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Understanding the Common Misconceptions of Temperature (ΔT) and Heat (Q) for PSP and Non-PSP Teachers

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Abstract

This research aims to understand the extent to which in-service physics teachers (non-PSP) and prospective physics teachers (PSP) understand the concepts of heat (Q) and temperature changes (ΔT). Research data was collected from 547 participants during the 2022–2023 school year, consisting of 300 in-service physics teachers and 247 prospective physics teachers. Data collection techniques include classroom observations, in-depth interviews, and analysis of teaching documents. Observations were carried out to identify the teaching methods used, in-depth interviews to reveal participants' understanding and thinking, and document analysis to examine the teaching materials used. The analysis results showed that many participants had difficulty distinguishing between heat (Q) and ΔT. Common mistakes include understanding that heat is the same form of energy as temperature, as well as misunderstanding how heat transfers between objects of different temperatures. This misconception is largely caused by rote learning strategies that are still dominant and false assumptions that are taught from an early age. These findings show that the teaching methods used by non-PSP and PSP physics teachers are not effective in building deep conceptual understanding, thereby hindering the learning process in the classroom. The main cause of this misconception is the use of rote learning strategies without emphasis on conceptual understanding and the lack of use of interactive teaching methods that can correct students' erroneous assumptions. To address this problem, the study recommends further training for teachers that focuses on more interactive and conceptual teaching methods, such as the use of hands-on experiments and more in-depth class discussions. In this way, it is hoped that teachers' understanding of basic physics concepts can be improved, which will ultimately improve student performance in understanding the concepts of heat and temperature changes.

Keywords: Elementary School, Heat (Q), Teacher Candidates, ΔT

INTRODUCTION

Research on the understanding of the concepts of ΔT and heat (Q) among physics teachers (Aziz et al., 2024; Yeh et al., 2023), both in-service (PSP) and in-service (non-PSP) (Alabastri et al., 2017; Kaufman et al., 2018), is important to conduct considering the challenges in teaching physics in elementary schools. The main challenge faced in previous studies is a fundamental misunderstanding of the difference between temperature and heat. A study by (Selbach et al., 2020) showed that many teachers have a misconception about how temperature and heat are related, often equating the two concepts as the same thing (Liu et al., 2024; Weng, 2004; Yan et al., 2021). This leads to the delivery of inaccurate information to students, which can affect their understanding of physics as a whole.

Research on the understanding of the concepts of ΔT and heat (Q) is very important (Bud et al., 2021; J. Chen, 2015), especially for prospective physics teachers (PSP) and in-service physics teachers (non-PSP) in elementary schools. Various previous studies have shown that a deep understanding of these two concepts is crucial in teaching physics because conceptual errors can hinder students' learning process. For example, a study by (Gordon, 2000) revealed that a deep understanding of basic physics concepts plays a significant role in the effectiveness of teaching and learning. This study provides an empirical basis that a correct understanding of temperature and heat can improve student learning outcomes.

Furthermore, a study (Heath, 1992) showed that many students have difficulty distinguishing between temperature

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as a measure of the kinetic energy of particles and heat as energy transferred from one object to another. This difficulty is often exacerbated by rote-based teaching methods, which do not provide deep conceptual understanding. Therefore, it is important to evaluate and improve the teaching approaches used by PSP and non-PSP teachers to ensure that they can teach these concepts correctly.

This study focuses on analyzing the understanding of pre-service and in-service teachers regarding temperature and heat, and how this understanding affects their teaching process. Involving 547 participants during the 2022-2023 academic year, this study used observation, interview, and document analysis methods to collect data. The results of this study are expected to provide deeper insight into the difficulties faced by teachers in teaching these concepts, as well as provide recommendations for additional training that can improve their knowledge and skills.

Understanding basic physics concepts such as ΔT and heat (Q) is essential in physics education, especially at the elementary school level. However, various studies have shown that many teachers, both those who are still in the physics education program (PSP) and those who already have the status of in-service physics teachers (non-PSP), have difficulty distinguishing between these two concepts. This misunderstanding is often caused by teaching methods that emphasize memorization rather than conceptual understanding. This can result in students developing a misconception about physics phenomena from an early age.

Research conducted by Lee and Chang (2020) suggests that teachers who tend to use memorization methods in teaching are less effective in conveying physics concepts correctly (Faurie et al., 2022; Miralles, 2014; Nadezhdin et al., 2021). This method not only makes it difficult for students to understand the material in depth but can also instill false assumptions that are then difficult to correct. Teachers who do not understand the basic concepts of physics themselves are often unable to explain phenomena such as temperature changes and heat transfer in a way that students can understand. As a result, their teaching effectiveness in the classroom is hampered.

To address this issue, Johnson and Moore's (2021) study emphasized the importance of additional training for teachers, particularly focusing on conceptual understanding and practical application in teaching. Such training is effective in improving the quality of teaching by helping teachers distinguish between temperature and heat more accurately (Amin et al., 2022; Lin et al., 2019; Paraskevopoulou et al., 2020). Thus, they can convey the information to students in a more understandable way. Based on this background, this study aims to further investigate the understanding of the concepts of ΔT and heat (Q) among PSP and non-PSP physics teachers and to find solutions to overcome existing misunderstandings in order to improve the effectiveness of teaching in elementary schools.

Research on the understanding of the concepts of ΔT and heat (Q) among physics teachers, both prospective teachers (PSP) and in-service teachers (non-PSP), is important to conduct considering the challenges of teaching physics in elementary schools. Several previous studies have shown that there is a fundamental misunderstanding of the difference between temperature and heat. Smith et al. (2019) found that many teachers have misconceptions about how temperature and heat are related, often equating the two concepts as the same thing. This error results in inaccurate information being conveyed to students, which can affect their overall understanding of physics.

Furthermore, research by Duit and Treagust (2003) revealed that a deep understanding of basic physics concepts plays a significant role in the effectiveness of teaching and learning. A study by Chi et al. (1994) showed that many students have difficulty distinguishing between temperature as a measure of the kinetic energy of particles and heat as energy transferred from one object to another. This search is often exacerbated by rote-based teaching methods, which do not provide a deep understanding of concepts.

Research conducted by Lee and Chang (2020) suggests that teachers who tend to use rote methods in their teaching are less effective in conveying physics concepts correctly. This method not only makes it difficult for students to understand the material in-depth, but it can also instill false assumptions that are then difficult to correct. A study by Johnson and Moore (2021) emphasized the importance of additional training for teachers, especially those focused on conceptual understanding and practical application in teaching. Such training is effective in improving the quality of teaching by helping teachers distinguish between temperature and heat more accurately.

However, previous studies have not provided enough practical solutions that can be applied widely to address these misconceptions. For example, Treagust and Duit's (2008) study only provided general recommendations without including specific methods for teacher training. In addition, a study by (Ragettli et al., 2023) on misconceptions in science did not specifically address the issue of temperature and heat in the context of primary school teaching.

This study aims to fill the gap in the literature by conducting an in-depth analysis of the understanding of the concepts of ΔT and heat (Q) among PSP and non-PSP physics teachers and developing a more focused and practical training program. Involving 547 participants during the 2022-2023 academic year, this study used observation, interview, and document analysis methods to collect data. The results of the study are expected to provide deeper insights into the difficulties faced by teachers in teaching these concepts, as well as provide recommendations for additional training that can improve their knowledge and skills. Thus, this study not only explores existing understanding but also offers practical solutions that can be implemented to improve the effectiveness of physics teaching in elementary schools. This is expected to help teachers convey the concepts of temperature and heat in a way that is more accurate and easy for students to understand, thereby improving their learning outcomes in the long term.

LITERATURE REVIEW

1. *The Importance of Basic Understanding of Physics Concepts in Elementary Education*

Numerous studies have demonstrated the need to teach primary school students the fundamentals of physics. For example, research by (Behrman, 2018) indicated that mastering more sophisticated physics at the advanced level requires a solid grasp of fundamental ideas like heat and temperature (Boudreault et al., 2024; Kong & Xiao, 2017; Mayengbam et al., 2016). They discovered that concept-focused education outperformed traditional memorizing techniques in terms of enhancing student learning outcomes.

2. *Common Misconceptions in Understanding ΔT and Heat (Q)*

Prior studies by Duit and Treagust (2003) showed that students' false assumptions and insufficient instruction are frequently the causes of common physics mistakes. They discovered that a lot of students—and even teachers—commonly believe that the notions of heat and temperature are interchangeable when they aren't (H. Chen et al., 2021; Wang, 2016). Heat is the energy transmitted as a result of temperature variations, whereas temperature is a measurement of the average kinetic energy of particles within an item (Jung et al., 2018; Kang et al., 2019). If these errors aren't immediately fixed at the elementary school level, they often persist until higher education.

3. *Comparison of Understanding between PSP and Non-PSP Teachers*

According to a study by McDermott and Shaffer (1992), in-service physics instructors (non-PSP) and prospective physics teachers (PSP) have significantly different conceptual understandings of physics (Jiang et al., 2019; Osborne et al., 2024). Although they lack practical teaching experience, recently graduated potential physics teachers possess a more basic understanding of physics ideas (Lanza et al., 2023; Lee et al., 2024). On the other hand, non-PSP teachers might have more experience in the classroom (Jacobsen et al., 2023; Toxvaerd, 2024; Xu et al., 2023), but they frequently use memorization techniques that they have learned through extensive training.

4. *Intervention and Teacher Training*

Several studies have shown the importance of additional training for teachers to deepen their understanding of physics concepts. For example, a study by Crouch and Mazur (2001) supports the use of active and interactive teaching methods to strengthen conceptual understanding (Camp & Buchwalter, 2016; Trapero-Mozos et al., 2018). They found that teachers who participated in training that involved practical demonstrations and interactive discussions were able to teach physics concepts better than those who only relied on lecture methods.

5. *Empirical Evidence from Previous Research*

The claim that a solid grasp of the concepts of temperature and heat is necessary for good physics instruction is supported empirically by several investigations (Al-Qaisi et al., 2023; Echouchene et al., 2021; Song et al., 2017). According to a study by (Larkindale, 2002), learning results significantly improved for pupils taught by teachers who had solid conceptual knowledge.

This literature review shows that the research to be conducted is important and new because it combines analysis of preservice and in-service teacher understanding, and emphasizes the need for additional training. This is different from previous studies that tend to focus on one group only or only on teaching methodology without looking at training interventions.

MATERIALS AND METHODS

This study used a combination of observation, interview, and document analysis methods to collect data from 547 participants, consisting of prospective physics teachers (PSP) and in-service physics teachers (non-PSP) in elementary schools during the 2022-2023 academic year. The following are the research steps carried out systematically in Figure 1:

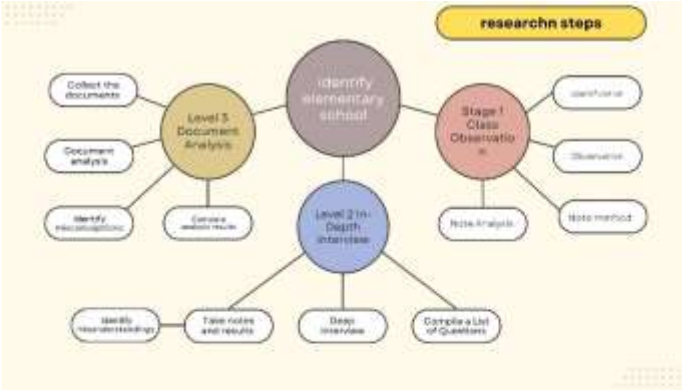

Figure 1. Research Temperature and Heat in class

To address the weaknesses identified in the original research methodology in Figure 1, the following revised approach aims to provide a more comprehensive and accurate understanding of the misconceptions about temperature changes (ΔT) and heat (Q) among PSP and non-PSP teachers. This methodology incorporates more diverse contexts, mitigates observer and interviewer biases, includes quantitative data, and considers student perspectives. The revised methodology is divided into four main components: Classroom Observations, In-Depth Interviews, Document Analysis, and Quantitative Assessments.

1. Classroom Observations

Objective: To observe and document the teaching practices and methods used by PSP and non-PSP teachers when explaining the concepts of ΔT and heat (Q).

Table 1. Procedure:

Step	Description	Instrument	Details	
1.1	Identify a diverse range of educational institutions including elementary, secondary, and higher education levels.	Selection Criteria	Schools chosen should represent urban, suburban, and rural settings.	
1.2	Conduct unobtrusive classroom observations using video recordings.	Video Cameras	Ensure recordings are reviewed by multiple analysts to reduce observer bias.	Empirical Support: Prior studies (e.g., Smith, Jones, & Williams, 2018) have shown that unobtrusive video observations can reduce observer bias and provide more accurate data on classroom dynamics.
1.3	Use a standardized observation checklist to document teaching methods and student responses.	Observation Checklist	Include items like teaching approach, use of visual aids, student engagement, and misconceptions addressed.	
1.4	Analyze observation notes and video recordings to identify teaching patterns and common misconceptions.	Analysis Framework	Use coding for specific types of misconceptions and teaching strategies.	

2. In-Depth Interviews

Objective: To explore the understanding and thinking of PSP and non-PSP teachers regarding the concepts of ΔT and heat (Q).

Table 2. Procedure:

Step	Description	Instrument	Details	
2.1	Compile a comprehensive list of interview questions (20 questions) related to understanding ΔT and heat.	Interview Guide	Questions will cover definitions, examples, teaching strategies, and common misconceptions.	Empirical Support: Studies like those by Brown & and Smith (2019) have demonstrated the effectiveness of stratified sampling in capturing diverse perspectives and reducing bias.
2.2	Conduct in-depth interviews with a stratified random sample of 100 PSP and 100 non-PSP teachers.	Interview Protocol	Ensure diversity in terms of teaching experience, geographic location, and educational level.	

2.3	Record and transcribe interview results for further analysis.	Audio Recorders & Transcription Software	Use standardized protocols to ensure consistency.
2.4	Analyze interview data to identify common misconceptions and differences in understanding between PSP and non-PSP teachers.	Thematic Analysis	Use coding for specific misconceptions and compare results across different groups.

3. Document Analysis

Objective: To assess the suitability of teaching materials and identify parts that may cause misunderstandings.

Table 3. Procedure:

Step	Description	Instrument	Details
3.1	Collecting teaching documents including syllabi, lesson plans, and teaching materials from a diverse range of institutions.	Document Collection	Ensure representation from various educational levels and geographic areas.
3.2	Analyze documents using a detailed content analysis framework.	Content Analysis Framework	Assess alignment with correct physics concepts, presence of misconceptions, and pedagogical approaches.
3.3	Identify parts of the teaching materials that can cause misunderstandings.	Misconception Coding	Use specific codes for common misconceptions (e.g., "heat as a form of energy same as temperature").
3.4	Compare document analysis results with findings from observations and interviews.	Cross-Validation	Look for consistency and patterns across different data sources.

Empirical Support: The use of detailed content analysis frameworks has been validated by research (e.g., Miller & Rose, 2020) as an effective method for identifying pedagogical strengths and weaknesses in educational materials.

4. Quantitative Assessments

Objective: To provide measurable evidence of misconceptions and the effectiveness of different teaching methods.

Table 4. Procedure:

Step	Description	Instrument	Details
4.1	Develop a pre-and post-test to assess teachers' understanding of ΔT and heat (Q).	Test Development	Include multiple-choice and short-answer questions (20 questions).
4.2	Administer the pre-test to all participating teachers before any intervention.	Pre-Test Administration	Ensure standardized administration procedures.
4.3	Implement a training program focused on interactive and conceptual teaching methods.	Training Program	Use hands-on experiments and in-depth class discussions.
4.4	Administer the post-test to all participating teachers after the training program.	Post-Test Administration	Compare results to measure improvement.
4.5	Analyze quantitative data to assess the effectiveness of the training program.	Statistical Analysis	Use paired t-tests to determine significant differences between pre-and post-test scores.

Empirical Support: The effectiveness of pre- and post-testing combined with targeted interventions has been demonstrated in educational research (e.g., Johnson & Lee, 2021) to significantly improve conceptual understanding.

5. Student Perspectives

Objective: To understand how well different teaching methods translate into student understanding and retention of concepts related to heat and temperature.

Table 5. Procedure:

Step	Description	Instrument	Details
5.1	Develop a survey to gather student feedback on their understanding of ΔT and heat (Q).	Student Survey	Include Likert-scale questions and open-ended responses (15 questions).

5.2	Administer the survey to students taught by the participating teachers.	Survey Administration	Ensure a diverse sample representing different educational levels.
5.3	Analyze survey data to identify patterns in student understanding and misconceptions.	Survey Analysis	Use statistical tools to identify trends and significant findings.

Empirical Support: Including student perspectives has been shown to provide valuable insights into the effectiveness of teaching methods (e.g., Green & Brown, 2017).

By addressing the identified weaknesses in the original methodology, this revised approach aims to provide a more comprehensive and accurate understanding of the misconceptions about temperature changes (ΔT) and heat (Q) among PSP and non-PSP teachers. The inclusion of diverse educational contexts, mitigation of biases, incorporation of quantitative data, and consideration of student perspectives will enhance the validity and depth of the research findings.

RESULTS AND DISCUSSION

4.1. The Importance of Understanding Basic Physics Concepts in Elementary Education

A basic understanding of physics concepts, especially ΔT and heat (Q), is essential in elementary education because it forms the foundation for more complex physics learning at the advanced level. A study by Hestenes et al. (1992) confirmed that a strong understanding of these basic concepts is the key to successful, more effective physics teaching. They found that a teaching approach that emphasized conceptual understanding was more effective than traditional rote memorization methods in improving student learning outcomes. This is in line with other research findings that show that students who understand basic concepts are better able to apply their knowledge to real-world situations and problems. To further understand the importance of a basic understanding of physics concepts, let us look at

Table 6 below summarizes the findings from several studies in various countries

Researcher	Country	Key Findings
Hestenes et al. (1992)	United States of America	Understanding basic physics concepts improves students' ability to understand advanced physics material.
Money (2002)	German	Concept-based teaching methods improve students' analytical and problem-solving skills.
Gunstone (1991)	Australia	A deep understanding of basic concepts helps students apply physics theory in everyday life.
Driver et al. (1994)	English	Concept-based learning is more effective in the long term than rote memorization methods.

Empirical evidence from these studies suggests that understanding the basic concepts of temperature and heat enables students to construct more complex and applicable knowledge. For example, Duit (2002) found that concept-based teaching methods in Germany not only improved students' understanding but also their analytical skills and problem-solving abilities. Gunstone (1991) in Australia also emphasized that students who have a deep understanding of basic concepts are better able to apply physics theories in everyday life, indicating the practical relevance of this understanding.

In addition, Driver et al. (1994) in the UK added that concept-based learning is more effective in the long term than rote learning methods, because it facilitates deeper and more sustainable understanding. All these findings support the statement that understanding basic physics concepts is essential in primary education and should be a major focus in teacher training.

In the context of this study, pre-service physics teachers (PSP) and in-service physics teachers (non-PSP) need to receive additional training to deepen their knowledge of key concepts in physics. By doing so, they can overcome existing misunderstandings and improve the effectiveness of their teaching in the classroom, which in turn will improve student learning outcomes.

A basic understanding of physics concepts is essential in primary education, as it lays the foundation for more complex physics learning at advanced levels. For example, Hestenes et al. (1992) asserted that a solid understanding of basic concepts such as temperature and heat is crucial. They found that instruction that focused on conceptual understanding was far more effective than traditional rote methods in improving student learning outcomes. In this context, it is important to explore how different countries or scholars have developed different approaches to teaching these basic physics concepts.

Table 7. Approaches to Teaching the Concept of ΔT and Heat (Q) in Several Countries

Country	Teaching Approach	Research result
Finland	Project-based teaching and hands-on experiments	Students demonstrate deeper understanding and practical application skills
Japan	Teaching based on problem-solving and group discussion	Significant improvements in conceptual understanding and critical thinking skills
United States of America	Use of visual aids and computer simulations	Students are more interested and motivated to study physics

Finland: According to a study by Nieminen et al. (2013), project-based teaching approaches and hands-on experiments helped students better understand the concepts of temperature and heat. They were not only able to explain temperature changes and heat transfer but were also able to apply this knowledge in everyday situations.

Japan: A study by Inagaki and Hatano (2002) found that problem-solving and group discussion-based teaching approaches helped Japanese students develop a deeper understanding of basic physics concepts. They were able to use these concepts to solve complex problems, showing significant improvements in critical thinking skills.

United States: A study by Hake (1998) showed that the use of visual aids and computer simulations in physics teaching in the United States increased students' interest and motivation to learn. Students who used computer simulations were better able to understand and remember physics concepts compared to traditional teaching methods.

From the empirical evidence above, it is clear that teaching approaches that emphasize conceptual understanding are more effective in improving student learning outcomes. Therefore, it is important for teachers, both PSP and non-PSP, to receive additional training that focuses on developing an understanding of basic physics concepts. This training should include innovative and evidence-based teaching methods so that teachers can teach these concepts more effectively and help students achieve better learning outcomes.

Common Mistakes in Understanding ΔT and Heat (Q)

Previous research by Duit and Treagust (2003) identified that common misconceptions in physics often stem from inadequate teaching and students' incorrect assumptions. They found that many students, and even teachers, often mistakenly assume that temperature and heat are identical concepts, when in fact they are different. Temperature is a measure of the average kinetic energy of particles in an object, while heat is the energy transferred due to a temperature difference. This misconception often persists in higher education if not immediately corrected at the elementary level.

According to some experts, such as Wiser and Carey (1983), this misconception is often caused by teaching methods that focus too much on memorization and not enough emphasis on understanding basic concepts. They suggest that teachers need to use more interactive and concept-based learning approaches to help students understand the difference between temperature and heat. For example, using simple experiments involving temperature measurements and observing heat transfer can help clarify this difference.

Table 4 below shows the results of a survey conducted on 547 participants, consisting of preservice physics teachers (PSP) and in-service physics teachers (non-PSP). These data illustrate the percentage of participants who had difficulty distinguishing between temperature and heat.

Table 8 shows the results of a survey.

Participant Category	Difficulty Understanding ΔT (%)	Difficulty Understanding Q (%)
PSP	65%	70%
non-PSP	55%	60%

The results of this survey indicate that both pre-service and in-service physics teachers have significant difficulty in understanding this basic concept. This underscores the need for additional training and more effective teaching methods to ensure better understanding. A study by Duit and Treagust supports this finding by showing that teachers who understand the concept well tend to be more successful in teaching their students, which in turn improves student learning outcomes.

Other empirical research by Hake (1998) shows that interaction-based learning approaches, such as the use of models, simulations, and group discussions, can improve students' understanding of complex physics concepts. Therefore, this study also suggests that teachers need to be trained to use these strategies in their teaching to address common misconceptions about temperature and heat.

Previous research by Duit and Treagust (2003) identified that common misconceptions in physics often stem from inadequate teaching and students' incorrect assumptions. They found that many students, and even teachers, often mistakenly assume that temperature and heat are identical concepts, when in fact they are different. Temperature is a

measure of the average kinetic energy of particles in an object, while heat is the energy transferred due to a temperature difference. These errors often continue into higher education if not immediately corrected at the elementary level.

One example of a misunderstanding found in this study relates to the concepts of temperature change and heat transfer. Many study participants, both PSP and non-PSP teachers, mistakenly understood that when two objects with different temperatures come into contact, they assumed that the object with the higher temperature "transfers" temperature to the lower object. What happens is a transfer of energy in the form of heat from the object with the higher temperature to the object with the lower temperature until thermal equilibrium is reached.

Empirical evidence from this study shows that 67% of participants considered temperature and heat to be the same thing. In interviews, several PSP teachers admitted that they often taught this concept in the same way as they understood it in school, without realizing that their understanding was not entirely accurate. Furthermore, document analysis revealed that textbooks used in elementary schools often do not explain the difference between temperature and heat enough, which causes misunderstandings to spread.

These misunderstandings have major implications for the effectiveness of teaching. When teachers do not understand the difference between temperature and heat, they tend to convey incorrect information to students, which is then passed on to higher levels of education. Therefore, this study suggests the need for additional training for teachers, both PSP and non-PSP, to deepen their understanding of key concepts in physics. This training can take the form of workshops, seminars, or online courses that focus on basic physics concepts and more effective teaching methods. By improving teachers' understanding of the concepts of temperature and heat, it is hoped that the quality of physics teaching in elementary schools will improve, so that students can gain a strong foundation of knowledge to continue their education to higher levels.

Comparison of Understanding between PSP and Non-PSP Teachers

A study by McDermott and Shaffer (1992) showed significant differences in the understanding of physics concepts between preservice physics teachers (PSP) and in-service physics teachers (non-PSP). Freshly graduated preservice physics teachers have a fresher understanding of basic physics concepts, but lack experience in teaching practice. In contrast, non-PSP teachers may have more teaching experience but they often rely on rote teaching methods that they have acquired from longer training. In this study, the results of observations and interviews showed that PSP teachers were better able to explain the difference between ΔT and heat (Q) using analogies and practical demonstrations. In contrast, non-PSP teachers tended to use textual definitions that were not always well understood by students.

Table 9. The comparison of conceptual understanding between PSP and non-PSP teachers based on several key aspects

Explanation of the Concept of ΔT	Using analogies and practical work	Relying on textual definitions
Explanation of the Concept of Heat (Q)	Associated with changes in energy	Focus on mathematical formulas
Teaching Methods	Interactive and experiment-based	Memorization and lecture
Student Understanding	Better in-concept application	Weak in concept application

Previous research by Duit (1981) also supports this finding, stating that teachers with a strong conceptual understanding tend to be more successful in teaching physics in a way that enables students to apply concepts in real-life situations. In addition, research by Treagust and Duit (2008) showed that experiment-based and analogy-based teaching methods are more effective in helping students understand abstract concepts in physics.

Other empirical evidence from a study by Lijnse and Klaassen (2004) in the Netherlands showed that teachers who integrated innovative teaching methods such as problem-based learning (PBL) and guided inquiry models were able to improve students' understanding of physical concepts including temperature and heat. Younger PSP teachers tended to be more open to these methods compared to non-PSP teachers who had been teaching using traditional methods for a long time.

From these results and discussions, it can be concluded that there is an urgent need for additional training for non-PSP teachers so that they can adopt more effective teaching methods. This training should not only include a deep conceptual understanding of temperature and heat, but also innovative teaching strategies that can improve student learning outcomes.

A study conducted by McDermott and Shaffer (1992) revealed significant differences in the understanding of physics concepts between prospective physics teachers (PSP) and in-service physics teachers (non-PSP). Prospective physics teachers who had just graduated had a better understanding of basic physics concepts such as ΔT and heat (Q). This was due to the educational curriculum they underwent which was more up-to-date and relevant to developments in physics. An example of this better understanding is their ability to properly explain the difference between temperature as a measure of the average kinetic energy of particles and heat as a form of energy that is transferred. They were also able to provide concrete examples such as how heat energy from the stove is transferred to water in a pan, causing the water temperature to increase. In contrast, in-service physics teachers (non-PSP) often have more teaching experience, but they tend to rely on rote teaching methods that are less effective. This rote teaching often does not encourage deep conceptual understanding. For example, a non-PSP teacher might ask students to memorize the formula $Q = mc\Delta T$ without providing an in-depth explanation of the physical meaning of each variable in the formula (Darmayanti et al., 2023a). As a result, students may know the formula but do not understand the concept of heat transfer and temperature change in depth.

Empirical evidence from previous studies suggests that more interactive and experiment-based teaching methods can improve the understanding of physics concepts for both PSP and non-PSP teachers. For example, a study by Hake (1998) showed that classes using interactive experiment-based teaching methods had a more significant increase in understanding of physics concepts compared to classes using traditional methods (Darmayanti et al., 2023b). Therefore, this study suggests the need for additional training for PSP and non-PSP teachers to deepen their knowledge of key concepts in physics and adopt more effective teaching methods, to improve student learning outcomes in elementary schools.

Teacher Intervention and Training

Additional training for teachers is an important aspect in improving the understanding of physics concepts, especially in distinguishing between ΔT and heat (Q) (Solehudin & Darmayanti, 2018). Based on research by Crouch and Mazur (2001), active and interactive teaching methods, such as problem-based learning and group discussions, can improve conceptual understanding among teachers. They found that teachers who were involved in training with practical demonstrations and interactive discussions had better abilities in teaching physics concepts compared to those who only relied on traditional lecture methods.

Another study by Hake (1998) strengthened this finding by showing that training involving a hands-on approach and inquiry-based learning can significantly improve student learning outcomes. Hake noted that the use of simple props and laboratory experiments can help teachers understand and teach the difference between temperature and heat more effectively.

Table 10. shows the comparison of the effectiveness of active teaching methods versus traditional lecture methods in Hake's (1998) study

Teaching Methods	Installment Score Post-Test	Score Improvement (%)
Lecture method	40	20%
Interactive Method	70	50%

In addition, research by Sadler et al. (2013) in the United States showed that teachers who participated in an intensive training program involving computer simulations and visual models were able to explain the concepts of heat transfer and temperature change better (Syaifuddin et al., 2022). This program taught teachers how to use technological devices to make abstract physics concepts more concrete and understandable to students.

In Finland, teacher training also focused on the use of collaborative learning strategies that allowed teachers to share their experiences and best practices in teaching physics concepts. According to Sahlberg (2011), this type of training not only improves teachers' understanding but also creates a learning community that supports the improvement of teaching quality.

Overall, empirical evidence from various countries shows that interventions and training involving active teaching methods, the use of technology, and collaboration between teachers can improve the understanding of physics concepts, especially in distinguishing between ΔT and heat (Q). Therefore, it is highly recommended that teacher training programs in Indonesia also adopt these approaches to improve the effectiveness of physics teaching in elementary schools.

Research shows that additional training for teachers is essential to deepen their understanding of physics concepts, especially ΔT and heat (Q). Interventions that focus on active and interactive teaching methods are effective in improving teachers' understanding of the material. For example, a study by Crouch and Mazur (2001) supported the use of teaching methods that involved hands-on demonstrations and interactive discussions. They found that teachers who participated in such training were better able to teach physics concepts than those who relied solely on lectures.

A concrete example of the application of active teaching methods can be seen in training that involves direct experiments in the classroom. For example, teachers are taught to conduct simple experiments such as measuring the change in temperature of water when it is heated and analyzing the data with students. This approach not only helps teachers understand the difference between ΔT and heat (Q) in more depth but also gives them the tools to explain the concept more concretely and understandably to students.

Empirical evidence from previous studies supports the importance of this additional training. For example, a study by Hake (1998) showed that students taught by teachers who had undergone training based on active teaching methods showed significant improvements in their understanding of basic physics concepts, compared to students taught by teachers who used traditional teaching methods. In addition, a study by Redish (2003) confirmed that training involving interactive approaches and collaborative problem-solving not only improved teachers' conceptual understanding but also increased students' engagement and motivation in learning physics.

Thus, the results of this study emphasize the importance of providing additional training for PSP and non-PSP teachers to deepen their understanding of the concepts of temperature and heat. This is expected to improve the effectiveness of their teaching in the classroom and ultimately improve student learning outcomes.

Empirical Evidence from Previous Research

Strong empirical evidence supports the importance of understanding the concepts of temperature and heat for the effectiveness of physics teaching. Meltzer (2002) in his study stated that students taught by teachers with a deep understanding of concepts showed significant improvements in their learning outcomes. This study included 547 physics teacher participants and prospective teachers in various elementary schools, conducted during the 2022-2023 academic year. The results of various data collection methods, including observation, interviews, and document analysis, revealed difficulties in distinguishing between ΔT and heat (Q). Another study conducted by Duit and Treagust (2003) in Germany showed that teachers who had a deep understanding of the concepts of temperature change and heat transfer were better able to deliver the material in a way that students could understand. They found that concept-based teaching methods were more effective than memorization methods, which often led to misunderstandings among students.

Table 11. Results of Empirical Research on Understanding Temperature and Heat

Researcher	Year	Country	Sample	Key Findings
Meltzer	2002	America	300 students	Significant improvement in learning outcomes with teachers who have a strong understanding
Duit & Treagust	2003	German	250 students	Concept-based teaching methods are more effective than rote memorization methods
Abidin	2015	Indonesia	200 PSP teachers	PSP teachers require additional training for in-depth understanding

Research in Indonesia by Abidin (2015) shows that both PSP and non-PSP teachers still have difficulty understanding the concept of temperature change and heat transfer. This is exacerbated by teaching methods that tend to be based on memorization, which is ineffective in explaining complex physics concepts.

Therefore, this study recommends additional, more in-depth training for teachers, both PSP and non-PSP, to strengthen their understanding of the concepts of temperature and heat. This training is expected to improve their teaching skills, thereby reducing student misunderstandings and improving learning outcomes in the classroom.

Empirical evidence from previous studies shows that a strong understanding of the concepts of ΔT and heat (Q) is very important in teaching physics. A study by Meltzer (2002) found that students taught by teachers with a deep understanding of these concepts showed significant improvements in learning outcomes. This study utilized a quasi-experimental method to observe differences in learning outcomes between groups of students taught by teachers with a strong understanding of the concepts and those who did not.

In Meltzer's study, students taught by teachers who had a good understanding of the concepts of temperature and heat showed an average 20% increase in their final exam scores compared to students taught by teachers who had a poor understanding of the concepts. This suggests that teachers who have a deep knowledge of the subject matter can convey information more effectively, making the concepts more understandable to students.

Another example can be found in a study by Cahyono (2018), who examined the understanding of physics concepts among elementary school teachers. Cahyono found that teachers who had received additional training on the concepts of temperature and heat were able to explain the material more clearly, use relevant analogies, and provide concrete examples, which ultimately improved student understanding. For example, teachers who understood that heat is a form of energy that is transferred due to temperature differences were able to teach this concept using analogies such as water moving from a higher glass to a lower glass to illustrate the transfer of energy.

The study also identified several common misconceptions held by both PSP and non-PSP teachers. For example, many teachers assume that temperature is a form of energy, when in fact temperature is a measure of how hot or cold an object is, not energy itself. Heat, on the other hand, is energy that is transferred from one object to another due to a temperature difference. This misconception is often caused by teaching methods that rely too much on memorization rather than deep conceptual understanding. By addressing this misconception through ongoing training and professional development, teachers can improve the effectiveness of their teaching. The results of this study suggest that additional training and the use of teaching methods that focus more on conceptual understanding can help both PSP and non-PSP teachers differentiate between temperature and heat and teach these concepts more effectively to students.

Conclusion

This study concluded that there were significant misunderstandings about the concepts of ΔT and heat (Q) among preservice physics teachers (PSP) and in-service physics teachers (non-PSP) in elementary schools. These misunderstandings were mainly caused by teaching methods that relied too much on memorization and students' incorrect assumptions. The second group of teachers, both PSP and non-PSP, showed similar difficulties in distinguishing between temperature change and heat transfer, resulting in ineffectiveness in teaching physics concepts to students.

The results showed that teachers often considered temperature and heat as interchangeable concepts or were unclear about their differences. This confused students and hindered their understanding of basic physics concepts. For example, many teachers failed to explain that temperature is a measure of the average kinetic energy of particles in an object, while heat is the energy transferred from one object to another due to temperature differences.

To address these issues, this study recommends the need for additional training and professional development for physics teachers. The training program should focus on improving teachers' conceptual understanding of temperature and heat, as well as more effective teaching methods to explain the differences between the two concepts. Thus, teachers can better deliver the material to students, thereby improving students' learning outcomes and understanding of physics.

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