Contemporary Mathematics and Science Education
2023, 4(2), ep23023
ISSN 2634-4076 (Online)
https://www.conmaths.com/

Research Article

OPEN ACCESS

Undergraduate physics students' understanding of thermal phenomena in everyday life

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Citation: Stylos, G., & Kotsis, K. T. (2023). Undergraduate physics students' understanding of thermal phenomena in everyday life. *Contemporary Mathematics and Science Education*, 4(2), ep23023. https://doi.org/10.30935/conmaths/13406

ABSTRACT

This paper presents the results from postgraduate students in the physics department at University of Ioannina in Greece about their perceptions of thermal phenomena. For this purpose, an open-ended questionnaire comprised questions about heat transfer and conductance in everyday life. The results showed that many students need clarification about the various concepts of thermal phenomena and demonstrate the conflict between everyday experience and scientific models in explaining phenomena.

Keywords: misconceptions, thermal phenomena, department of physics students

Received: 27 May 2023 ◆ Accepted: 09 Jun 2023

INTRODUCTION

Sciences are a complex and broad scientific field and research in science education. It is full of misconceptions and difficulties for pupils and students in their learning (Garbett, 2011). These misconceptions are persistent and difficult to change in conjunction with the traditional practices teachers use in their teaching. This results in many students at all levels of education, from primary to tertiary education, approaching and explaining everyday phenomena and situations based on their alternative understandings (Chu et al., 2012; Kotsis et al. 2023). Heat and generality thermodynamics are important topics in the teaching of physics because they are fundamental concepts for areas such as energy and mechanics and are applied to many areas of chemistry, physics, and technology (Adadan & Yavuzkaya, 2023).

According to Hewitt (2002), the temperature is proportional to the average kinetic energy of the molecules. Furthermore, when two bodies of different temperatures come into contact, energy (heat) flows from the body with the higher temperature to the body with the lower temperature. Therefore, heat is the energy transferred from one body to another due to their different temperatures. It ceases to be heated when transferred, and as a body does not contain work, it does not contain heat (Halliday et al., 2013). The literature review showed that many students have misconceptions about heat and temperature, such as heat and temperature are the same, heat depends on the temperature of the object, heat is not energy, bodies contain heat, etc. (Alwan, 2010; Georgiou & Smalma, 2012; Stylos et al., 2021). The most important thing about these concepts is that they can be useful in the everyday life of students and teachers (Kruatong et al., 2006).

Based on the same scientific interpretation, this paper investigates the students' perceptions of thermal phenomena and their conceptual connections in similar everyday situations.

METHODOLOGY

Research Tool

Two-question scenarios of the research tool (open-ended questionnaire) come from the Greek adaptation of the corresponding questionnaire by Georgiou and Sharma (2011). The students were asked for each scenario to choose the concept (among five concepts) that is conceptually connected to each case and then to justify their choice. The two scenarios are, as follows:

1. **Scenario 1.** When we walk barefoot on tiles, we feel a significant cold sensation compared to when we walk on carpets.
2. **Scenario 2.** On a very hot summer day, Konstantinos decides to buy a soft drink, which comes in two packages, glass and plastic. He chooses the soft drink that feels the coldest. His choice is the soft drink with the glass packaging.

The concepts they had to choose were cold transfer, conduction, heat transfer, insulation, and temperature.

Sample

The research population is 51 second-year students of department of physics at University of Ioannina who have yet to be taught heat concepts in the undergraduate program context.

Table 1. Number of responses to selected concept & scientific interpretation for scenario 1

	Scenario 1 (frequencies)	
Selected concept	**Choice concept**	**Scientific interpretation**
Cold transfer	1	-
Conductance	7	1
Heat transfer	34	15
Insulation	3	-
Temperature	6	1

Table 2. Number of responses to selected concept & scientific interpretation for scenario 2

	Scenario 1 (frequencies)	
Selected concept	**Choice concept**	**Scientific interpretation**
Cold transfer	2	-
Conductance	24	6
Heat transfer	8	2
Insulation	10	2
Temperature	5	-

Validity and Reliability of Research

Two coders were used to check the reliability of the measurement (Bonidis, 2004). The degree of agreement between coders was tested with Cohen's kappa index and was estimated at 0.95 on a sample of 10 questionnaires using Atlas. The validity of the questions was ensured through the pilot application on five physics department students during which it was found that each question explores what was originally defined.

RESULTS

Connections Between Chosen Concept & Scientific Standard

The number of students who chose the correct concepts and formulated the corresponding explanations in line with the scientific standard in both scenarios was only six. These students chose heat transfer or conduction concepts, and their explanations did not show contradictory interpretations.

In the first scenario, many students (43) choose the correct concepts that are directly related to the case, with most of them choosing heat transfer (34) and fewer of them choosing conduction (seven). However, less than half (16) interpret and connect the above concepts successfully with the scientific standard (**Table 1**).

In the second scenario, the frequency of correct selection of the concept is realized by only 32 students. Fewer than the first scenario chose heat transfer (eight), as most of them (24) used the concept of conduction. Only eight interpret the phenomenon according to the scientific standard (**Table 2**).

The choice of concept is not simply the scientific concept it represents. It involves a complex relationship between students' understanding of the concept and their views on the appropriateness of the concept in each scenario (Georgiou & Sharma, 2011). According to sociocultural theory, choice, and corresponding explanation incorporate the interrelationship between two cultural situations that a student brings to the classroom, the situation of their own experiences and the situation of scientific explanation (John-Steiner & Mahn, 1996). Also, the result shows how scientific concepts conceal different underlying understandings by students in similar everyday contexts.

Alternative Perceptions

The alternative perceptions of the students are in line with those recorded in the international and Greek literature both in university students (Chiou & Anderson, 2010; Gavrilas et al., 2022; Georgiou & Sharma, 2011; Kotsis et al., 2023; Olympiou & Zacharias, 2009; Stylos et al., 2021) and in high school students (Tsichouridis et al., 2009) as well in pre-service primary education teachers (Gavrilas & Kotsis, 2023; Kotsis & Kotsinas, 2011; Stylos et al. 2023; Vavoulioti et al. 2023). In particular, heat exhibits characteristics of substance, appears with two entities (heat and cold), and depends on certain characteristics of the body (composition, size) (Skoumios & Xatzinikita, (2000). Also, cold can be transferred, and temperature is transferred. Finally, several students explain the above phenomena regarding the properties of bodies and the action of one body on another. Next, some students' answers are presented, highlighting their misconceptions, and categorized according to their content.

Material's Characteristics:

> "The composition of the material is appropriate."
>
> "I think that because the carpet is made of a different material than the tile and because of the smooth surface, heat is transferred more easily from the foot, which is perceived as colder when they are the same temperature."
>
> "Heat transfer due to different material and smooth surface."
>
> "The thickness of the glass of the bottle is much greater than that of the plastic packaging. So, the temperature of the glass is maintained for a longer period at the same temperature conditions."
>
> "Glass, unlike plastic, freezes if placed at low temperatures."
>
> "Glass is a better insulating material than plastic."
>
> "It may be because the different materials and the shape of the surface above are to blame for the different sensations because heat is transferred from our body to the material in a different way, but it may also be a matter of insulation."

Temperature transfer

> "As he walks barefoot, he transfers his temperature to the tiles and takes the temperature from the cold tiles."
>
> "Glass transfers the temperature better, so we have a cold transfer."
>
> "Glass packaging will keep the soft drink colder because it does not absorb the sun as much as plastic."
>
> "Glass is a better conductor of heat."
>
> "Bodies have a different temperature than the room, and this happens due to heat transfer."

Cold transfer

> "Transfer of cold because the glass on the bare hand radiates more temperature (cold), so it feels colder."

"Our body has a different temperature than the tiles, and that is why when the surface of the foot comes into contact with the tiles with a lower temperature, cold is transferred to balance the system."

"The tiles are cold and therefore transfer the cold to the feet, while the carpet is warmer and transfers its temperature."

"Transfer of cold because the glass on the bare hand radiates more temperature (cold), so it feels colder."

"... therefore, since plastic and glass are two different materials, heat (cold) passes through glass faster."

Heat transfer from cold to hot

"Heat is transferred from colder to hotter."

"Both have the same temperature, but the glass absorbs heat more slowly than the tin."

"I believe that we have heat transfer in this particular example from the cold body (tiles) in relation to the hot body (human body), which is a basic principle of thermodynamics (knowledge from school)."

Insulating properties

"Logically, both soft drinks are at the same temperature, but the plastic has better insulation, so Constantine cannot feel cold when he touches it."

"Plastic is used as an insulator."

"Glass is better insulated than plastic."

"Glass is a better insulating material than plastic."

"Because the carpet holds the heat."

"Glass packaging is a better insulator of temperature, as a result of which it keeps the soft drink frozen longer than plastic packaging."

"... because the carpet is an insulator of heat."

Bodies in same conditions at different temperatures

"Tiles have a lower temperature than carpets."

"If we leave both materials (glass and plastic) at the same temperature, e.g., in the refrigerator, then the glass will reach a lower temperature because it may behave more like a conductor of cold."

"The temperature is lower on the tile's surface and higher on the carpet."

CONCLUSIONS

This work shows that most students need to have better perceptions about thermal phenomena. Their daily experience with the world causes conflict and the development of alternative conceptual models for interpreting everyday phenomena when asked to explain a thermal phenomenon, leading to incorrect interpretations (Georgiou & Sharma, 2011; Vosniadou, 1994). It also highlights students' wide range of ideas in a familiar situation and the importance of exploring alternative perceptions thoroughly. Promoting understanding of thermal phenomena can be achieved by investigating what students do, what they do not understand, and why (Georgiou & Sharma, 2011) so that these are considered during teaching approaches.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Acknowledgments: The authors would like to thank all students of the department of physics at University of Ioannina who participated in this research.

Ethics declaration: Authors declared at the beginning of each questionnaire that the questionnaires were anonymous and the findings will be used exclusively for research purposes. Authors further declared that the issues of voluntary participation, privacy and confidentiality were explained to participants, and that their informed consents were obtained before their participation.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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