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A CROSS-AGE STUDY:
A Cross-Age Study on the Understanding of Heat and Temperature

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Abstract
The aims of this study were considered below under three headings. At these headings; the first was to elicit misconceptions that students had on the terms heat and temperature. The second was to understand how students' prior learning affected their misconceptions. The third was to determine if students were able to make a connection between their own knowledge and physics in everyday life. To achieve these aims, a paper and-pencil test composed of 14 multiple-chosen questions was designed, but only five questions related to heat and temperature. The test was administered to 342 students from different grades that ranged from grade 6 with students aged 11-12 years to Grade 8 with students aged 14-15 years. For this research qualitative methods were used. As a result of the analyses undertaken, it was found that students' misunderstanding about the heat and temperature influenced their knowledge about these terms. Moreover, it was found that students had difficulties making connections between their knowledge and life experiences. Therefore, it was concluded that although students' conceptions and misconceptions were acquired and stored, they occurred without ostensible links between everyday life and school experiences. Furthermore, depending on the instruction students received and over time, it was deduced that their conceptual understanding showed a steady increase from Grade 6 to Grade 8, except in the case of Item 1.

Key words: physics education, misconceptions, heat and temperature

Introduction

Concepts associated with heat and temperature are prevalent throughout the science curriculum at all levels of elementary, secondary, and graduate education. The science education literature contains several studies of students' understanding of scientific phenomena. These studies have revealed that students bring to instruction views and explanations of natural phenomena that differ from the views held by scientists (Osborne, 1982). Students' preconceptions generally accepted in science are not only quite different from these, but also they are quite resistant to ordinary classroom teaching (Stavy, 1991). Such views of the world held by children are not simply isolated ideas but form conceptual structures that provide a coherent understanding of the world from the child's point of view (Gilbert, Osborne & Fensham, 1982; Hackling & Garnett, 1985). In recent years, there has been an increasing interest to determine students' alternative views on science concepts and scientific events. Sutton (1996) described learning science in school as managing to use science knowledge when talking on everyday phenomena in a new way. This does not mean that students replace their old structures of thinking with new ones. In some studies, where the researchers had the individual's learning as a starting-point, there were some results where the individual learning was not attached to changes of the mental structures. Taber (2000a, 2001), and Tytler (1998) all means that students used different models of thinking when talking on

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everyday phenomena. According to Leach and Scott (2003), learning science as learning to use science language could be understood as a process of internalization. The learner must interpret, reorganize, and reconstruct his/her experiences from the interaction with others. We can see a similar situation to thermal events.

Thermal equilibrium and thermodynamics are more broadly topic areas that the research literature considers challenging and age appropriate for the 6^{th} grade to 8^{th} grade students of this study. As shown in the early misconceptions literature, students hold many intuitive ideas on heat and temperature (Buluş Kırıkkaya & Güllü, 2008; Clough & Driver, 1985; Erickson, 1979; Erickson & Tiberghien, 1985; Rogan, 1988; Tiberghien, 1980), and everyday experiences form the basis for these ideas. These ideas often involve predominantly substance-based conceptions, as might be predicted from an ontological perspective (Chi, 2000; 1992). Everyday, children are exposed to the colloquial term "heat" as a noun, verb, adverb, and adjective, and these multiple uses may lead to confusion (Erickson & Tiberghien, 1985; Romer, 2001; Tiberghien, 1980; 1983). Students in high school have also great difficulty with energy concepts, the particle model, and the distinction between heat and temperature (Kesidou & Duit, 1993). Furthermore, these concepts are also challenging to scientists, who may make more accurate predictions than students, but who also have difficulty explaining everyday phenomena in interviews (Lewis, 1996; Lewis & Linn, 1994), and who maintain divergent representations in their writings (Tarsitani & Vicentini, 1996). Studies have also examined the actual processes of conceptual change and conceptual development within the domain. While some of the early conceptual change work in thermodynamics proposed a Piagetian view of heat concepts through which students develop chronologically (Albert, 1978; Shayer & Wylam, 1981), other early studies on conceptual change in thermodynamics claim that students' concept development parallels historical development of the same concepts (Wiser, 1988a; Wiser & Carey, 1983). At the heart of Wiser and Carey's study is the idea that early scientists and students have similar theories on thermal phenomena that are coherent but incommensurable with the current day thermal theories that differentiate heat and temperature. Albert (1978) found that for four and five years-old 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 of. Studies with very young children who have received no formal teaching on thermal physics show that they have learned, by experience, which certain things feel warm to the touch and others feel cold. Later at age eight it was found that the notion of heat as something more dynamic that flows becomes popular. At a later stage of development the prevailing idea is one in which heat is treated as though it was a fluid that flows between bodies (Erickson, 1979; Tiberghien, 1980).

Despite the fact that these studies dealt with younger children, Clough and Driver (1985) found that such concepts are held by children at least up to age 16. It would appear that ideas on thermal physics are built up by experience through childhood and remain until challenged by situations that they fail to explain. It is the role of the teachers to discover the ideas held by the students and to present them with concrete examples that bring about this restructuring of the world view on the concepts of thermal physics.

The cited studies have tried to answer several questions: (a) what kinds of misconceptions students have; (b) how these misconceptions may be replaced with correct ideas; and (c) suggestions as to what teachers can do to improve teaching-learning environment that would reduce students' misconceptions. These studies have used a number of terms such as preconceptions, misconceptions, and alternative conceptions that students have and these terms also reflect some researchers' view of knowledge. That is, alternative conceptions fit ideas associated with constructivism, and misconceptions which are associated with a positivist tendency (Taber, 2000b).

As can be seen from the related literature, even though the cited studies on heat and temperature on different perspectives, there appears to be an absence of what students understand on the terms 'heat' and 'temperature', whether they are able to apply theoretical knowledge to unusual situations, whether the students are able to make connections between school and life experiences, and how the instruction that students received influences on their ideas. In this article, the term 'misconception' is used to describe any conceptual difficulties, which are different from or inconsistent with those accepted by the scientific community. In present study, primary school students' misconceptions related to heat and temperature are investigated.

Heat and temperature is a conceptually reach area from primary school to undergraduate levels. From the point of view of misconceptions it seems not to have been explored much. Especially in the Turkey context so far there has not been much work done on cross-age study in this area. This has prompted us to undertake the present study and the current study has tried to fill this gap.

Method

The study context

In the Turkish educational system, the first physics and chemistry teaching begins with a brief introduction to 'matter and its nature', as a part of the science curriculum at the age of 11-12 years in Grade 5 (Tebliğler dergisi, 2004). Then the introductory material on concepts such as 'atomic structure and heat transfer at chemical reactions' is taught to students aged between 14-15 years (Grade 8) (Milli Eğitim Bakanlığı [M.E.B]., 2000; Tebliğler dergisi, 2000). The formal physics lessons begin with secondary education at 15-16 years (Grade 9).

Instruments and data collection procedure

In order to examine students' level of understanding, taking into account their grade levels and comprehension, cross-age and longitudinal studies are often used (Abraham, Williamson & Westbrook, 1994). However, Abraham et al. (1994) have implied that a cross-age study is more applicable than a longitudinal study if there is limited time, and several researchers have carried out cross-age studies with satisfactory results (Çalık & Ayas, 2005; Blanco & Prieto, 1997; Krnel, Glažar & Watson, 2003; Westbrook & Marek, 1991). Therefore, in this study, a cross-age study has been undertaken.

In this article, a case study research design was used (Yin, 1994). To use this method, a paper and pencil test composed of 14 multiple-chosen questions was developed but only five questions related to heat and temperature are used directly. Furthermore, a group of physics educators and physicians checked the test for validity and reliability and then confirmed the content validity of the instrument. There are four choices for each question and after the questions; cause of the selecting each answer was asked the students.

Moreover, all the topics under investigation were taught in first semester and all of the students in the sample passed the courses at a satisfactory level and had begun the second semester. This study was also undertaken during the second semester. The students were given 30 minutes to answer the test and were encouraged to answer all the questions.

The test items considered in this study are shown in Table 1.

Table 1. Five test items used in the study

Two substances made same matter which initial temperatures are equal put in the same room that has higher temperature and waiting enough time. If their masses are different;	
Item 1. Which substance is hotter? A. Substance has small mass is hotter. B. Substance has big mass is hotter. C. Both substances have equal temperature. D. Their temperatures are incomparable. Because:…………………………….	**Item 2.** Which substance's heat is more? A. Substance has small mass is more heat than big one. B. Substance has big mass is more heat than small one. C. Both substances have equal heat. D. Their heat are incomparable. Because:…………………………….
Two substances put in the same room which has higher temperature and waiting enough time. If this substances initial temperatures and masses are equal but one of them made of iron other one made of wood.	
Item 3. Which substance is hotter? A. Substance which made of wood is hotter. B. Substance which made of iron is hotter. C. Both substances have equal temperature. D. Their temperatures are incomparable. Because:…………………………….	**Item 4.** Which matter's heat is more? A. Substance which made of wood has more heat than iron. B. Substance which made of iron has more heat than wood. C. Both substances have equal heat. D. Their heat are incomparable. Because:…………………………….
Item 5. Two substances which initial temperatures are different put in the same box and isolated their surroundings. What can you say about the heat transfer between these substances?	
A. Hot substance takes heat. B. Cold substance takes heat. C. Both of them takes heat D. There is no heat transfer between them. Because: …………………………………	

Data Analysis

The open-ended questions listed in Table 1 were analyzed under the following categories and headings, which were suggested by Abraham et al. (1994).

- *Sound Understanding:* Responses that included all components of the validated response.
- *Partial Understanding:* Responses that included at least one of the components of validated response, but not all the components.
- *Specific Misconceptions:* Responses that included illogical or incorrect information.
- *No Understanding:* Repeated the question; contained irrelevant information or an unclear response.
- *No Answer:* There is not marked a choice related to the question.

These criteria provided an opportunity to classify students' responses and make comparisons on their level of understanding.

Results

The results obtained from the test are presented below by taking each item into consideration. Percentages of the obtained responses for each item are shown in Table 2.

For Item 1, sound understanding included knowledge that substances temperatures are equal for located same area. Therefore, temperature of the substances does not depend on their masses. As can be seen from Table 2, the students' responses categorized under the sound understanding category was 21, 25 and 21% respectively. The proportion of their responses categorized under the partial understanding category was 9, 8 and 4% respectively. Moreover, while 37% of Grade 6, 24% of Grade 7 and 41% of Grade 8 had specific misconceptions, and the proportion of their responses classified under no understanding category was 33, 43 and 33% respectively. Furthermore, 1% of Grade 8 did not respond to the question. Some examples from the given responses for Item 1 are presented in Table 3.

Table 2. Percentages of responses given to questions

Items	**1**			**2**			**3**			**4**			**5**		
Grades	**6**	**7**	**8**	**6**	**7**	**8**	**6**	**7**	**8**	**6**	**7**	**8**	**6**	**7**	**8**
SU	21	25	21	23	26	35	21	13	15	5	4	0	36	39	51
PU	9	8	4	5	4	7	3	2	2	3	2	2	4	7	10
SM	37	24	41	37	22	30	29	34	43	61	49	72	35	23	29
NU	33	43	33	35	45	26	45	49	38	31	43	25	25	31	10
NA	0	0	1	0	3	2	2	2	2	0	2	1	0	0	0

SU: Sound Understanding **PU:** Partial Understanding **SM:** Specific Misconception
NU: No Understanding **NA:** No Answer

In Item 2, sound understanding is as follows: the substances with big mass have more heat. Therefore, heat of the substances depends on their masses. As can be seen from Table 2, the students' responses categorized under the sound understanding category was 23, 26 and 35% respectively. The proportion of their responses categorized under the partial understanding category was 5% of Grade 6, 4% of Grade 7 and 7% of Grade 8. Moreover, while 37% of Grade 6, 22% of Grade 7 and 30% of Grade 8 had specific misconceptions, and the proportion of their responses classified under no understanding category was 35, 45 and 26% respectively. Furthermore, 3% of Grade 7 and 2% of Grade 8 did not respond to the question. Some examples from the given responses for Item 2 are presented in Table 4.

Table 3. Some examples from the responses given for Item 1 (X shows the kinds of responses identified at each grade)

UL	**Examples**	**Grade**		
		6	**7**	**8**
SU	• Both substances' temperatures are equal. Because, temperature does not depends on quantity of the matter.	X	X	X
	• Temperatures of substances are equal. Because, they located in same area.	X		X
	• Their temperatures are equal due to located same area.			X
	• Temperature does not depend on mass.		X	X
PU	• Both substances' temperatures are equal.	X	X	X
	• Both substances' initial temperature does not same since their mass are different.		X	
	• While two substances in the same medium, their temperatures do not change.	X	X	X
SM	• Substance with big mass has lower temperature.	X		X
	• Temperatures of substances depend on their masses.			X
	• Substance with big mass has higher temperature.	X	X	X
NU	• Temperature of substances is incomparable.	X	X	
	• Temperature of small substance is lower.		X	X
	• Warming of big substances takes along time.	X	X	X

UL: Understanding Level **SU:** Sound Understanding **PU:** Partial Understanding
SM: Specific Misconception **NU:** No Understanding

Table 4. Some examples from the responses given for Item 2

UL	Examples	Grade		
		6	7	8
SU	• The substance with big mass has more heat.	X	X	X
	• Heat depends on their masses.	X		X
	• If the substance has big mass also its heat is more.		X	X
PU	• The substance with big mass has more heat.	X	X	X
	• Substance has big volume takes more heat.	X		X
SM	• Heat of substance with small mass should be higher. Because, its volumes are small.	X	X	X
	• Substance with big volume takes more heat.	X	X	X
	• Substance with big specific heat every time takes more heat.		X	X
	• Which substance is hotter its heat is more.	X	X	X
NU	• We could not say which substance takes more heat.	X	X	X
	• I do not understand difference between their heat.	X	X	X

UL: Understanding Level **SU:** Sound Understanding **PU:** Partial Understanding
SM: Specific Misconception **NU:** No Understanding

In Item 3, sound understanding is as follows: Substances' temperatures are equal which located same medium. However, temperature does not depend on species of matter. As can be seen from Table 2, the students' responses categorized under the sound understanding category was 21% of Grade 6, 13% of Grade 7 and 15% of Grade 8. The proportion of their responses categorized under the partial understanding category was 3% of Grade 6, 2% of Grades 7 and 8. Moreover, while 29% of Grade 6, 34% of Grade 7 and 43% of Grade 8 had specific misconceptions, and the proportion of their responses classified under no understanding category was 45, 49 and 38% respectively. Furthermore, 2% of Grades 6, 7 and 8 did not respond to the question. Some examples from the given responses for Item 3 are presented in Table 5.

Table 5. Some examples from the responses given for Item 3

UL	Examples	Grade		
		6	7	8
SU	Substances' temperatures are equal which located same medium. Because, temperature does not depend on species of matter.	X	X	
	When substances stay in same medium for a long time, reach to same temperature.	X	X	
	Substances reach same temperature with their environment.	X	X	
PU	We can say that substances are in equal temperatures.	X	X	X
	Temperature does not depend on species of matter.	X	X	
	Temperature does not depend on quantity of the matter.	X		X
SM	The substance warms more which has made of wood. For that reason its temperature is more.	X	X	X
	The temperature of the substance is proportional with its heat.		X	X
	The substance made of wood has higher temperature.		X	X
NU	Comparing temperature of substances is difficult.	X	X	X
	The temperature of both substances stays unchangeable.	X	X	
	The temperatures should be same due to having equal masses. However, both substances' temperature changes due to their species are differ from each other.	X	X	X

UL: Understanding Level **SU:** Sound Understanding **PU:** Partial Understanding
SM: Specific Misconception **NU:** No Understanding

In Item 4, sound understanding is as follows: substance made wood which stays same medium for a long time has more heat than iron, due to equal masses. As can be seen from Table 2, the students' responses categorized under the sound understanding category was 5% of grade 6 and 4% of grade 7. However, no one student in Grade 8 responses this question correctly. The proportion of students' responses categorized under the partial understanding category was 3% of Grade 6 and 2% of Grades 7 and 8. Moreover, while 61% of Grade 6, 49% of Grade 7 and 72% of Grade 8 had specific misconceptions, and the proportion of their responses classified under no understanding category was 31, 43 and 25% respectively. Furthermore, 2% of Grade 7 and 1% Grade 8 did not respond to the question. Some examples from the given responses for Item 4 are presented in Table 6.

In Item 5, sound understanding is as follows: When two substances which initial temperatures are different put in the same box and isolated their surroundings, the cold one takes heat from the hot one. As can be seen from Table 2, the students' responses categorized under the sound understanding category was 36% of grade 6 and 39% of grade 7 and 51% of Grade 8. The proportion of their responses categorized under the partial understanding category was 4% of Grade 6, 7% of Grade 7 and 10% of Grade 8. Moreover, while 35% of Grade 6, 23% of Grade 7 and 29% of Grade 8 had specific misconceptions, and the proportion of their responses classified under no understanding category was 25, 31 and 10% respectively. Some examples from the given responses for Item 5 are presented in Table 7.

Table 6. Some examples from the responses given for Item 4

UL	Examples	Grade		
		6	7	8
SU	• Substance made of wood which stays in same medium for a long time has more heat, due to equal masses.	X	X	X
	• Substance made of wood takes more heat because, both substances have same masses.	X	X	X
PU	• Substance made of wood should be taking more heat, so that heat related to species.			X
	• Substance made of wood warms earlier.	X	X	X
	• Substance with big mass stores more heat, in this case they should be same heat since they have equal masses.	X	X	X
SM	• Substance made of iron has more heat. Because iron warms earlier than wood.	X		X
	• Heat does not depend on species of the matter. Their heat are equal.	X	X	X
	• The heat of substances are equal due to their last temperatures are equal.	X	X	X
NU	• The substances' heat is incomparable due to having different species.	X	X	X
	• The substances should have same heat due to having same masses.	X	X	X
	• I did not understand difference between wood and iron heat.	X	X	

UL: Understanding Level **SU:** Sound Understanding **PU:** Partial Understanding
SM: Specific Misconception **NU:** No Understanding

Table 7. Some examples from the responses given for Item 5

UL	Examples	Grade 6	Grade 7	Grade 8
SU	• Cold substance takes heat. Because, heat transfer become facts from hot substance to cold.	X	X	X
	• The substance with lower temperature takes heat. Because, heat is transported cold substance.	X	X	X
	• Heat transfers towards from hot substance to cold substance.	X	X	X
	• The direction of heat conduction is from hot substance to cold.		X	X
PU	• Cold substance takes heat.			X
	• Hot substance should give heat.	X	X	X
	• Hot substance always gives heat.	X	X	X
SM	• Hot substance is hotter because, it takes heat from cold substance.	X		X
	• Hot substance takes heat every time.	X	X	X
	• Heat transports from cold substance to hot.	X	X	X
NU	• Substances do not make heat exchange.	X	X	X
	• We could not determine which substance takes heat.	X	X	X
	• We could not determine which substance gives heat.	X	X	X
	• Heat exchange does not depend on difference of temperature.	X	X	

UL: Understanding Level **SU:** Sound Understanding **PU:** Partial Understanding
SM: Specific Misconception **NU:** No Understanding

Discussion

The responses to all questions asked in this study point to a general misunderstanding of ideas related to thermal equilibrium, heat exchange and temperature concepts. Stavy (1990) maintains that the various types of knowledge existed in the cognitive system and compete with acquired knowledge, which may be available in the cognitive system. Therefore, this process is a struggle in which the strongest knowledge dominates. Thus, this study's findings indicate that even though some students in the sample have an accurate understanding of physical processes, their knowledge of heat and temperature concepts should be greater. As a matter of fact, the present study reveals those students' misconceptions on relation between mass and heat, and the distinction between temperature and heat and those differences in temperature can lead to transfer of heat energy. Although defining heat as energy in the process of being transferred due to a difference in temperature is rather wordy, teacher does not have to teach the definition by rote (Taber 1995) as long as she is consistent in using 'heat' for this, and only in this concept. These concepts may even outweigh their knowledge on the information under investigation. Heat and temperature concepts are important in physics, chemistry and biology. Therefore, they must be regarded as basic knowledge item to be used to develop physical ideas among students. The aim of this study was to probe students' understanding on the heat exchange and physical meaning of heat and temperature concepts. The findings obtained in present study show that they have difficulties on describing and using the terms heat and temperature and some of them did not realize that heat and temperature are different concepts. In addition some students have misconceptions on these concepts. The most common misconceptions they held on unrelated between mass and temperature.

The first research question in this study was: "*Two substances made of same matter which initial temperatures are equal put in the same room that has higher temperature and waiting enough time. If their masses are different; which substance is hotter?*" Some students in grade 6 and 8 think that "Substance has big mass's temperature is lower", some students in grade 8 think that "Temperatures of substances depend on their masses", and some students in grade 6, 7 and 8 think that "Substance has big mass's temperature is higher" (Table 2 and 3).

Misconceptions in this area had been investigated by Erickson (1979) on 12 age's students firstly and then also performed another investigation on students' grades 5, 7 and 9 (Erickson, 1980). The results both studies parallels to each other and present study. The students under this investigation also no understanding to "temperature does not depend on mass". Some students in grades 6 and 7 state that "temperature of substances are incomparable", some students in grades 7 and 8 state that "temperature of small substance is lower" and some students in grades 6, 7 and 8 state that "Warming of big substances take along time" (Table 2 and 3). These statements indicated that many primary school students have misconceptions concerning to temperature of matter. They believe that temperature of matter is proportional with its mass. Similar results reported in some studies that performed on ages groups (Erickson, 1980; Lewis & Linn, 1994).

The second research question in this study was: "*Two substances made of same matter which initial temperatures are equal put in the same room that has higher temperature and waiting enough time. If their masses are different; which substance's heat is more?"* Some students in grades 6, 7 and 8 think that "heat of substance with small mass should be higher. Because, its volume is small", "substance with big volume takes more heat", and "which substance is hotter its heat is more", some students in grades 7 and 8 think that "Substance with big specific heat takes more heat every time". The students under this investigation also no understand relation between mass and heat. Some students in grades 6, 7 and 8 states that "we could not say which substance takes more heat" and "I do not understand differences between their heat" (Table 2 and 4). Erickson (1979) found that the temperature of a body was thought to be related to its size (or to the amount of stuff present), for example, his 12-years-old students thought large ice cubes took longer to melt than small ones because they had 'colder temperatures'. Thereby, present study's findings are consistent with Erickson's (1979) research findings.

The third research question in this study was: "*Two substances put in the same room which has higher temperature. If this substances initial temperatures and masses are equal but one of them made of iron and other one made of wood. Which substance is hotter?*" Some students in grades 6, 7 and 8 think that "the substance made of wood warms more. For that reason its temperature is more", some students in grades 7 and 8 think that "the temperature of the substance is proportional with its heat" and "the substance made of wood has higher temperature". The students under this investigation also no understand relation between temperature and species of the matter. Some students in grades 6, 7 and 8 state that "it is difficult to compare temperature of substances" and "the temperatures should be same due to having equal masses. However, both substances temperature change due to their species are differ from each other" and some of the students in grades 6 and 7 state that "The temperature of both substances stay unchangeable" (Table 2 and 5).

The fourth research question in this study was: "*Two substances made of same matter which initial temperatures are equal put in the same room that has higher temperature and waiting enough time. If their masses are different; which matter's heat is more?*" Some students in grades 6, 7 and 8 think that "heat does not depend on species of the matter and their heat are equal due to their last temperatures are equal", some students in grades 6 and 8 think that "substance made of iron has more heat therefore iron warms earlier than wood". The students under this investigation also no understand relation between heat and species of the matter. Some students in grades 6, 7 and 8 state that "the substances' heat are incomparable due to having different species" and "the substances should have same heat due to having same masses" and some of the students in grades 6 and 7 state that "I did not understand difference between wood and iron heat" (Table 2 and 6).

There are a number of difficulties which children have in distinguishing between heat and temperature. It is part of children's everyday experience that some objects tend to feel warmer to touch than others; therefore, they tend to suggest that temperature is a property of the material that, for example, the substance warms more which is made of wood. For that reason its temperature is more (for all grades). Tiberghien (1980) asked children to choose from a number of containers made of different materials the one which would be most suitable for keeping ice cool. The majority chose a metal container giving reasons like "*because, iron is cold*". Thereby, present study's findings are consistent with Tiberghien's (1980) research findings. Thomaz, Malaquias, Valente & Antunes (1995) suggest that there are five common misconceptions held on heat. These are that heat is a kind of substance, the inability to differentiate between heat and temperature, a confusion between temperature and the 'feel' of an object, that the application of heat to a body always results in a rise in temperature and a misunderstanding of the temperature of a phase transition. The last two of these misconceptions are supported by the findings of Nachimias, Stavy & Avrams (1990), who found that 80% of the students in their study were unaware of the fact that the temperature of water remains constant while it is being boiled. In order to enable the students to progress in studies of thermal physics it is considered essential that they have mastered two fundamental concepts. They must have a concept of thermal equilibrium and they must have a concept of the difference between heat and temperature (Wiser, 1988b).

The fifth research question in this study was: "*Two substances which initial temperatures are different put in the same box and isolated their surroundings. What can you say about the heat transfer between these substances?*" Some students in grades 6, 7 and 8 think that "hot substance takes heat every time" and "heat transports from cold substance to hot", some students in grades 6 and 8 think that "hot substance is hotter because, it takes heat from cold substance". The students undertaken this investigation also no understand direction of heat conduction. Some students in grades 6, 7 and 8 state that "substances do not make heat exchange", "We could not determine which substance takes heat" and "we could not determine which substance gives heat", and some of the students in grades 6 and 7 state that "heat exchange does not depend on temperature difference" (Table 2 and 7). The students' responses in sound understanding category showed that if two bodies are left in a box at constant temperature for a long enough they will eventually reach the same temperature as each other and the box. So far they have been asked to recognize that substances will eventually reach to thermal equilibrium when placed in thermal contact, and this means that they are at the same temperature. Furthermore, Students should recognize body is defined as being at a higher temperature than lower if there is a spontaneous net flow of heat energy from hot substance to cold one when placed in thermal contact. However, some students under the specific misconception category are not able to recognize this phenomenon, and some students under the no understanding category are not able to understand direction of heat transfer. Similar results are obtained by Carlton (2000) and he state that ideas on thermal physics are built up by experience through childhood and remain until challenged by situations that they fail to explain.

In fact, the present study reveals those students' misconceptions on heat and temperature concepts may arise from by the knowledge of their teachers' impart because teachers are the prime source of instruction in the educational context. There are many studies confirm to this idea (Gabel, Samuel & Hunn, 1987; Haidar, 1997; Lin, Cheng & Lawrenz, 2000; Quilez-Pardo & Solas-Portalez, 1995). For instance, with the use of five open-ended questions in a chemical equilibrium for students and an item of integrating the five questions for teacher, Quilez-Pardo and Solas-Portalez, (1995) found that the teachers and the students hold similar misconceptions about Le Chatelier's principle. In addition, Lin, Cheng and

Lawrenz, (2000) used the same set of test questions about the gas laws to high school students and chemistry teachers. They found that the teachers' results explained, to a great extent, the misconceptions held by students. Students have rarely been taught how to use scientific concepts in different situations other than the examples given in textbooks. For that reason it can be state that negative effects of teachers' misconceptions are not only meaningful but also important. It enables us to understand possible origins and source of students' difficulties and misconceptions better. We think that another major source of students' misconceptions is science textbooks. Leite (1999) reported that some textbooks suggested that idea that heat was a fluid. The following statement was found in textbooks: "heat passes from bodies at a higher temperature to bodies at a lower temperature". Although this statement is not totally inconsistent with scientific meaning, lack of accuracy is likely to lead learners to over-generalize the original scientific meaning.

In Turkey, when science textbooks using in primary schools are examined it will be seen that some important concepts are not found, such as; specific heat and heat capacity. For that reason, the examples given by most of students in the investigations do not include these concepts while these concepts are very important for understanding both heat exchange process and calculating amount of heat. In grades 6, 7 and 8 students should be learn scientific meaning of specific heat and heat capacity. If misconceptions held by students are not corrected in these grades they will meet difficulties in their future education levels. In other words, these misconceptions will be kept by students both secondary and undergraduate levels. Many studies related to this topic had been indicated that similar misconceptions and misunderstandings were continued at the high school, collage and university levels (Erickson, 1979; Gönen & Akgün, 2005; Jasien & Oberem, 2002; Kesidou & Duit, 1993; van Roon, van Sprand & Verdonk, 1994; Warren, 1972).

Conclusion and Recommendations

Science education, science and technology literacy are supplementary to each other. Primary school science courses have three main aims. These are: (a) science literacy, (b) to develop students' cognitive and psycho-motor abilities via science courses, (c) and to constitute for vocational education in branches of science and technology (Ayas, Çepni, Akdeniz, Özmen, Yiğit & Ayvacı, 2005). When these aims take into consideration, some of the sample under investigation appear to lack some of these ideas and are unable to apply their knowledge to unusual situations; it may be concluded that although students' misconceptions affect one another directly, students' knowledge appears to be stored in a somewhat fragmented manner without relevant links between everyday life and knowledge acquired through school experiences.

When we look at the students' level of understanding by considering the sum of the percentages in 'sound understanding' and those at 'partial understanding' categories, there are some discrepancies. Their partial understanding percentages are low and closely to each other although percentages belong to their sound understanding levels. There is an increase from grade 6 to grade 8 at sum of the percentages 'sound understanding' category. Similarly, when we look at sum of the percentages of 'specific misconception' of sample we see that it shows approximately a 'V shaped'. When items handled one by one; it could be only in item 3 incompatible with other one but in totally student under this category compatible with this shaped. For that reason it could be stated that students' specific misconceptions in grade 6 and grade 8 are higher than grade 7. Finally, for 'no understanding' category of sample we can see 'Λ shaped' for each items and sum of percentages for all items. Percentages of grade 7 students have 'no understanding' category are high in spite of low percentages belong to 'specific misconception' category. This situation might be arise from students in grade 6 are not able to assimilate their knowledge and students in grade 8 have confusions due to high school entrance examination anxiety.

These findings indicate that primary school students are not able to understand heat and temperature concepts which have big importance in science education. We concluded that most of students memorized these concepts and were not able to make a connection between their own knowledge and physics in everyday life. It has been noted long since that in everyday usage, "heat" is strongly associated with temperature which linguistic complications have often been blamed for conceptual confusion experienced by students. The term "heat" is even used ambiguously in some textbooks. Certainly, precise use of technical terms is to be strongly encouraged. However, for many students, the problem goes beyond incorrect or inexact use of terminology and reflects genuine in ability to distinguish among closely related concepts. In such cases, a linguistic remedy is unlikely to be sufficient. Surely, physics and science teachers have vital role in science and physics educations due to their educating role to our younger generation. From of this point of view, teacher training programs need to critically weigh the long-term consequences of having science and physics teachers before graduate they have chance to explore and try to alter their misconceptions about scientific ideas, because they will not be able to develop scientifically accurate conceptions on their students. Therefore, in recent years, special attention has been given in the research field of science education to nature of scientific knowledge and to its construction processes.

Turkey has a centralized educational system, and all schools implement the same curricula. Different authors write the textbooks by taking into consideration the curriculum for each subject area. The science teachers in each school are free to choose one of the science textbooks for their teaching. As is the case in many other countries, teachers can prepare supportive teaching materials for their students. Therefore, this study can help current science teachers rethink their way of teaching as well.

Curriculum developers, teachers and teacher educators should work together with researchers to design materials that help students to develop scientific ideas and enable them to make connections between life and school experiences.

Some of the phenomena that students encounter are significant in physics teaching; one is heat and temperature that students come across in their everyday life. In addition, some students also have significant misunderstandings about thermal diffusion processes. This shows students' lack of understanding of their own experiences and observations. Therefore, in the teaching-learning environment, we need to provide students with skills to interpret and express their own knowledge. To do so, it is necessary to devise strategies that provide students with the means to express their views as analogies, laboratory activities, and arguments. To overcome or reduce misconceptions some strategies such as worksheet, Vee and I diagrams, roundhouse diagram, group discussions should be improved and implemented to science classroom during teaching processes.

In addition to these, further research may focus on how primary school students' misconceptions and wrong beliefs could be remedied and their understanding levels could be developed.

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