RESEARCH ARTICLE

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# Students' Perceptions of the Heat and Temperature Concepts: A Comparative Study between Primary, Secondary, and University Levels

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**ABSTRACT**

**One of the fundamental problems that can impede the achievement of a sound understanding of a scientific concept is misconception. This study examines students' perceptions of the concepts related to heat and temperature and how they evolve during the various levels of education. The findings from the literature review of students' perceptions of heat issues combined with the results of this research, as obtained through the responses of students of primary, secondary, and tertiary education in Greece regarding the problems of temperature and heat, permitted the identification of alternative ideas of students for this conceptual area.**

**Keywords:** heat, misconceptions, temperature, thermal phenomena.

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## I. INTRODUCTION

Scientific literacy is one of the significant goals of science education (Stylos *et al.*, 2023; Suwono *et al.*, 2022). Scientific literacy is characterized as the individual's primary skill to cultivate scientific knowledge (Osborne *et al.*, 2004). This skill is divided into three sub-systemic skills, which focus on (a) Explaining natural and technological phenomena in a scientific way, (b) Evaluating and designing an epistemic investigation, and (c) Interpreting data and evidence, evaluating arguments, and drawing conclusions (OECD, 2016). While many features of scientific literacy have been determined, "the understanding of science concepts and level of mastery of conceptual science knowledge remains the central focus" (Wendt & Rockinson-Szapkiw, 2014, p. 1103).

Over the last four decades, studies have shown that school and university students hold misconceptions and low levels of understanding about the physical world and how it works (Chu *et al.*, 2012; Duit, 2009; Kotsis & Stylos, 2023a; Kotsis & Stylos, 2023b; Osborne & Freyberg, 1985, Panagou et al., 2022; Pantazis et al., 2021; Stylos *et al.*, 2008, Stylos *et al.*, 2021). About concepts of thermodynamics, they constitute a fundamental domain of science. According to Stylos *et al.*, (2021) review, these concepts are abstract, complicated, less transparent, and relate to many applications and real-life situations. However, many researchers have demonstrated that students have misconceptions about many aspects of thermodynamics such as heat, temperature, heat transfer, thermal properties, insulators, conductors, and thermal equilibrium.

Indicatively, students believe that heat and temperature are the same (Stylos *et al.*, 2021), the temperature can be transferred from one body to another (Adadan & Yavuzkaya, 2018), materials such as wood can warm things up (Schnittka & Bell, 2011), the terms "hot" and "cold" are different, not at opposite ends of a continuum in two disparate situations (Chu *et al.*, 2012). Regarding boiling, students believe that the temperature of boiling water is always 100°C (Kácovský, 2015) and the bubbles in the boiling water contain "oxygen," "hydrogen," and "air" (Senocak, 2009). In freezing and melting, students support that water cannot be at 0°C, and ice is always at 0°C regardless of external conditions. Finally, in thermal equilibrium and conductivity, students ignored that different materials have different heat conductivities in a state of thermal equilibrium (Stylos *et al.*, 2021).

There needs to be more work done, especially in the Greek context, on misconceptions about heat and thermodynamics. This prompted us to undertake a study in this area. The teacher is viewed as an ultimate authority in a typical Greek classroom. The student accepts the explanation of a concept delivered by a teacher as it is. One of the important reasons for this is the examination-driven system, which depends heavily on memory and recall skills and underemphasizes understanding. Teachers often need to give students an overview of the topic necessary to understand. This may lead to the formation of alternative models different from the relevant scientifically accepted models.

In this context, the present study investigates the misconceptions of Greek students in the three levels of education (primary, secondary, and tertiary) and how these ideas evolve as the students pass from one level to the next.

## II. Methods

### A. Participants

A random sampling method selected 486 students enrolled in the three levels of education in the Epirus region (Northwestern Greece). One hundred four (104) sixth-grade students were from a state primary school, 118 were from a Lower Secondary School, 102 were from an Upper Secondary School, and 104 third-year students were from the Physics Department of the University of Ioannina.

### B. Research Instrument

The questionnaire includes 13 multiple-choice questions with only one correct answer for each question. Questions used have been taken from research questionnaires TIMSS, MCAS (Massachusetts Comprehensive Assessment System) high school Introductory Physics test, and Thermal Concept Evaluation-TCE (Yeo & Zadnik, 2001).

## III. Results-Discussion

All the questions are presented in the following, and an interpretation of the participants' responses is also attempted. The question gives the research results in tables of students' responses per class. Each question is compared by class and by discussion of response.

### A. Thermal phenomena

*Question 1*: 200gr of water boils at 100ºC. If we have 400gr of water, at which temperature does it boil?

A. 50ºC,
B. 100ºC,
C. 200ºC.

The purpose of those questions was to reveal the students' perception of the boiling point of water. The first question is designed to determine whether students understand that water's boiling point is independent of the quantity. The results are presented in Table I.

TABLE I: Students' Answers to Question 1

| | A:50ºC (%) | B: 100ºC (%) | C: 200ºC (%) |
|---|---|---|---|
| Elementary | 0.00 | 86.80 | 13.20 |
| Secondary school | 3.50 | 56.10 | 40.40 |
| High school | 0.00 | 60.80 | 39.20 |
| University | 0.00 | 92.20 | 7.80 |

As can be seen from the Table I, most elementary students (86.8%) have answered correctly, probably because they are not familiar with numerical methods that will lead to A or C option, and they have accepted as an established knowledge that the boiling point of water corresponds to a temperature of 100°C. In this case, notice that math knowledge gained by lower and upper secondary schools has caused more confusion. Instead of using existing knowledge, students calculate the temperature of boiling water about its quantity of it. Those students believed a body's temperature was related to its size or the amount of stuff present, so they thought a more significant amount of water boils at a higher temperature. Furthermore, 56.10% of lower secondary education students, 60.80% of high school students, and most third-year students in Greek Physics Departments answered correctly (92.20%). Students who have responded to 200°C consider that the boiling point of water depends on the quantity. Similar results have also been reported by Andersson (1979).

*Question 2*: A student takes six ice cubes from the freezer and puts them into a glass of water. He stirs until the ice cubes are much smaller and have stopped melting. What is the most likely temperature of the water at this stage?

A. -10ºC,
B. 0ºC,
C. 5ºC,
D. 10ºC.

The results are presented in Table II. The answers to this question point out that many students must understand that water can exist at 0ºC. More specifically, 69.20% of elementary, 41.30% of secondary school, 28.00% of high school, and 52.90% of university students consider that the water temperature in the glass with ice cubes can be greater than 0ºC.

TABLE II: Students' Answers to Question 2

| | A: -10ºC (%) | B: 0ºC (%) | C: 5ºC (%) | D: 10ºC (%) |
|---|---|---|---|---|
| Elementary | 5.80 | 25.00 | 69.20 | 0.00 |
| Secondary school | 12.10 | 46.00 | 29.20 | 12.10 |
| High school | 8.00 | 64.00 | 20.00 | 8.00 |
| University | 0.00 | 47.10 | 35.30 | 17.60 |

These students answered options C or D and have yet to understand that there is a thermal equilibrium between the water and the ice cube. Students instinctively believe that ice is colder than water and have difficulty understanding that the temperature at which water freezes and the temperature at which ice melts are the same. It is worth mentioning that although most of the university participants chose the correct temperature, this percentage (47.10%) is considerably lower than that of high school students (64.00%). Secondary education pupils and third-year students of the Physics Department can know that it is possible in a mixture of water and ice, in which the water does not freeze, and ice has stopped melting, there can be no energy flow, and therefore both be in thermal equilibrium at the same temperature. The evidence is strong that most students have not understood that the temperature remains constant as long as the ice melts. Instead, most of them believe that the temperature increases. These conclusions are identical to another research (Carlton, 2000; Stylos *et* *al*., 2021; Yeo & Zadnik, 2001).

*Question 3*: The diagram represents the arrangement of particles in a metal before it has been heated (Fig 1).

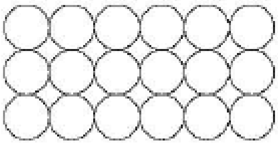
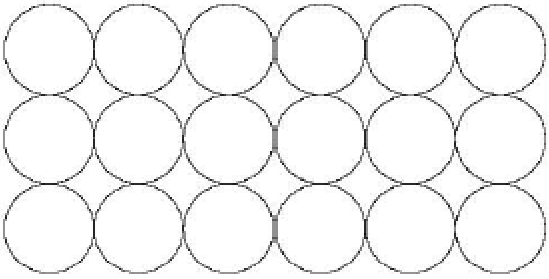


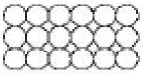
Fig. 1. Particles in a metal before it has been heated.

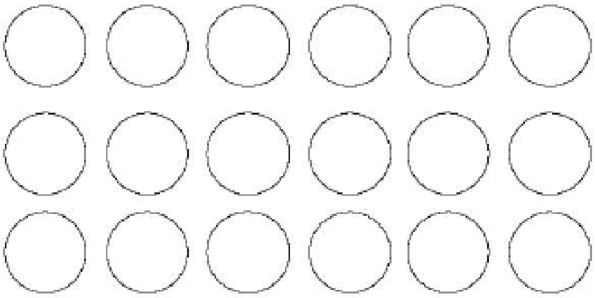
Which diagram represents the arrangement of particles in the metal after it has been heated (Fig 2)?



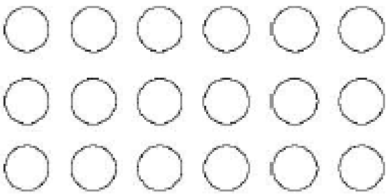
A.

B.





C.



D.

Fig. 2. A, B, C and D. Particles in the metal after it has been heated.

The purpose of selecting the above problem is to record students' perceptions about phenomena that are accompanied by changes in temperature. The size of the above diagrams shows the different ways of metal expansion. Thus, the sixth question refers to metal expansion after a temperature increase. The results are presented in Table III.

The analysis shows that the minority of students in elementary school, secondary school, and high school (percentages 0%, 8.80%, and 27.50%, respectively) answered correctly.

TABLE III: STUDENTS' ANSWERS TO QUESTION 3

| | Diagram A (%) | Diagram B (%) | Diagram C (%) | Diagram D (%) |
|---|---|---|---|---|
| Elementary | 6.10 | 6.10 | 87.80 | 0.00 |
| Secondary school | 19.80 | 22.80 | 52.60 | 8.80 |
| High school | 19.60 | 19.60 | 33.30 | 27.50 |
| University | 15.70 | 0.00 | 17.60 | 66.70 |

Three alternative ideas are extracted from the wrong answers. The most popular opinion among students of all ages is that metal expands because the particles of metal expand, and at the same time, the distance between the particles increases. These students have answered option C. The second alternative idea, which fewer students embrace, is that the particles of metal expand, so the metal expands. These students have answered option A. Finally, some secondary school students consider that the metal will be thermally stressed after heating by answering choice B.

*Question 4*: We wrap a cotton ball on the edge of a thermometer and note the temperature. We throw alcohol of the same temperature on cotton, and after a while, we report the new temperature. The new temperature compared with the initial one is:

A. Same.
B. Less.
C. Greater.

The purpose of this question is to determine whether students have understood that evaporation is a cooling process. The results are presented in Table IV.

TABLE IV: STUDENTS' ANSWERS TO QUESTION 4

| | A: Less (%) | B: Same or Greater (%) |
|---|---|---|
| Elementary | 23.40 | 76.60 |
| Secondary school | 35.10 | 64.90 |
| High school | 33.30 | 66.70 |
| University | 55.10 | 44.90 |

There is a low percentage of primary school pupils (23.40%) who have understood that when a liquid evaporates, it cools. A slight deviation of the correct answer between secondary and high school students is observed (35.10% for lower secondary school and 33.30% for upper secondary school). However, at this level of education, the question reflects on the state of knowledge of students, and the percentage of correct answers should have been higher. As for the physics department students, although 55.10% have responded that the temperature of the thermometer is less than the original, this rate is relatively low for their level of education.

*Question 5*: When a small volume of water is boiled, a large volume of steam is produced. Why?

1) The molecules are further apart in steam than in water.
2) The change from water to steam causes the number of molecules to increase.

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3) Atmospheric pressure works more on water molecules than on steam molecules.
4) Water molecules repel each other when heated.

The above question is designed to record students' alternative ideas about the phase change of water from liquid to vapor. Based on the results depicted in Table V, in elementary school, most students (50%) believe that water molecules repel each other when heated because they chose option D. The popularity of this opinion does not seem to change with the age of the students, because as noted from previous figures, both secondary school students and high school students share this alternative concept with students at elementary school, (percentages 35.70% and 21.60% respectively).

TABLE V: STUDENTS' ANSWERS TO QUESTION 5

| | Answer A (%) | Answer B (%) | Answer C (%) | Answer D (%) |
|---|---|---|---|---|
| Elementary | 4.80 | 11.90 | 33.30 | 50.00 |
| Secondary school | 12.50 | 12.50 | 39.30 | 35.70 |
| High school | 43.10 | 19.60 | 15.70 | 21.60 |
| University | 56.90 | 7.80 | 15.70 | 19.60 |

What also should be considered is that a relatively high percentage of students in tertiary education (19.60%) share the same philosophy as younger students.

Another alternative idea is that the large volume of steam during the phase change of water is because atmospheric pressure affects water molecules resulting in a decrease in their volume. This perception is more prevalent among elementary and secondary school students (percentages 33.30% and 39.30%, respectively). It is maintained among high school and university students at lower rates for both (15.70%).

Another student's misconception is that the change from water to steam causes the number of molecules to increase with percentages of 11.90%, 12.50%, 19.60%, and 7.80% for each grade.

### B. *Thermal Equilibrium*

Question 6: In a closed room, there is a wooden staircase, a marble floor, and a woolen carpet. Which of these is the lowest temperature?

A. All have the same temperature.
B. The carpet.
C. The staircase.
D. The floor.

The results are presented in Table VI.

TABLE VI: STUDENTS' ANSWERS TO QUESTION 6

| | A: All have the same temperature (%) | B: The carpet (%) | C: The staircase (%) | D: The floor (%) |
|---|---|---|---|---|
| Elementary | 1.90 | 0.00 | 0.00 | 98.10 |
| Secondary school | 10.00 | 5.20 | 8.60 | 67.20 |
| High school | 39.20 | 2.00 | 0.00 | 58.80 |
| University | 51.00 | 3.90 | 0.00 | 45.10 |

At the early teaching of heat, primary school children learn not to evaluate the temperature based on their senses. From the analysis of responses, many students in elementary school, secondary school, and high school (percentages 98.00%, 67.20%, and 58.80%, respectively) answered relying on everyday experience. In students' minds, experience rather than knowledge prevails; Thus, they need to realize that they should not rely upon their senses to make a correct choice on this issue. Students' responses indicate the association of the temperature of an object with the feeling of hot or cold. Students instinctively believe that the floor is colder than the carpet and have difficulty understanding the thermal equilibrium. According to most students, objects in thermal equilibrium with their environment acquire different temperatures. Moreover, the students consider that temperature is a property of materials, and it is not recognized as a physical factor that can describe the state of an object. Summarizing the results obtained by the question seems that most students also do not recognize that the same object can acquire different temperatures, and thus categorize the objects as always low temperatures exclusively and those that only have higher temperatures. Similar results have also been reported (Adadan & Yavuzkaya, 2018; Chu *et al*., 2012; Harrison *et al*., 1999; Skoumios, 2005; Stylos *et al*., 2021).

*Question 7*: A student takes a can of cola and a plastic bottle of cola from the refrigerator, where they have been overnight. He quickly puts a thermometer in the cola in the can. The temperature is 7°C. What are the most likely temperatures of the plastic bottle and cola?

A. They are both less than 7°C.
B. They are both equal to 7°C.
C. They are both greater than 7°C.
D. The cola is at 7° C, but the bottle is greater than 7°C.
E. It depends on the amount of cola and/or the bottle size.

The question aims to ascertain whether students understand the concept of thermal equilibrium between objects in the same environment. The results are presented in Table VII.

TABLE VII: STUDENTS' ANSWERS TO QUESTION 7

| | A (%) | B (%) | C (%) | D (%) | E (%) |
|---|---|---|---|---|---|
| Elementary | 10.00 | 8.00 | 0.00 | 6.008 | 14.00 |
| Secondary school | 17.90 | 21.40 | 12.50 | 16.10 | 32.10 |
| High school | 7.80 | 33.30 | 9.80 | 39.20 | 9.80 |
| University | 6.30 | 43.80 | 8.30 | 29.20 | 12.50 |

Many primary school pupils believe that the temperature of an object when it is long enough in an environment depends on a single characteristic of this object and, more specifically, its composition. Those students (68%) answered that the cola is at 7° C, but the bottle is greater than 7°C. In students' minds, their sense of hot or cold, which they feel when they touch objects in thermal equilibrium, shall be equivalent to high or low temperature. For example, students who believe plastic is "naturally warmer than metal" will not accept that plastic and metal containers taken from the refrigerator can be at the same temperature. Thus, they consider that different senses equal with different temperatures, a conclusion that was also found by: Tiberghein (1985), Appleton (1985), Erickson (1979), Frenkel & Strauss (1985), Lewis (1994), Skoumios

(2005). Those students who can distinguish between an insulator and/or conductor often state that an insulator is "something that keeps things hot" and a conductor is "something that keeps things cold." Children learn early that plastic objects are "insulators" and that, in cool environments, they feel warm. It is a reasonable next step to conclude that insulators are hot or have some property that allows them to remain warmer than other materials in the same environment.

Mainly secondary school students (32.10%) cannot predict the final temperature of the cola and the bottle because they don't know the amount of cola and/or the size of the bottle. Although the temperature is an intensive rather than an extensive variable, children do not take this into account to give answers. A common perception is also that the temperatures of objects would be either less than 7°C or higher. Those who have chosen these answers do not further understand the concept of thermal equilibrium. These results are like those obtained in other studies (Adadan & Yavuzkaya, 2018; Chu *et al.*, 2012; Stylos *et al.*, 2021; Yeo & Zadnik, 2001).

### C. *Heat Transfer*

*Question 8*: A metal spoon, a wooden spoon, and a plastic spoon are placed in hot water.

After 15 seconds, which spoon feels hotter?

A. The metal spoons,
B. The wooden spoon,
C. The plastic spoons,
D. The three spoons will feel the same.

The results are presented in Table VIII.

TABLE VIII: STUDENTS' ANSWERS TO QUESTION 8

| | A: The metal spoon (%) | B: The wooden spoon (%) | C: The plastic spoon (%) | D: The three spoons will feel the same (%) |
|---|---|---|---|---|
| Elementary | 94.30 | 3.80 | 0.00 | 1.90 |
| Secondary School | 86.40 | 3.40 | 1.70 | 8.50 |
| High School | 90.20 | 2.00 | 3.90 | 3.90 |
| University | 94.00 | 0.00 | 0,00 | 6.00 |

This question is related to the feeling created by the conductors and insulators of heat. The answers elicited, in conjunction with those referred to previously, indicate that 94,3%, 86,4%, 90,2%, and 94% of students from each grade answered correctly. This question was used due to the absence of an interview to ensure reliable results to the extent that they trust their senses in such cases. The children show that they have learned, by experience, that certain things feel warm to the touch and others feel cold; the notion of heat as a substance that could be found in objects was prevalent. Thus, the link is made between heat and the material from which an object is made. They not only properly trust their senses, but also think the same way when attempting to estimate an object's temperature.

*Question 9*: Which of the following figures correctly shows the conduction of heat within the system of metal blocks (Fig 3)?

This question aims to bring out the perceptions of students about heat transfer. The results are presented in Table IX.

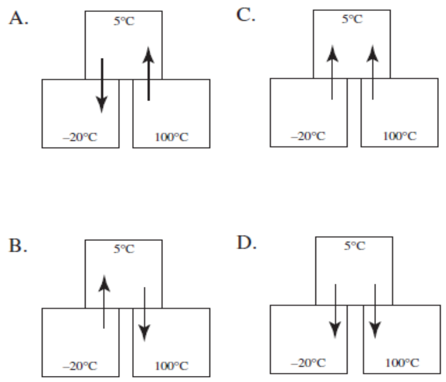


Fig. 3. Systems of metal blocks.

TABLE IX: STUDENTS' ANSWERS TO QUESTION 9

| | Figure A (%) | Figure B (%) | Other (%) |
|---|---|---|---|
| Elementary | 54.20 | 29.20 | 16.70 |
| Secondary school | 35.70 | 28.60 | 35.70 |
| High school | 54.00 | 38.00 | 8.00 |
| University | 87.70 | 12.20 | 2.00 |

The evidence indicates that most students at all levels recognize that the heat flows from the high to the low-temperature region (54.20% and 35.70%, 54.00%, 87.70% for elementary, secondary school, high school, and physics department students, respectively). However, many students have the alternative idea that heat transfer takes place in the opposite direction, i.e., from the metal cube with the lowest temperature to the metal cube with the highest temperature.

*Question 10*: A student takes a metal ruler and a wooden ruler from his pencil case. He announces that the metal one feels colder than the wooden one. What is your preferred explanation?

A. Metal conducts energy away from his hand more rapidly than wood.
B. Wood is a naturally warmer substance than metal.
C. The wooden ruler contains more heat than the metal ruler.
D. Metals are better heat radiators than wood.
E. Cold flows more readily from metal.

The question relates to conductors and insulators and is designed to bring out students' alternative conceptions of heat. The results are presented in Table X.

TABLE X: STUDENTS' ANSWERS TO QUESTION 10

| | A | B | C | D | E |
|---|---|---|---|---|---|
| Elementary | 11.50 | 19.20 | 13.50 | 7.70 | 48.01 |
| Secondary school | 16.90 | 32.20 | 11.90 | 15.30 | 23.70 |
| High school | 24.50 | 6.10 | 14.30 | 16.30 | 38.80 |
| University | 60.00 | 4.00 | 6.00 | 16.00 | 14.00 |

As illustrated in the above Table X, 48.10%, 23.70%, 38.80%, and 14.00% of the students from each level preserve the misconception that there are two types of heat, hot heat and cold heat. These students have answered that cold flows more readily from metal, and they believe that cold heat is more powerful and moves faster than hot heat (Stylos *et al.*, 2021). Another misconception of disciples is that hot and cold temperatures are properties of materials. In this case, elementary and secondary school students answered, "wood is a naturally warmer substance than metal" (percentages 19.20% and 32.20%, respectively). They think that metal objects are cold and wooden ones are hot (or at least warm) - when they are at room temperature. That is because they feel hot or cold when they touch objects made of them at room temperature. Metals feel cold because they are good conductors-they take heat quickly away from the body-so the sensors in our fingertips relay the information to the brain that we are losing heat energy from our bodies more quickly than before we touched the object. The converse is true with wood.

Also, some students in percentages 13.50%, 19.50%, 14.30%, and 6.00% from each level consider that "the wooden ruler contains more heat than the metal ruler," which points that they preserve the misconception that temperature is a measure of the heat contained in an object. Finally, several students think metals are better heat radiators than wood," as indicated by Pathare & Pradhan (2010).

*Question 11*: A heated rock is placed in a container of water cooler than room temperature. Which of the following statements best describes what happens?

A. Cold is removed from the water container until the rock, the container, and the water reaches the same final temperature.

B. The heated rock loses heat to the water container until the rock, the container, and the water reaches the same final temperature.

C. The heated rock loses heat to the water container until the rock, the container, and the water reaches a different final temperature.

D. Cold is removed from the water container until the rock, the container, and the water reaches a final temperature lower than their actual temperatures.

In this question, students are asked to combine the heat transfer between two objects in contact and to provide the final temperatures of the three objects qualitatively. The results are presented in Table XI.

TABLE XI: STUDENTS' ANSWERS TO QUESTION 11

| | A (%) | B (%) | C (%) | D (%) |
|---|---|---|---|---|
| Elementary | 28.30 | 22.60 | 30.20 | 18.90 |
| Secondary school | 22.80 | 40.40 | 22.80 | 14.00 |
| High school | 5.90 | 76.50 | 11.80 | 5.90 |
| University | 18.00 | 80.00 | 0.00 | 2.00 |

From these results, we notice that most students who participated in the research have responded correctly, except for the elementary school students. The percentage for each educational level is 22.80%, 40.40%, 76.50%, and 80.00%. Many students correctly predicted only one of the two processes: heat transfer or thermal equilibrium. Students who answered wrong considered that cold is a type of heat, or they couldn't correctly predict the final temperature of the three objects. Considering the above table, there is a significant improvement in the students' views about what happens in this example.

### D. Heat and Temperature

*Question* 12: Two solid metal blocks are placed in an insulated box. The two cubes are in thermal contact, and there is heat flow from one to another. What should be the difference between the two blocks?

A. Initial temperatures.

B. Heat.

C. Melting point.

D. Mass.

The results are presented in Table XII.

TABLE XII: STUDENTS' ANSWERS TO QUESTION 12

| | A: Initial temperatures (%) | B: Heat (%) | C: Melting point (%) | D: Mass (%) |
|---|---|---|---|---|
| Elementary | 26.40 | 52.90 | 7.50 | 13.20 |
| Secondary school | 29.80 | 31.60 | 21.10 | 17.50 |
| High school | 53.00 | 31.40 | 7.80 | 7.80 |
| University | 90.20 | 3.90 | 2.00 | 3.90 |

As the above Table XII illustrates, students have difficulty distinguishing between heat and temperature. This wrong perception may be interpreted as confusion between the terms "heat" and "temperature" because of the etymological root in the Greek language (Thermo), which, however, does not apply to languages like English, French, German, and Italian. As shown above, 26.40%, 29.80%, 53.00%, and 90.20% of students from each grade answered correctly. This alternative idea appears more in young students and less in high school and university informants. Most young students do not understand that Heat is defined as energy, only transmitted by means of a temperature difference. Another conclusion is that students are confused about the concept of heat since 38.27% of the sample of pupils in primary and secondary education have responded that the metal blocks must have "different heats," which shows that they are confused about the concept of heat. The idea that objects "have" or "contain" heat is at odds with scientific opinion. Similar results have also been reported (Phcyxaris *et al*., 2005; Skoumios, 2005). So far, the students have been asked to recognize that when placed in thermal contact, two bodies will eventually reach thermal equilibrium and are at the same temperature.

Furthermore, they should recognize that body A is defined as being at a higher temperature than body B if there is a spontaneous net flow of heat energy from A to B when they are placed in thermal contact. We noticed a significant difference in percentages during students' transition from one level of education to another. This demonstrates that further knowledge that was taught has benefited students.

*Question* 13: After cooking some eggs in boiling water, a student cools them in a bowl of cold water. Which of the following explains the cooling process?

A. Temperature is transferred from the eggs to the water.

B. Cold moves from the water into the eggs.

C. Hot objects naturally cool down.

D. Energy is transferred from the eggs to the water.

This question aims to bring out the perceptions of students about heat transfer. It differs, however, from the previous question because it describes an actual event from everyday life. The results are presented in Table XIII.

The responses revealed two main alternative ideas that students have. Of the pupils of the primary school, 30,80% consider that the temperature is transferred from the eggs to the water.

TABLE XIII: STUDENTS' ANSWERS TO QUESTION 13

| | A | B | C | C |
|---|---|---|---|---|
| Elementary | 30.80 | 44.20 | 7.70 | 17.30 |
| Secondary school | 43.10 | 19.00 | 24.10 | 13.80 |
| High school | 31.40 | 9.80 | 3.90 | 54.90 |
| University | 43.10 | 5.90 | 5.90 | 45.10 |

There is, therefore, confusion between "temperature" and "heat." In this case, students attribute the property to be transferred at the temperature. For students, there is no difference between heat and temperature; They think temperature can flow from one substance to another. Upper secondary school students have the same misconception at similar rates (31.40%), and lower secondary school students and students of the Physics Department support the same with rates of 43.10%.

For cooling the eggs in the water, most primary school pupils (44.20%) believe that "cold moves from the water into the eggs." Students who answered this believe there are two types of heat: cold heat and hot heat. They must think of "heat" as the energy that the particles gain or lose according to temperature differences and "cold" as referring to temperature. These results are similar to other studies (Adadan & Yavuzkaya, 2018; Aiello & Srerandeo, 2000; Stylos *et al*., 2021). Students in secondary school have the same misconception with a percentage of 19.00%, while most of them (24.10%) believe that "hot objects naturally cool down." Only high school students and students of the Physics Department knew the correct answer: "Energy is transferred from the eggs to the water" (percentages 54.90%, 45.10% respectively). We noticed a significant percentage difference during students' transition from high school to university. Considering a previous question, we concluded that students are inconsistent in their explanation; they use different conceptions to explain similar phenomena and generally do not recognize contradictions. Also, they do not apply ideas learned in school to "everyday" situations and express alternatives when explaining real-life situations, as indicated by Yeo & Zadnik (2001).

## IV. CONCLUSION

Summarizing the results obtained from the questionnaires' processing and subsequently decoding pupils' responses, we found that perceptions about the conceptual area of heat remain highly resistant. However, in their transition from one educational level to the next, the students repeat an important part of what has been taught, and they gain additional knowledge. The alternative ideas that emerged after the treatment of responses of the students remained unchanged from elementary to secondary level and were maintained at a lower degree at the University. These findings were expected because the questions included are part of the elementary school's curriculum. From the data processing, it is apparent that everyday experience is a restraining factor in the learning process and for the disciples' perception of thermal phenomena. Therefore, the differentiation of "heat" and "temperature" is necessary because most students consider the two concepts identical.

The findings revealed that most students held alternative heat and temperature conceptions. Many students needed clarification about the concepts of heat and temperature and needed help explaining the differences between heat and temperature. Some students still thought the words "heat" and "temperature" were the same. This finding was likely like the work by Kesidou and Duit (1993), which pointed out students' difficulties in distinguishing heat and temperature in the extensive, intensive framework. Additionally, many students held alternative conceptions that heat is dependent on the object's temperature only because they viewed that higher-temperature objects would have more heat energy (Kruatong *et al*., 2006). Students' ability to tell the difference between heat and temperature and their knowledge of the thermal properties of materials.

Are of primary importance to respond to these questions scientifically (Adadan & Yavuzkaya, 2018).

One of the essential concepts many students held alternative conceptions of was thermal equilibrium. Many of them could state the concept of thermal equilibrium correctly. However, they did not always consider that objects in the same surroundings had the same temperature when they were given new situations. These research studies discussed that confusion is reinforced by the contrast between the cold sensation generated by touching a good conductor such as metal, e.g., a spoon, and the warm feeling by touching an insulator. In contrast, many Greek students held the alternative conceptions of thermal equilibrium, caused by the hot sensation generated by connecting a good conductor and the warm feeling by touching an insulator in the hot air. These results indicate that the students learned by memorizing the concept without fundamental understanding. They faced the problem of transferring the thermal equilibrium concept because their personal experiences resisted the scientific concepts (Kruatong *et al*., 2006).

Children's alternative beliefs arise through interaction with their physical and social environment, including the cultural use of imprecise language (Yeo & Zadnik, 2001). This study has demonstrated how students struggle with ideas that do not fit their world experience. It is, therefore, useful to include everyday knowledge and experiences in instruction for several reasons. First, it encourages the integration of knowledge instead of the isolated "school knowledge" and "everyday" knowledge among students, nonscientists, and even a few scientists. Second, it encourages students to develop alternative explanations for intuitive conceptions consistent with scientific principles. Instruction can ground helpful notions of causality in students' everyday experiences. Additionally, it makes scientific knowledge easier to remember. Students' everyday experiences can serve as prototypes and cueing mechanisms for new intuitive conceptions and more principled understanding (Lewis & Lin, 1994).

In popular speech, the word "heat" has many meanings. It is, therefore, customary for pupils to be taught the distinction between certain of these meanings and to learn the concept of temperature. Unfortunately, this process is often done incompletely, with the two distinct ideas of heat and internal energy remaining undistinguished. A further difficulty may then be caused by ignoring the existence of intermolecular potential energy.

In conclusion, it is understood that the existing ideas and the way of thinking of students about the thermal phenomena and concepts of heat and temperature should be the starting point for teachers' organization of their teaching strategy. This work can be a source of configuration instructional interventions to restructure the alternative ideas of students, especially in the first two levels of education, so that there now appears regression to earlier views.

## Conflict of Interest

Authors declare that they do not have any conflict of interest.

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