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CONCEPTIONS OF PRIMARY SCHOOL STUDENTS WITH MILD EDUCATIONAL NEEDS ABOUT THE CONCEPTUAL AREA OF HEAT

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Abstract:
Although students' conceptions of science concepts have been extensively investigated, research examining the conceptions of students with mild special education needs is limited. This study aims to investigate the conceptions of primary school students with mild special educational needs about heat, temperature, thermal equilibrium, and thermal conductivity. Semi-structured interviews were used as a data collection tool and were applied to five 12-year-old students with mild special educational needs. The analysis of the students' responses revealed that they use conceptions about heat, temperature, thermal equilibrium, and thermal conductivity that are different from school knowledge. The findings of this work may be applied in both research and educational contexts.

Keywords: conceptions, primary school students, mild special educational needs, heat, temperature

1. Introduction

This paper is part of the larger body of research that studies students' conceptions of science concepts and phenomena (Taber, 2017). In particular, it focuses on investigating students' conceptions of the conceptual domain of heat.

Over the last forty years, identifying and recording students' conceptions of the main concepts in science has been the subject of extensive research (Pfundt & Duit 2004). These studies have shown that as students enter the school environment, they have already formed conceptions of science concepts and phenomena that are usually different from school knowledge (Driver et al., 1985). Knowledge of these students' conceptions allows for more effective organization of instruction (Krajcik & Shin, 2023). Therefore, it is necessary to conduct research on students' conceptions.

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In this paper, the conceptual area of heat was chosen as it occupies an important place in primary and secondary school curricula, and a number of studies have demonstrated the difficulties that primary and secondary school students face in this area (Kotsis et al., 2023).

Also, this paper focuses on students with mild special educational needs. These are students who have specific learning disabilities, mild intellectual disability, behavioral problems, and Attention Deficit and/or Hyperactivity Disorder (Stollar & Bolinger, 2008).

Research on students with mild special education needs' conceptions of science concepts and phenomena is particularly limited (Katsidimas et al., 2023). There is a lack of work that systematically explores the conceptions of students with mild special educational needs about the conceptual domain of heat. Investigating this issue is the focus of the present study.

2. Theoretical Framework

Students' conceptions constitute networks of meanings with stable rules of operation and strong interpretive systems by which experiences are 'translated' and the information received is assimilated by students (Driver et al., 1985). Based on their sensory experiences of the physical and social environment, students have formed conceptions of concepts and phenomena in science before coming to school (Vosniadou, 2019). Learning is significantly influenced by what students already know and understand, as prior knowledge is a determinant of the learning process (Taber, 2017). In most cases, students' initial conceptions differ from the views of scientific knowledge and its school version, and often these conceptions resist any attempt to modify them and are little influenced by teaching (Chi, Kristensen & Roscoe, 2012). The cultural context in which students live and especially the language through which they communicate, plays an important role in shaping their conceptions (Joung, 2009).

Research on the conceptions of students at all levels of education has shown that conceptions share certain common characteristics, regardless of the gender, age or country of origin of the students (Driver et al. 1985): (a) when students are confronted with a problem, they tend to make a 'reading' of the situation based initially on data perceived through the senses; (b) students tend to focus their attention and take into account only certain aspects of the situations they are studying, ignoring others; (c) students usually use indiscriminately concepts which have different meanings according to scientific knowledge; and (d) students, due to the application of a 'localised' approach, tend to use concepts which have different meanings according to scientific knowledge.

3. Literature Review

Students' conceptions of the conceptual area of heat have been extensively studied. Regarding heat, students perceive it as a qualitative or quantitative quantity that occurs with two entities (heat, cold) and is emitted or absorbed spontaneously by bodies (Wiser, 1988). Usually, students do not differentiate heat from temperature (Salame et al, 2025). In particular, students tend to assume that temperature is an indication of the intensity of heat (Wiser 1986) or that temperature is a measure of the amount of heat contained in a body (Kotsis et al., 2023). Students who do not differentiate temperature from heat consider that two bodies have the same heat if they are at the same temperature and vice versa (Kesidou & Duit 1993). Regarding the temperature that bodies acquire, students usually assume that temperature depends on the size (Erickson 1979) or the composition of the body (Thomaz et al. 1995). According to students, insulators (and more specifically wool and cotton bodies) have the property of absorbing but mainly creating (generating) heat and thus warming bodies (Lewis & Linn 1994).

With regard to students with mild special educational needs, the conceptions of children aged 4-7 years about conductors and insulators and body expansion have been identified and documented (Katsidimas et al, 2023). However, there is a lack of research that studies the conceptions of students with mild educational needs on the topics related to the conceptual area of heat and, in particular, the concept of temperature and the factors that influence it, the concept of heat and its relationship with temperature, thermal equilibrium and thermal conductivity.

4. Purpose and Research Questions

The purpose of this study is to investigate the conceptions of students with mild educational needs in the last grade of primary school (age 12), in the conceptual area of heat.

In particular, the research questions of this paper are as follows:

1) What are the conceptions of students with mild educational needs aged 12 years about temperature?
2) What are the conceptions of students with mild educational needs aged 12 years about heat and its relationship with temperature?
3) What are the conceptions of students with mild learning needs aged 12 years about thermal equilibrium?
4) What are the conceptions of students with mild educational needs aged 12 years about the thermal conductivity of bodies?

5. Methodology

5.1 Research process and participants

This paper is qualitative research (case study). In the first phase (pilot study), the data collection instrument (semi-structured interview) was set up. In the second phase (main research), the interviews with the students were conducted, and then their responses were analysed.

Five students aged 12 years old, attending the last grade of a primary school, participated in this research. These were pupils with mild special educational needs who attended a support structure operating within the school and offering individualised or group teaching by a special education teacher. These pupils had been taught the concepts of heat and temperature in their previous class in science lessons.

5.2 Data collection and analysis

A semi-structured interview was used as a data collection tool. Based on the research questions of the survey, the issues to be covered were determined, and the relevant questions were formulated.

The constitution of the questions was completed in two phases. First, the questions were administered to a small number of students (2 students) to ascertain any points that were difficult for students to understand or read. Also, the questions were given to three primary school teachers and two science teaching researchers to check for any missing or unclear questions. Corrections were then made, and the questions were given their final form.

The interview set up included 7 questions. Table 1 presents the issues that the questions addressed.

Table 1: The issues to be explored and the corresponding interview questions

Issues	Questions
Temperature: factors that determine the temperature of a body in thermal equilibrium with its environment	1 and 2
Temperature: Mixing of liquids of different temperatures	3
Thermal equilibrium	4
Thermal conductivity	5
Heat: Use of one or two entities to explain thermal phenomena	6
Relationship between temperature and heat	7

Question 1 was designed to investigate whether students think that the temperature a body acquires depends on its size. It was mentioned to the students that there was a small and a very large ice cube on a table surface. They were asked to compare their temperatures and then to justify their answer.

Question 2 was designed to investigate whether students thought that the temperature that a body acquires depends on its composition. It was mentioned to the students that an iron ruler and a wooden ruler of the same size had been left in a room for some time. They were asked to say which of the two rulers would have the lowest temperature and then to justify their answer.

Question 3 aimed to investigate the temperature that results from mixing liquids of different temperatures. The students were told that we have two identical glasses containing equal amounts of water, one of which contains water at a temperature of 40 °C and the other at a temperature of 70 °C. They were then told that we should add the water from these two glasses to another container. They were asked to predict what the temperature of the liquid in the container would be and then to justify their answer.

Question 4 was designed to investigate whether students thought that thermal equilibrium was a possible state or a necessity. It was mentioned to the students that a wooden and a metal spoon are present in a container of hot water for several hours. They were asked to choose which of the two spoons would have the highest temperature and then to justify their answer.

Question 5 was designed to investigate whether students think that insulators produce heat. It was mentioned to the students that they were asked to carry home an ice cream, which should stay as cold as possible. They were asked to choose whether they would prefer to wrap it in foil or wool cloth and then to justify their answer.

Question 6 aimed to investigate whether students explained thermal phenomena using two different entities (heat and cold). It was mentioned to the students that they hold an ice cube in their hand, and after a while, they notice that their hand gets cold. They were asked to justify why their hand were getting cold and then to justify their answer.

Question 7 aimed to investigate whether students perceive temperature as an indication of intensity or as a measure of the amount of heat present in the body. Students were told that we have a glass of water at 80°C and a swimming pool with water at 20°C. They were asked to predict whether the water in the glass or the water in the pool would have more heat and then to justify their answer.

Prior to conducting the interviews with the students, a meeting was held with the school principal and the classroom teacher, during which permission was sought and granted. An information note along with a consent form was then distributed to the parents of the students who would be participating in the survey. After obtaining the consent of all parents, the day and time of the interviews were set in consultation with the head teacher and the class teacher. The interviews were conducted in the school library, individually for each student, and lasted approximately 7-8 minutes per participant.

The students' answers to the questions of the questionnaire were the data of the survey. After the students were interviewed, the interviews were transcribed. Data analysis was based on Miles and Huberman's (1994) approach, which consisted of three separate steps: data reduction, data presentation, and inference. Based on this analysis, students' conceptions were sorted into categories.

6. Results

6.1. Factors affecting the temperature of a body in thermal equilibrium with its environment

With regard to the temperature of two ice cubes of different sizes in the same environment, it emerged that all students believed that the two ice cubes would have different temperatures due to their different sizes.

In particular, four students (students B, C, D, and E) believed that the larger ice cube would have a lower temperature due to its greater quantity. The following is an excerpt from the researcher's dialogue with Student E.

Student E: *"The large ice cube has a lower temperature."*
Researcher: *"Why do you think the larger ice cube has the lower temperature?"*
Student E: *"Because the larger ice cube consists of a larger amount of water, while the smaller ice cube contains much less water. Therefore, the ice cube that has more frozen water will also have the lowest temperature."*

Also, one student (student A) thought that the two ice cubes would have different temperatures and that the smaller ice cube would have a lower temperature because of their different sizes.

The following is an excerpt from the researcher's dialogue with Student A.

Student A: *"I believe that the small ice cube will have the lower temperature."*
Researcher: *"Why do you think the small one will have the lower temperature? Could you explain that to me?"*
Student A: *"Because it is smaller than the large one, so it will have a lower temperature than the large ice cube."*

No students were found who believed that the temperatures of the two ice cubes would be the same because they are in the same environment (school knowledge).

Regarding the temperature of two rulers of the same size, one made of iron and one made of wood, which were left in a room for a long time, it turned out that all students believed that the two rulers would have different temperatures, some because of the sense of touch and others because of their cooling rate.

In particular, four students (students A, C, D, and E) believed that the iron ruler would have a lower temperature, based on their sense of touch and the different cooling rates of the objects. The following is an excerpt from the researcher's dialogue with Student A.

Student A: *"I think the iron ruler will have the lowest temperature."*
Researcher: *"Why do you think the iron ruler will have the lowest temperature? Can you explain your reasoning?"*
Student A: *"Because when we touch an iron object, it always feels colder than a wooden one. Therefore, the iron ruler will have a lower temperature."*

Another student (Student B) believed that the iron and wooden rulers would have different temperatures and that the wooden ruler would have a lower temperature, based on the sense of touch.

The following is an excerpt from the researcher's dialogue with Student B.

Student B: *"I believe that the wooden ruler will have the lowest temperature."*
Researcher: *"Why do you believe that? Could you justify your answer?"*
Student B: *"Because wood feels colder when we touch it, while iron is not as cold."*

No students were found who believed that the temperatures of the two rulers would be the same because they are in the same environment (school knowledge).

6.2. Temperature: Mixing liquids of different temperatures

Regarding the mixing of two glasses of water with exactly the same amount of water but different temperatures, it emerged that the majority of students believed that the temperature of the resulting water would be equal to the sum of their temperatures. However, one student believed that the temperature of the resulting water would be equal to the difference between their temperatures, and another student believed that the resulting water would be equal to the average of their initial temperatures.

Specifically, three students (students A, C, and E) believed that the resulting water would have a temperature of 110 °C, because they believed that the temperature resulting from mixing liquids of different temperatures is equal to the sum of their temperatures.

The following is an excerpt from the researcher's dialogue with Student A.

Student A: *"The temperature of the new liquid will be 110 °C."*
Researcher: *"How did you come to that conclusion? Can you explain it to me?"*
Student A: *"Because the temperatures of the two glasses will be added together. Just as the two liquids will be added together, so will their temperatures."*

Also, one student (Student B) thought that the resulting water would have a temperature of 55 °C, because he thought that the temperature resulting from mixing liquids of different temperatures is equal to the average of their initial temperatures.

The following is an excerpt from the researcher's dialogue with Student B.

Student B: *"I believe that the water will be lukewarm."*
Researcher: *"So, what do you think the temperature of the liquid will be after mixing?"*
Student B: *"I think the temperature of the resulting liquid will be somewhere between 40 °C and 70 °C. Let's say it will be 55 °C, because the liquid that is 70 °C will cool down a little when it comes into contact with the liquid that is 40 °C, so it will be somewhere in between."*

Only one student (student B) considered that the temperature resulting from mixing two liquids is equal to the average of their initial temperatures (school knowledge).

6.3. Thermal equilibrium

Regarding the temperature of a wooden spoon and a metal spoon that had been left for several hours in a container of hot water, it turned out that all students believed that the spoons would have different temperatures, based on their sense of touch and their different hardness. Only one student believed that the spoons would have the same temperature, because temperature depends on their environment.

In particular, three students (students A, B, and E) believed that the iron spoon would have a higher temperature because of the sense of touch. The following is an excerpt from the researcher's dialogue with Student E.

Student E: *"The iron spoon will have the highest temperature."*
Researcher: *"Why do you think that?"*
Student E: *"Because if we touch both spoons, the iron one will feel warmer."*

Also, one student (Student C) believed that the wooden spoon would have a higher temperature because of its composition. The following is an excerpt from the researcher's dialogue with Student C.

Student C: *"I believe that the wooden spoon will have the highest temperature."*
Researcher: *"Why do you believe that? Can you explain it to me?"*
Student C: *"Because the wooden spoon is made of a material that allows the temperature of the water to pass through it and heat it up, while the iron spoon is hard and will not allow this."*

Also, one student (student D) believed that both spoons would have the same temperature, because the temperature a body acquires depends on the temperature of its environment.

The following is an excerpt from the researcher's dialogue with Student D.

Student D: *"Both spoons will have the same temperature."*
Researcher: *"Why do you think that? Please explain it to me if you can."*
Student D: *"Because both spoons are in the water, and so they will take on its temperature."*

Only one student (student D) was found to consider thermal equilibrium a necessity, since the temperature a body acquires depends on its environment (school knowledge).

6.4. Thermal conductivity

Regarding the material they prefer to wrap ice cream in so that it stays as cold as possible, it emerged that all students considered that it should be wrapped in aluminum foil, except for one who considered that it should be wrapped in woolen fabric.

In particular, three students (students A, C, D, and E) believed that it should be wrapped in aluminum foil because woolen materials warm bodies and metal materials keep bodies cold.

The following is an excerpt from the researcher's dialogue with Student C.

Student C: *"The question was why does our hand freeze?"*
Researcher: *"Yes! Imagine you have an ice cube in your hand and slowly your hand gets cold. Why do you think this happens?"*
Student C: *"Because the ice cube on the hand transfers the cold from it to the hand."*

Another student (Student B) thought that it should be wrapped in woolen fabric because heat passes through metal objects but not through woolen objects.

The following is an excerpt from the researcher's dialogue with Student B.

Student B: *"With woolen fabric."*
Researcher: *"Why would you wrap it in woolen fabric? Can you explain your reasoning?"*
Student B: *"Because if I wrap it in aluminum foil, the heat will pass through and it will melt faster, while with woolen fabric it will not pass through."*

Only one student (Student B) believed that heat spreads faster through metal objects than through wool (school knowledge).

6.5. Heat: using one or two entities to explain thermal phenomena

With regard to an ice cube that they hold in their hand and after a while notice that their hand is getting cold, it turned out that all students believed that the cold would be transferred from the ice cube to their hand.

Specifically, all students believed that cold would be transferred from the ice cube to their hands due to the transfer of cold from the ice cube to the hand.

The following is an excerpt from the researcher's dialogue with Student B.

Student B: *"Because the ice cube is frozen."*
Researcher: *"What do you mean? Can you explain it to me?"*
Student B: *"I mean that the cold contained in the ice cube is transferred from the ice cube to the hand."*

No student was found to consider heat as an entity that is transferred from a body of higher temperature to a body of lower temperature (school knowledge).

6.6. Relationship between temperature and heat

When asked whether a glass of water at 80°C or a swimming pool at 20°C would have more heat, the students concluded that the water in the glass would have more heat than the water in the pool. All students believed that the cold would be transferred from the ice cube to the hand.

In particular, all students believed that the water in the glass would have more heat than the water in the pool because temperature indicates the intensity of heat.

The following is an excerpt from the researcher's dialogue with Student D.

Student D: *"The water in the glass will have the highest temperature."*
Researcher: *"Why do you believe that?"*
Student D: *"Because it is warmer, it has a higher temperature."*

No student was found to believe that temperature is related to the amount of heat per unit of mass of the body (school knowledge).

7. Discussion and Conclusions

This study investigated the conceptions of sixth-grade elementary school students with mild special educational needs regarding the concepts of heat and temperature.

The results show that the students believed that the temperature of a body depends on its size. This perception is consistent with the results of studies in which students believe that the temperature of a body is determined by its size and not by the temperature of its environment (Appleton 1984, 1985; Driver & Russell 1982; Erickson 1979, 1980; Frenkel & Strauss 1985; Stavy & Berkovitz 1980; Rozier & Viennot 1991; Viennot 1979).

Furthermore, this study found that the majority of students believed that the temperature of a body depends on its composition. This perception is consistent with the results of studies in which students believe that the temperature of a body is determined by its composition (Appleton, 1985b; Erickson & Tiberghien, 1985; Tiberghien, 1985). In fact, research data show that many students believe that metal objects are colder than wooden objects (Tiberghien, 1985).

In addition, this study found that, with regard to the temperature resulting from mixing liquids of different temperatures, the majority of students with mild special educational needs who participated in this study believed that the temperature resulting from mixing liquids of different temperatures is equal to the sum of their temperatures. The above perception is consistent with the results of studies where students believed that the temperature resulting from mixing two liquids equals the sum of their initial temperatures (Driver & Russel 1982; Engel 1982; Erickson 1979; Stavy & Berkovitz 1980; Strauss & Stavy 1983).

With regard to thermal conductivity, the majority of students believed that woolen objects warm bodies and metal objects keep bodies cold. This perception is consistent with research findings, where students believe that insulators have the property of generating heat and therefore warming bodies (Bruce & Kopnicek, 1990; Erickson &

Tiberghien, 1985; Jara-Guerrero, 1993; Harrison, 1994; Lewis, 1991, 1996; Lewis & Linn, 1994; Newell & Ross, 1996; Vosniadou & Kempner, 1993; Stylianidou, 1997).

Furthermore, it emerged from the present study that the majority of students considered cold to be an entity emitted by cold bodies. This perception is consistent with the results of studies in which students believe that heat is responsible for warming bodies and cold (coolness or chill) is responsible for cooling bodies (Aiello-Nicosia & Sperandeo-Mineo, 2000; Appleton, 1984, 1985; Arnold & Millar, 1996; Briggs & Brook, 1984; Engel Clough & Driver, 1985; Erickson, 1979, 1980; Magnusson, Krajcik & Borko, 1993; Watts & Gilbert, 1985).

In addition, this study found that the majority of students considered temperature to indicate the intensity of heat, while at the same time, none of the students seemed to differentiate between heat and temperature. This perception is consistent with the results of studies in which students do not differentiate between heat and temperature (Arnold & Millar, 1996; Briggs & Brooks, 1984; Ellse, 1988; Erickson, 1979, 1980; Harrison et al., 1999; Summers, 1983; Tiberghien, 1985; Warren, 1983).

This study examined the conceptions of students with mild educational needs regarding the conceptual area of heat and temperature, an issue for which no empirical data existed. This study found that students with mild special educational needs who participated in this research had formed conceptions of heat, temperature, thermal equilibrium, and thermal conductivity that differed from what they learned in school. In fact, it turned out that the ideas of kids with mild educational needs were in line with the ideas of kids in the general population. The results of this study can be used both in the field of research and in the design of new educational material on the conceptual area of heat.

However, a limited number of students with mild special educational needs participated in this study, which constitutes a limitation of the research. Another limitation is that only semi-structured interviews were used as a means of data collection. It is recommended that the same study be conducted on a larger sample of students and in more areas to investigate whether the results can be generalized. In addition, a similar study could be conducted in other elementary school classes with students with mild special educational needs, as well as with secondary school students. It is also recommended that a teaching intervention be designed and implemented, taking into account the findings of this study, with the aim of teaching students with mild special educational needs about heat, temperature, thermal equilibrium, and thermal conductivity.

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The authors declare no conflicts of interest.

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