lack adequate technological infrastructure. Limitations in devices such as computers, tablets, or interactive projectors can hinder the effective use of technology in teaching (Demirbilek, 2024; Nikolopoulou, 2021). Without adequate equipment, teachers and students cannot fully utilize the potential of computer-based physics simulations or interactive applications that can help in understanding physics concepts in a more visual and practical way.

The lack of training for teachers in utilizing technology is also a significant barrier. Although technology can offer many benefits in education, teachers need to have the necessary skills and understanding to effectively integrate it into their teaching. Without proper training, teachers may struggle to adopt new technology or use it in ways that support learning objectives. Previous research shows that teachers' readiness to use technology largely depends on the training they receive and their belief in the benefits of technology in improving student learning outcomes (Akram et al., 2022; Park & Son, 2022). Therefore, intensive and ongoing teacher training is essential to ensure that technology can be applied effectively in the classroom.

Limited internet access is also a major challenge in the implementation of educational technology. In many schools, especially those in rural areas or with limited budgets, stable and fast internet access remains an issue. Cloud-based technology, online simulations, or educational applications that require a stable internet connection are often inaccessible to students in areas with poor internet infrastructure (Matthew et al., 2021; Wu & Plakhtii, 2021). This reduces students' ability to fully utilize technology-based educational resources, ultimately limiting the potential of technology to address misconceptions and enhance their understanding of physics material.

Although technology can offer an effective way to enhance learning, it is important to remember that technology is not a one-size-fits-all solution to educational challenges. The integration of technology should be done carefully and combined with appropriate teaching methods. The unplanned or poorly coordinated use of technology can lead to dependency on tools without considering a more holistic learning process. Therefore, while technology can be a powerful tool in addressing misconceptions, effective teaching strategies and adequate support for both teachers and students are still necessary for technology to be used optimally.

## Conclusion

The study highlights that misconceptions in physics, particularly in concepts such as temperature and heat, are prevalent among high school students. These misconceptions arise from students' prior knowledge, often rooted in everyday experiences that do not align with scientific principles. The most common misconception identified in this study was that students believe water temperature will continuously increase as heat is applied, without considering the effects of phase changes. Addressing these misconceptions is crucial, as they hinder students' ability to grasp more complex concepts in thermodynamics and energy transfer. Therefore, early identification and intervention are necessary to foster accurate understanding and build a solid foundation in physics education.

The integration of technology into physics education proves to be an effective strategy for addressing these misconceptions. Through the use of interactive digital tools, such as physics simulations and augmented reality (AR), students can visualize and engage with abstract concepts in a more tangible way. For instance, simulations allow students to witness how temperature behaves during phase changes, and AR applications provide immersive experiences that help clarify complex physical processes. These technologies not only enhance students' understanding but also provide immediate feedback, which is essential in correcting misconceptions as they arise. The use of technology aligns with the constructivist learning theory, supporting active learning and engagement with the material, ultimately improving students' comprehension of physics concepts.

Despite the promising impact of technology, the study also recognizes several challenges. Issues such as inadequate technological infrastructure, limited access to the internet, and the lack of teacher training in utilizing digital tools effectively can hinder the successful implementation of technology in classrooms. Therefore, it is essential for educational institutions to invest in both technological resources and professional development for teachers to ensure that the full potential of digital tools is realized. In conclusion, while technology offers significant benefits in overcoming misconceptions in physics, a balanced approach that combines technological innovation with traditional teaching methods is necessary for optimal student learning outcomes.

**Conflicts of Interest**

The authors declare no conflicts of interest related to this study. No external funding was involved in the design, data collection, analysis, interpretation, writing of the manuscript, or the decision to publish. All research was conducted with full transparency and in adherence to ethical standards.

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