A Review of Selected Literature on Students' Misconceptions of Heat and Temperature

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ABSTRACT

This study is intended to review some of the studies carried out on students' understandings of heat and temperature. The review puts together the important findings of the studies, summarises the misconceptions identified so far and the possible sources of these misconceptions. Therefore, this study would be beneficial for researchers and lecturers in science education area and for science teachers.

Keywords: Misconceptions, heat, temperature.

Ever since the classical studies of Piaget, there has been an interest in the conceptions of science held by young children (Osborne and Wittrock, 1983). Even a casual observer of the field of science education in the last three decades knows that this has been a period of unprecedented exposure of the ideas held by children, adolescents, and to lesser extent adults, about a wide range of scientific phenomena (Griffiths, 1994). It might be said that one of the best documented areas in science education is students' ideas and misconceptions of heat and temperature. The main reason for this attention might be the fact that heat and temperature are familiar words from daily life. Students' understanding of these concepts is the key to understanding many other scientific concepts. It is also important for science educators to understand students' knowledge of these concepts and to develop new curriculum and teaching methods for science classes. Studies show that even adolescents and scientists have similar misconceptions about heat, temperature as those of pupils (Lewis and Linn, 1994). This could be examined therefore as a crucial point. In this study, it was intended to review some of the studies which most influenced the science education research and revealed students' understandings of heat and temperature concepts and to put together the identified misconceptions together with the sources. It should be noted that this is not a complete review of the studies on heat and temperature. The review is basically composed of two sections. First, the debate on terminology used for heat and temperature is dealt with and second, the misconceptions identified are summarised.

Debates on Terminology and Definitions of Heat and Temperature

Meat is undoubtedly one of the most difficult concepts of the whole secondary-science curriculum. Nearly all text books which deal with heat offer different explanations of the term, for example, 'heat is energy', 'heat is a form of energy', 'heat comes from sun', 'heat is internal energy', etc. These different explanations may cause confusion in understanding the concept. Another source of difficulty in understanding

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the concept might be the use of words like ‘heat capacity' and ‘heat flow.’ Driver et al (1994) reported that students’ tendency to think of heat as a ‘substance’ which flows from place to place is not very different from that of Lavoisier’s concept of heat. The oldest theory about heat was ‘caloric,’ which was widely accepted during the period before the 1850's (Fuchs, 1987). According to this theory it was assumed that heat (caloric) was conserved. This theory was treated for the cases by Carnot and later by thermodynamicists. Fuchs explains that:

> The main problem with the caloric theory of heat can be traced to irreversible processes in which, as Davy’s experiment (melting two blocks of ice by rubbing them) had demonstrated, heat must be generated. Today we know heat cannot be caloric if we accept that the usual calorimetric measurements determine amounts of heat, (p.162).

Fuchs (1987) also reported that Rumford's experiments, which were supposed to have demonstrated that heat could not be caloric, did not even prove that caloric was not conserved. In addition, Linn and Songer (1991) used a heat flow model which was similar to the ‘caloric’ theory embraced by scientists in the 1850’s, but differed in that it stressed that heat lacked mass in their heat flow model. Heat was distributed in substances and flowed from warmer to cooler substances until equilibrium was reached. They stressed that heat lacked mass and that temperature is a measure of the intensity of heat at a given point. Moreover, Su-Yuen Mak and Young (1987) argued that the caloric theory was probably the major confusion in which there is a conserved substance called heat which is contained inside a body and which flows from a hotter to a cooler body when the two are in contact with each other. They insisted that traces of this old and incorrect idea remained in the somewhat misleading terms ‘heat capacity’ and ‘heat gain’ which might mislead students into the notion that a body contains some heat, which might be lost or gained.

Another theory about heat is kinetic theory. Linn and Songer (1991) referred to Blanc et al (1971) who say:

> According to this theory, the temperature of a substance, whether it is a solid, liquid or gas, is determined by the speed of its moving molecules. As the molecules of a substance collide with each other, their kinetic energy is changed into heat. Friction increases the speed of the molecules. Therefore, the kinetic energy in each molecule is increased. The greater the number of collisions among molecules, the greater increase in the kinetic energy of the molecules. The amount of heat, as a result, greatly increases (p.888).

Their opinion about this model was that it was too abstract for students and also offered explanations at a level of analysis that did not apply to the results of experiments or to their observations of the natural world. According to them, a model should be chosen that communicates to all students and integrates their observations and experiences. Consequently, they support the caloric theory with some reservations.

Another argument related to the kinetic theory comes from Summers (1983). It was argued that it is not true that the temperature of a substance is proportional to the kinetic energy of its molecules, when the kinetic theory of ideal gases is applied to real substances. Summers explained this as follows:

> ...it is true to say that the greater the internal energy (which, of course, involves kinetic and potential components) of any one substance, the higher its temperature will be. But this is an approximation (certainly not a proportionality), and even then is only valid if there is no change of state. In the case of two different substances, it is interesting to note that the same mean energy (total or kinetic) per molecule does not mean that they are at the same temperature (p.674).

Summers' (1983) argument was that the results for ideal gases should not be extrapolated for real gases, and Summers believed that the kinetic theory of gases was not an ideal vehicle for developing thermodynamic concepts at 'A' level. In addition, Baierlein (1990) discussed the kinetic models in his theoretical paper and concluded that the statements 'temperature is a measure of the average kinetic energy of the molecules or atoms in a substance' is misleading. Baierlein insists that the function of temperature is not to tell us about a system's tendency to transfer energy (as heat). According to Baierlein, we must return to the definition that 'temperature is hotness measured on some definite scale.'

With regard to heat, there is a variety of definitions for the concept, varying from scientists' to students' viewpoints. Waite (1985) produced a theoretical description and defined heat as a random or non-directed internal energy transfer between different bodies at different temperatures. Waite also accepted the kinetic theory to interpret the temperature changes in any system and concluded that heat and work should not be considered as forms of energy, but rather as different mechanisms by which internal energy is transferred from system to surroundings. Roon (1992) also related the definition of heat and work to system and surroundings. Roon concluded his argument by stressing that:

> ...'heat' and 'work' were words dominating important founding of classical thermodynamics. The thermodynamic quantities, heat and work, are not changes of state quantities. They are process quantities, meaningless in the one important thermodynamic state: the equilibrium state. Perhaps this is one of the main sources of difficulties with these thermodynamic concepts (p. 138).

With regard to the terminology used, both 'heat' and 'heating' are commonly used. Summers (1983) argued that using 'heat' as a noun should be avoided and 'heating' should be used as a process. Summers defined 'heating' as 'the name given to the process by which internal energy transfer occurs as the result of a temperature difference' (p.671). However, Su-Yuen Mak and Young (1987) disagreed with Summers' definition by writing:

> ...like to use 'heating' another new term to describe this process. We feel that 'heating' is still not entirely satisfactory. The reason is that the gerund 'heating' in everyday usage can mean (i) the process of heat flows, or (ii) the increase in temperature. In fact, the opposite of heating, namely cooling...

usually means the decrease of temperature of a body. The two meanings of 'heating' are not equivalent (p.468).

Finally, they conclude that the term 'heat' is perfectly adequate so long as attention is drawn to the fact that it is not something stored in a system. The accurate use of terminology in science teaching and research is a disputed area (Slisko and Dykstra 1997). Perhaps this discussion would be the subject of a separate paper in which heat and temperature would be discussed in terms of linguistics and everyday language usage. This discussion could consider both Turkish English usage.

Students' Understanding of Heat and Temperature

Several studies (Erickson 1979, 1980; Brook et al 1984, 1985; Tiberghien 1985; Duit and Kesidou 1988; Linn and Songer 1991; Kesidou and Duit 1993; Lewis and Linn 1994; Grayson et al 1995; Harrison et al 1999) have shown that students have different ideas about heat and temperature from those held by scientists. Students can derive these ideas from their daily experiences and even from misrepresented instructions in school. Some of the misconceptions identified so far are given in Table 1.

Table 1. Identified students' misconceptions about heat and temperature

Identified Misconceptions	Students' age	Revealed by
There are two types of heat, cold heat and hot heat Heat is a material substance like air or steam Heat is a form of energy The temperature of an object is related to its size	6-13 year old	Erickson (1979, 1980,1985)
Heat is hot, but temperature can be cold or hot There is no difference between heat and temperature Temperature will change during melting or boiling	12 year old	Tiberghien (1985)
Heat and temperature are the same Some substances are naturally colder than others Heat and cold are opposite and both are fluid materials	15 year old	Brook et al. (1984,1985)

Heat transfer start and does not stop at once when the temperature equalized Air only cools other bodies if they are surrounded by air Heat is attracted by the cold body until heat and cold have neutralised Heat is not an extensive quantity, but an intensive quantity	15-16 year old	Duit and Kesidou (1988)
Temperature is the amount of heat If two bodies are at the same temperature they have the same energy or heat Heat enters and leaves different materials at different ease Different materials attract heat or retain heat differently	15-16 year old	Kesidou and Duit (1993)
Objects at room temperature that feel cold have different temperatures Objects could have a certain quantity of heat in them Objects could get hotter than their surroundings The temperature of water could exceed the boiling point	17-18 year old	Grayson et al. (1995)
Constant heat means no heat exchange possible Heat is a 'state quantity'', something in a body	University'	Roon(1992)
Metals attract, hold, or absorb cold Conductors conduct heat more slowly than insulators Insulators conduct heat fast and heat leaves so insulators don't feel hot Insulators absorb/trap heat Wool warms things	12-14 year old, Adults (19-45 year old), Scientist,	Lewis and Linn (1994)

Children’s thinking about heat and temperature is well documented by Erickson (1979, 1980). In the former study Erickson aimed to address two issues which illustrate one approach to identifying a pattern of children’s ideas about heat and temperature and indicate that how this knowledge might be used in an instructional setting. After a number of open-ended informal interviews, Erickson interviewed 12 Canadian children ranging in age from 6 to 13. Erickson used a ‘clinical interview method’ in which no rigid schedule of questions was used. Rather, the investigator first attempted to get the child involved in some aspect of a task. Having established some avenue of inquiry or interest, open-ended questions were posed, using the child’s own language where appropriate. The main point of confusion was that there were two types of heat, ‘hot heat’ and ‘cold heat’. However, children perceived heat as a material substance, which reflects the caloric theory of heat. The other interesting belief was that heat (or cold) was a type of substance like air or steam, which is capable of flowing into or out of objects.

Erickson (1980) documented children’s difficulties in differentiating heat from matter. In this study, Erickson developed an instrument called Conceptual Profile Inventory (CPI) to determine the students’ beliefs about heat and temperature. Three different viewpoints were taken into consideration; those are Kinetic Viewpoint, Caloric Viewpoint and Children’s Viewpoint, which were determined during in depth clinical interviews. The research instrument was administrated in two steps; first a demonstration relating to the topic was performed in front of the classroom and then students were asked to make their judgements on a set of six bipolar scales. A total of 276 subjects (76 fifth graders, 117 seventh graders and 83 ninth graders) from classes in three different large urban centres in British Columbia were included this study. As a result, Erickson reported that caloric theory was rated higher than other viewpoints and that previously younger students thought heat and cold to be intrinsic qualities of different substances. After teaching, students’ ideas changed to thoughts of heat transfer. For a couple of years later, Erickson (1985) reviewed related studies on heat and temperature. It was reported that most pupils were aware of the transfer of heat from objects at a higher temperature to those at a lower temperature and that they also had a number of plausible explanations for the process. Erickson also reported that pupils believed that the temperature of an object is related to its size. For example, more than half of the 76 children (12 years old) thought that a large ice cube would have a lower temperature than a small one.

In another review, Tiberghien (1985) revealed students’ ideas of the kinetic molecular theory; many of these students had received formal instruction in the subject. Tiberghien noted that children had an idea that heat is hot, but temperature can be cold or hot and also that some of them thought that there is no difference between heat and temperature. In addition, children thought that temperature will change during melting or boiling.

In a study conducted in Germany, Duit and Kesidou (1988) have carried out clinical interviews with 14 German I0^{,h} graders (15-16 years old) for the purpose of mapping students’ conceptions of heat and temperature. These students had four years of physics instruction in which heat, temperature and energy had been taught in a traditional way. Their study showed that these students had several misconceptions. Firstly, around 80% of the students had the opinion that when two bodies at different temperatures get in touch they would not reach the same temperature as a result of the heat exchange process. They express this situation by writing:

> Temperature equalization was explained by properties of the bodies involved (e.g. the property to 'be hot' or 'be cold') or the ability to 'give heat' (or cold respectively to other bodies). Usually only the properties of one of the bodies involved were considered (p. 191).

In addition, only 2 out of 14 students they interviewed had the view' that air has the quality to cool other bodies if they are surrounded by air. Moreover, they had noticed that students view heat and cold as entities of their own. In explaining heat exchange, students said that heat is attracted by the cold body until heat and cold have neutralised. This misconception supports the Su-Yuen Mak and Young (1987) view that student think 'heat' as 'hot' as opposed to 'cold'. This finding suggests that teachers should be cautious when teaching heat and temperature. With respect to students' conceptions of irreversibility, Duit and Kcsidou (1988) found that a temperature difference may arise out of equalisation when the direction of temperature changes does not alter. This view leads to the misconception that 'heat transfer starts and does not stop at once when temperatures have equalised'. This notion was further investigated in a follow-up study (Kesidou and Duit 1993) and the main reasons for this kind of thinking was given as (a) the ease with which heat enters and leaves different materials varies, (b) different materials attract heat or retain heat differently, and (c) the particles are not equally close to one another - they have different qualities (p.96).

In this follow-up study, Kesidou and Duit (1993) conducted clinical interviews with 34 10^{lh} graders (15-16 years old) students. They intended to determine whether some slight enlargement and reorganisation of traditional physics instruction are sufficient or major changes are necessary in order to familiarise students with the basic ideas of the second law. They used open-ended questions to help students to develop their own ideas. The results showed that the majority of the students (53%) viewed temperature as a variable that can be measured and/or quantified, while heat was not seen as a measurable or quantifiable concept. The results also showed that only a small number of students, around 21%, used the particle model to explain the concept. It was also found that about 30% of the students thought of heat as an extensive quantity; however, some of these students viewed temperature as the amount of heat contained in a body. In addition, some of them also viewed temperature as something that passes from one body to another, the degrees indicating the amount of temperature transported. In their studies, 50% of the students did not perceive heat as a form of energy and the responses indicated that they thought of energy as an intensive quantity. Moreover, the idea of the transformation of kinetic energy to heat was not well developed. They summarised:

> ...Students' ideas about whether or not heat energy may be transformed into kinetic energy were also very' limited. Heat energy was often considered only

> as a cause of temperature changes, and motion only as an effect of kinetic energy (p.96).

Finally, they argued that in terms of thermal equilibrium, a minority of students' responses revealed some uncertainties about temperature, heat and energy equalisation. They suggested that this may be due to the idea that two bodies have the same energy or heat if they are at the same temperature. Quit and Kesidou (1988) reported that students were under the impression that 'heat transfer starts and does not stop at once when temperature is equalized, and also students' ideas of the process running in a natural direction are mainly based on everyday experiences and not on a scientific basis as taught in school.

Brook et al (1984, 1985) conducted extensive research to reveal students' ideas about heat and temperature and to find answers to the following four questions.

1. Do students differentiate between heat and temperature?
2. Do students appreciate that heat is required to produce a change of state, and that temperature remains constant during a change of state?
3. Do they understand change of state in terms of the particulate model of matter?
4. How do students conceptualize the conduction of heat through materials?

They prepared seven different written questions which were given to a group of 300 students aged 15. Their findings revealed that students had several views of heat such as 'heat and temperature are the same,' 'heat and cold are opposite and both are fluid materials' and 'some substances are naturally colder than others.' Also, the results suggested that the process of heat transfer is better understood by students when it produces a temperature change than it does not. Students were less able to understand heat transfer and change of state in terms of the behaviour of particles. They concluded that the alternative ideas about change of the state and heat transfer were question-specific. Furthermore, they argued that students do not need to understand the behaviour of particles in order to understand that heat is transferred from an object at a higher temperature to one at a lower temperature.

Grayson et al. (1995) conducted a research study with a physics class comprising fifth grade (11 year old) boys in Australia in order to track pupils' development of the concepts of heat and temperature when instructional strategies were employed. The students were given course material called 'Physics by Inquiry: Heat and Temperature' and then changes in their understanding were monitored. A number of misunderstandings were identified:

- Objects at room temperature that feel different have different temperatures.
- Objects could have a certain quantity of heat in them.
- Objects could get hotter than their surroundings.
- The temperature of water could exceed the boiling point.

They suggested that the use of instructional materials and approaches adopted in their study promoted changes in pupils' understandings of fundamental concepts of heat and temperature.

In a study, Lewis and Linn (1994) identified concepts of heat and temperature held by adolescents, adults and scientists. They investigated about 160 students and conducted clinical interviews with 37 students from the 8th grade (ages 12-14 years old), 9 adults (aged 19-45 and selected from non-science faculties), and 8 chemists and physicists (3 physicists and 5 chemists involved in active science research and teaching and all holding either PhD or MSc) to reveal their predictions and explanations of real world phenomena. Many students believed that metals 'conduct,' 'absorb,' 'trap' or 'hold' cold better than other materials and that aluminium foil would be better than wool or cotton as a wrapping material to keep cold objects cold (p. 155). While adolescents and adults gave remarkably similar responses to the interview questions, scientists gave meaningful explanations for the real-world phenomena. Some scientists also used intuitive conceptions in responding to the interview questions. The results of the study indicated that there was no relationship between the scientists' responses and their level of education, research and teaching experience.

Two studies were compiled with the aim of understanding the university students' ideas about heat and work by Roon (1992) and Roon et al. (1994). Roon (1992) reported that students thought that 'constant heat' meant 'no heat exchange possible' and that heat was perceived as a 'state quantity,' 'something in a body' instead of a process quantity. In the subsequent study, Roon et al. (1994) reached the conclusion that students' conception of heat was what they term an 'energetic heat concept,' because the students perceived heat as a kind of energy.

There were also studies carried out in order to test the effects of different teaching approaches to overcome the students' learning difficulties of heat and temperature (Rogan, 1988; Linn and Songer, 1991; Harrison et al, 1999). In order to determine the key factors affecting understanding of the kinetic theory of heat by children who hold alternative viewpoints, Rogan conducted a classroom based study in order for the results to be more readily put into practice by science teachers. 145 students whose mean age was 14.61 years participated about the study. The study was focussed on the question that 'can the utilisation of certain teaching strategies bring in about conceptual change?' and the following three themes were explored.

The first was that students whose prior notions of heat are taken into consideration will experience a conceptual change in favour of an energy theory of heat. This was tested by designing a teaching sequence based on a conceptual-change approach proposed by Hewson (1981). The second was that students who are placed in cooperative learning groups will acquire a better understanding of heat than students working individually and interacting with only the teacher. This thesis was achieved by designing two different learning environments. The one, designated cooperative learning groups, composed of four mixed ability students, involved students working together, and the second learning environment, called individual, in which students worked by themselves and got help from the teacher. The third was that students who show more advanced forms of logical reasoning will be more likely than less-advanced students to make a conceptual shift. This thesis was explored by dividing the entire sample into roughly two groups, one of low and one of high reasoners, both receiving the identical treatment. In the research two instruments, Lawson's (1978) Formal

Reasoning Test and Erickson's (1980) Conceptual Profile Inventory (CPI), were used. The instruments were used as pre-test, post-test and retention test. According to the results, Hewson suggested that the articulation of different viewpoints in no way hinders the acquisition of the desired conceptual framework. Students in both instructional approaches showed similar gains in their acceptance of the kinetic theory of heat. In addition, it was found that students with high reasoning skills appeared to be more adept at making conceptual shift, regardless of instructional approach.

In order to improve the teaching of elementary thermodynamics Linn and Songer (1991) designed a thermodynamics curriculum by using earlier test results. All curricula focussed on the teaching of a 'pragmatic model' of the thermal phenomena based on the idea of heat flow similar to the caloric theory. Their curriculum called CLP (Computer as Lab Partner) devoted 13 weeks to experiments and 20 weeks to instruction and took place in physical science class during one semester. In order to assess students' understanding of thermodynamics, they used the HTA (Heat and Temperature Assessment) tests. They suggested that the kinetic theory model was ignored by the students and that they did not integrate the results of their experiments with the theory.

Harrison et al (1999) took an in-depth case study with only 5 students, purposefully selected from a classroom, to investigate the effect of a carefully designed concept substitution approach (open-ended inquiry based teaching) on grade 11 students' conceptions of heat and temperature. They argued that their course activities and concomitant use of concept substitution helped their students differentiate heat and temperature and integrate them in a more scientifically acceptable way. The research results suggest that a degree of affective and epistemological change was also identified as the course progressed.

Studies carried out in Turkey

Under this section, the studies carried out in Turkey and reported in Turkish are reviewed. There are a limited number of papers written in Turkish about heat and temperature. The contents of the studies carried out in Turkey fall into two main areas. The first group could be considered studies that focused on the identification of students' misconceptions about heat and temperature and the second group studies that were aimed at how to teach heat and temperature concisely and avoid and overcome the identified misconceptions. There is only one study that does not fall in either of the above groups, which was intended to develop three-tier diagnostic questions that could be used effectively and correctly identifying students' misconceptions about heat and temperature.

There are four papers in the first group of studies that focused on documenting students' misconceptions about heat and temperature. In a study carried out with 256 first year secondary' school students (aged 15), students' conceptions of heat, temperature, phase changes and heat transfer were investigated through diagnostic questions and interviews (Kocakülah and Mergen Kocakülah, 2002). The results of the study show several mental structures that students developed through intuition. These mental structures are mostly inconsistent with the current scientific view. A case study with 118 primary school students from 4,5,6,7 and 8"' grades attending the same school in Erzurum city center in order to determine students' conceptions of heat and temperature was carried out by Şenocak et al (2003). The study employed diagnostic questions based on theoretical and everyday aspects of heat and temperature for determining students' learning difficulties. The results of the study demonstrated that students were more successful and willing to answer the questions related to everyday life than theoretical questions. On the basis of this finding, the study suggests that using examples and questions based on everyday aspects of heat and temperature during teaching would improve the quality of students' learning. The third study, a survey study, carried out by Aydoğan et al (2003), focuses purely on documenting students' misconceptions through multiple choice questions. The data were collected through 15 open-ended questions developed by the researchers and applied to over thousand secondary school and university students. Similar misconceptions as in previous studies were reported. The study concludes that the misconceptions documented were common among university and high school students and also were consisted through university education. The last study in this group was done by Gümüş et al (2003), and the subjects were 240 first year students in primary science and mathematics education departments. The study focused on determining misconceptions prior to teaching heat and temperature and looks into the relationships and differences between the students in different departments and students different gender. The study suggests using diagnostic tests prior to teaching these concepts.

Three studies reported in Turkish focused on developing a syllabus and alternative teaching sequences for better teaching of heat and temperature. Two of these studies were focused on developing alternative teaching sequences. Şenocak et al (2002) focused on the primary level and aimed to determine the effect of demonstrations and students' questions on student learning of heat, temperature and energy transfer concepts. In this case study, demonstrations were used during teaching, students were asked to write questions about the topics taught, and these questions were discussed during class hours in the experimental group, traditional teaching strategies were employed in the control group. The results indicated that students in the experimental group had a better understanding of the concepts than those in the control group. In another case study, Gürses et al (2002) employed assessment-embedded approach to teach heat and temperature concepts to third year prospective chemistry teachers enrolled in a physical chemistry course. The study was focused on formative assessment procedures through quizzes, assignments, class discussions, and diagnostic tests. In this in-depth study, students demonstrated significant improvement in understanding and also positive attitudes towards thermodynamics. The last study was focused on developing a syllabus for high school level covering heat and temperature topics in a physics course. The study was intended to identify students' learning difficulties in the light of the literature. A syllabus developed for the study was tested on a small number of students in a high school in Izmir. This syllabus was experimented with a small number of students in a high school in Izmir. The result of this experimentation provided encouraging conclusions and suggestions were made to curriculum developers (Kalem et al 2002).

One other study by Eryılmaz and Sürmeli (2002) developed their diagnostic questions that could be used to identify students' misconceptions about heat and temperature. The study argues that achievements tests based on multiple choice questions have weaknesses in identifying misconceptions, and proposes that two or three-tier diagnostic questions are more successful in correctly identifying misconceptions. This argument was supported by an experimental study using a test composed of three-tier diagnostic questions, which were developed on the basis of previous studies on heat and temperature. The results of the study suggested that the percentage of students who demonstrate misconceptions about heat and temperature falls when the questions are designed in the form of tiers instead of multiple choice questions.

Conclusions and Implications for Teaching

It has been shown that there are many misconceptions held by students about heat and temperature. Heat and temperature are undoubtedly among the most difficult concepts in the secondary science curriculum and also at university. The above review strongly suggests that many of the ideas about heat previously associated with the think of young children remain with many of students up to university and even after postgraduate education (Engel Clough and Driver, 1985). Perhaps this is not surprising as we all have built up a fund of experimental knowledge about heat from an early age as young as 1 year old.

This difficulty' may arise from several sources including the terminology used .The same word used in everyday life and school curriculum may have different meanings. Also heat and temperature are sometimes used interchangeably by mistake in everyday life. As Schuster (1983) suggested, labels or terminology can be useful in organising ideas in a field, but they can inhibit creative thinking or alternative approaches if they are overly simplistic or inappropriate. Students are usually relatively quick at learning verbal labels and scientific-sounding phrases. In the usual classroom interaction between teacher and student, exchanges are rarely long enough to reveal what kind of understanding lies behind such words or phrases. When we take the language of everyday life as a point of departure, it is possible to start by first distinguishing heat from temperature. Another possible source of these misunderstandings could be the definitions of the terms in text books. Some misunderstandings may also come from the teachers and textbook writers who do not agree on the definition of the terms. Engel Clough and Driver (1985) argued that in teaching an idea such as conduction of heat teachers tend to focus on one or two simple phenomena and students' discussion or writing about these may suggest that they understand them. However, when students are asked to use the ideas in another, slightly novel context, their misunderstanding is revealed.

In the studies reviewed above, it is evident that students think of heat as a state quantity especially at university level and as ‘a form of energy.’ The form of energy approach is not accepted in thermodynamics. Goedhart and Kapper (2002) argues that the most easy solution to this problem seems to be the abandonment of the forms of energy approach in secondary schools, as was decided for the science curriculum in the UK (DBS, 1989). The authors concluded that forms-of-energy language is resistant to empirical challenges, unless students perceive forms-of-energy terms as models that have to be tested for their usefulness. A less factual introduction to (forms of) energy in secondary' education seems desirable (p. 351).

Although a number of studies have been carried out on the topic, there are still unexplored areas surrounding the meaning of the terms as used by university students (Sözbilir, 2001). The understanding of the concepts of heat and temperature could be different for them. The model (e.g. the kinetic molecular theory or caloric theory) accepted and used by university students to explain the concepts can be an important point start with. It is worth investigating further to reveal the university students’ understanding of the differentiation of heat and work and differences from the kinetic molecular theory and caloric model points of views. In addition, a linguistic discussion of the words ‘heat’ and ‘temperature’ would provide a rich source of information for the researchers and teachers in science education. Moreover it is worth looking at students’ explanations about heat and heat capacities too. Although interesting ideas have been proposed to teach thermodynamic concepts at primary and university level, most of these approaches were not evaluated in a systematic way and therefore cannot be said to be research-based (Goedhart and Raper, 2002).

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Öğrencilerin Isı ve Sıcaklık Kavramları Hakkındaki Kavram Yanılgıları Üzerine Yapılmış Olan Seçilmiş Bazı Araştırmalardan Bir Derleme

Özet

Bu çalışmada, öğrencilerin ısı ve sıcaklık kavramlarını anlama düzeyleri üzerine yapılmış olan araştırmalardan bazılarının derlenmesine çalışılmıştır. Derlemede, bu alanda yapılan araştırmaların önemli bulguları, saptanan kavram yanılgıları ve bunların muhtemel sebepleri bir arada ele alınmış ve incelemiştir. Bu nedenle, bu çalışma fen eğitimindeki araştırmacılara, eğiticilere ve fen öğretmenlerine yararlı olacağı düşünülmüştür.

Anahtar sözcükler: Kavram yanılgıları, ısı, sıcaklık