Third Misconceptions Seminar Proceedings (1993)

Paper Title: AN ATTEMPT TO OVERCOME ALTERNATIVE CONCEPTIONS RELATED TO HEAT AND TEMPERATURE

Author: Thomaz, Marília F.; Malaquias, I. M.; Valente, M. C. & Antunes, M.J.

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The study was conducted by two university teachers and two secondary school teachers. The latter implemented the teaching model in their classes.

During the first year the pilot study, providing an opportunity for the training of the school teachers, enabled the improvement of the teaching model in the next year.

The findings suggest that the model has potentialities for promoting a better understanding of the phenomena concerning heat and temperature.

In the all process the role of action research involving the two categories of teachers acting as researchers, was also analised and proved to be a very useful and efficient activity for in-service teacher education.

Keywords: Teacher Education,Educational Methods,Concept Formation,Teaching for conceptual Change,Educational Strategies,Misconceptions Inservice Teacher Education,Constructivist Teaching,Scientific Concepts,Secondary School

General School Subject: Thermodynamics

Specific School Subject:

Students: Physics

Macintosh File Name: Thomaz - Heat & Temperature

Release Date: 12-16-1993 C, 11-7-1994 I

Publisher: Misconceptions Trust

Publisher Location: Ithaca, NY

Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics

Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

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AN ATTEMPT TO OVERCOME ALTERNATIVE CONCEPTIONS RELATED TO HEAT AND TEMPERATURE

Thomaz, Marília F., Malaquias I. M., Valente, M. C. and Antunes, M.J.
Physics Department, University of Aveiro. 3880 Aveiro Portugal

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INTRODUCTION

Teaching has been described (Zumwalt, 1982) as a deliberative process requiring teachers to see and think about what they do. Khun (1986) points out that "a long and distinguished theoretical literature in the field of education, which may be traced to the beginning of the century, reflects the opinion that the only way to improve teachers thinking is to involve them in it."

On the other hand, over the last two decades a large number of studies has been conducted on misconceptions or alternative conceptions in physics (e.g. Driver 1981, Gilbert and Watts 1983, MacDermontt 1984, Novack, 1987, Vasconcelos 1987, Maurines, 1992). These studies have given strong evidence of the importance of those ideas in the understanding of key concepts in physics.

One of the topics to be covered in secondary school physics curriculum concerns the introduction of thermodynamics, more precisely thermometry. In Portugal this has been allocated to the 9th grade (14-15 years old). However, studies conducted with science university students, (Thomaz 1990, Latas ,1992) show that many of these students held ideas related to heat and temperature similar to the ones held by children before formal teaching or even adults whose formal science education finished at the 9th grade.

For the domain of thermodynamics a number of studies has been made of the ideas that young children have about heat and temperature (e.g. Erickson and Tiberghien 1985, 1980, Clough and Drive, 1985, Thomaz, 1990, Latas, 1992). The following alternative conceptions among pupils answering qualitative questions have been noted:

(i) Many pupils seem to believe that heat is a kind of substance residing in objects, that can move through them and can pass from one to another. This is sometimes reinforced by textbooks, like for instance, the book "Physics for You ", O-level Edition (Keith Johnson, 1981) in which it is written "Heat is the total amount of energy in an object"

(ii) Most of the pupils discriminate insufficiently between heat and temperature. For them temperature is a property of the material from which a body is made and is a measure of its heat.

(iii) Pupils tend also to reason that different sensations mean different temperature and the concept of thermal equilibrium, taken for granted by teachers and textbooks writers, is not held by the majority of pupils.When in contact with its surroundings the temperature of an object is seen, by a great number of students, as dependent primarily on the substance from which the objects are made

(iv) Many pupils think that heating a substance always means increasing its temperature. The temperature of a phase transition is not considered as a characteristic of a pure substance.

(v) The temperature of a phase transition is seen, by many pupils, as the maximum temperature that a substance can have when it is heated.

There is strong evidence suggesting that many ideas about heat and temperature previously associated with the thinking of young children, remain with many secondary and even university students.

Clough and Driver, 1985 suggest that "the students´alternative perspectives have not been noticed before because the way teaching is conceptualised and carried out". Nevertheless, as pointed out by Rowell et al (1990), while there has been a wealth of published research identifying students´ideas about scientific concepts, relatively little has appeared detailing how alternative conceptions might best be changed and why proposed strategies might be expected to work.

On the other hand, there is great evidence that, the success or unsuccess of any curriculum implementation depends first of all on the way teachers see it. The implementation can be seen by teachers as a process externally imposed on them, and the probability of failing is very high, or it can be seen as a process in which teachers are genuinely interested in, very much involved in its development and about which they have reflected and discussed strongly. In the last situation the implementation has a much greater probability of success.

Sharing Khun´s views on the necessity to involve teachers in the thinking of teaching for improving the teacher thinking, a study was conducted by a team of two university researchers and two secondary school teachers on the design and implementation of a teaching model aimed to overcome alternative conceptions on heat and temperature. The study was undertaken with mixed ability pupils in the normal physics context of the secondary school teachers´ classes at school.

THE STUDY

The study consists of three phases. In a first phase, the two secondary school teachers from the same city school, came to the university during several sessions in which they were introduced to the problematic of alternative conceptions. A review of the literature on this topic and a joint reflexion and discussion on it, helped them to become acquainted with the problem upon which they had never reflected

In a second phase, in the school year 1991/92, before formal teaching of phenomona related to heat and temperature had started, a first diagnostic questionnaire, a pre-test, on pupils´ideas about these concepts was designed and applied to 92 students - 79 from the teachers´ classes and 13 from a class of another teacher of the same school not involved in the study. The latter provided a class control. Each student was required to make a choice response and to give a reason for it. This was considered essential because the reason provided gives an idea of the logic used and of any alternative conception. The last question was an open one asking for students´ideas about the concepts of heat and temperature.

Based on the findings of the analysis of the results of this questionnaire, the team took various sessions developing the teaching model. This model was then implemented by the secondary school teachers in their classes. Meanwhile, a post-test was designed with the same objectives as the first one, in order to be applied at the end of the implementation. Ten lessons of each teacher were videorecorded and analised by the team. Various sessions of reflexion took place then. These sessions were very rich for both the university and the secondary school researchers because they provided opportunities for interesting discussions not only on the events that happened in the lessons (either scientific or pedagogical) but they also allowed for a more in-depth discussion of the scientific aspects involved.

This first study was used not only as a pilot study but also as a mean to promote a training period for the secondary school teachers who acted as researchers for the first time in their professional life.

In the third phase, in the following year, 1992/93, based on the findings of the first year implementation, a new cicle took place and it will be the results of this cicle that will be presented in this communication.

In this phase the class control was chosen from a different school in the surroundings of the city in order to avoid any interference with the implementation. It was decided to follow one class of both secondary school teacher. The pre-test was aplied to 48 students in the experimental classes and to 31 students in the class control.

Examples of items of both tests are presented in Apendix 1.

OUTLINE OF A TEACHING MODEL FOR THE TEACHING OF HEAT AND TEMPERATURE

One of the most impressive findings of the content analysis of the responses to the first questionnaire was the difficulty revealed by students to accept that different objects are at the same temperature when in contact, for a long time, with the same surroundings. The temperature of an object is seen as a characteristic of the material from which the object is made. This means that the concept of thermal equilibrium, taken for granted by teachers and textbook writers, is not present in the majority of the students (91,7 % - 96,9% in the experimental and in the control classes respectively).

The concept of thermal equilibrium is a key concept for the study of heat and temperature because it is a mental construct, the understanding of which is a basic prerequisite for many other concepts of thermodynamics. At an introductory level temperature is defined as "a macroscopic quantity related to the mean kinetic energy of each particle and it determines whether or not two or more ordinary objects are in thermal equilibrium when placed in contact with each other." Heat is also defined in terms of thermal equilibrium: "heat is energy which is transferred from an object at a high temperature to another at a low temperature, until they reach the state of thermal equilibrium".

So this implies that in order to reach the scientific meaning of heat and temperature pupils must understand correctly what it is meant by thermal equilibrium. It is known that the concept of temperature, like that of force, originated in man´s sense perceptions. But man´s temperature sense, like his force sense, is unreliable and restricted in range. Out of the primitive concepts of relative hotness and coldness there has been developed an objective science of thermometry, just as an objective method of defining and measuring forces has grown out of the naive concept of a force as a push or a pull. However, there is strong evidence showing that in students´mind the sensation of hotness or coldness felt when touching objects in thermal equilibrium with the same surroundings is synonymous of high or low temperature. An analysis of textbooks used by teachers revealed that this concept of thermal equilibrium is treated briefly or not treated at all.

Based on the above mentioned it was decided to consider the key concept of thermal equilibrium as the central concept from which all the others would appear as a necessity to interpret and understand it.
Figure 1 presents a concept map useful for the teaching of heat and temperature.

The model for the teaching of heat and temperature proposed is based on a constructivist one . This model takes that students are best seen as active constructors of their own knowledge. They are not seen as coming to instruction without prior ideas about the topic in question. Rather, pupils are like to have access to ideas derived from informal experience and from language usage, which may influence their receptivity to new ideas. This view of learning is particularly valuable in approaching the teaching of heat and temperature.

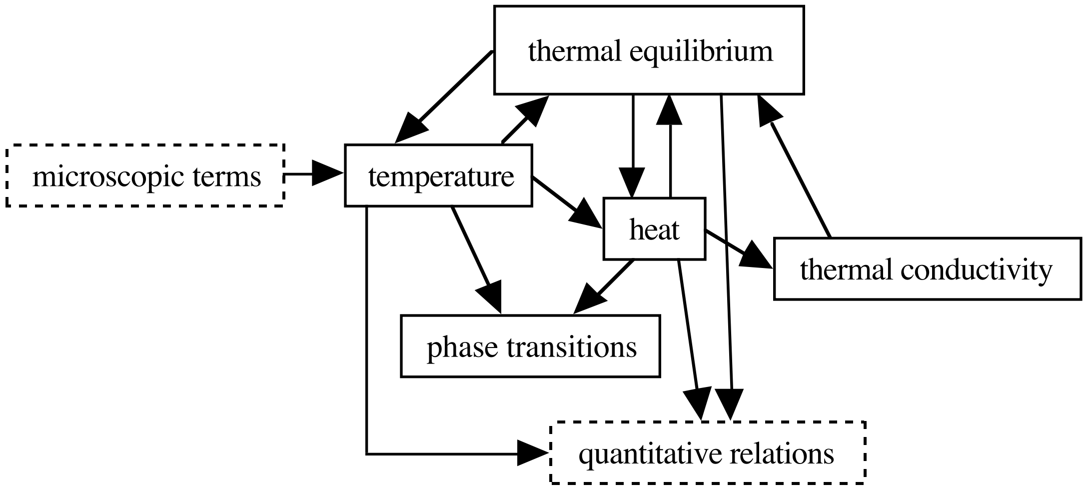

Fig. 1 - Map of concepts useful for the study of heat and temperature

The important part of this model is the emphasis on the active involvement of the learner in his/her own learning. The information presented to the student is not carried by the information itself. Rather, the student has to give meaning to the information as a result of its interaction with student´s prior knowledge. However the student may not be able to make links between "old" and "new" knowledge without guidance, and it is here where the skill of the science teachers can be used to a great effect.

The framework for the model of teaching aimed to promote conceptual change, was based on Rogers´developmental model of the adoption process, described elsewhere (Thomaz 1986).

The framework contains five stages identified in the mental process of adopters of "new" concepts: (1)- awareness, (2)- interest, (3)- evaluation, (4)- trial and (5)- adoption .

The primary function of the awareness stage is to initiate the sequence of later stages that lead to eventual adoption or rejection of the new concepts. Hassinger (1959) points out that information about a new idea often does not create awareness, even though the individual may be exposed to this information, unless the individual has a problem or a need that the new idea promises to solve. The individual must be aware of his own ideas. Presented with situations to which he is asked to interpret, there must be dissatisfaction with these existing ideas or conceptions and the individual feels the necessity to change them. At the interest stage the individual becames interested in the "new" idea and seeks additional information about it. The function of the interest stage is mainly to increase the individual´s information about the "new" idea that must be intelligible and plausible to him.

A sort of "mental trial" occurs at the evaluation stage. If the individual feels that the advantage of the "new" idea outweigh the disadvantages he will decide to try the "new" idea.

At the trial stage the individual uses the new concept in order to determine its usefulness for possible complete adoption.

In the model proposed the role of the teacher is to create opportunities which can promote the development of the different stages in the students´mental process of the adoption of a new concept. It is in the adoption stage that a conceptual change can take place.

Table 1 shows the five stages of the model of teaching aimed to promote conceptual change concerning concepts related to heat and temperature and the activities that took place in each stage.

At the awareness stage students are exposed to situations in which they are "forced" to be aware and use their own ideas for the interpretation of phenomena presented to them in those situations.

To promote this awareness students must be presented with situations in which they could:

i) be aware of their own and peers ideas concerning sensations and temperature;

ii) verify that different sensations do not mean different temperature;

iii) recognize that temperature is not a characteristic of each substance (when in the same surroundings an object of metal is at same temperature than an object of wood);

iv) recognize that whether objects are of the same material or not when put in contact an end state is reached in which the reading of the thermometer is the same.

In a first step students should have opportunities to get aware that different sensations do not mean different temperature. For that, the teacher starts the lesson by asking students to touch different objects in the room and discuss the sensations felt. Then students are invited to give their ideas about the temperature of each one. Students use here their familiar term of temperature. After this first set of questions students should be offered opportunities to measure the temperature of a set of objects adequately brought by the teacher. These objects should be in the room since the beginning of the lecture (as for instances, a glass of water at room temperature, a piece of cotton wool, a glass full of small balls of plumb, a bloc of wood, etc. Care must be taken to choose objects whose temperature is easy to measure with simple thermometers existent in the school). This activity functions as an opportunity to promote conflict situations.

A situation in which two objects at different temperatures are brought into contact, should be provided allowing students the possibility to read the thermometer regularly until the thermal equilibrium is reached.

Table 1 - The five stages´framework and the activities that took place in each stage

Awareness stage	1st step - Awareness of pupils´own ideas about sensations and temperature. (Experimental) 2nd step - Exposition to conflict situations - temperature measurements of different objects in contact with the same surroundings. (Experimental)
Interest stage	3rd step - Understanding of temperature in microscopic terms. (Experimental) 4th step - Understanding of heat as energy transferred at microscopic level.
Evaluation stage	5th step - Interpretation of thermal equilibrium.
Trial stage	6th step - Use of thermal conductivity for explaining why different sensations do not mean different temperature (Experimental) 7th step - Reinforcing the discrimination between heat and temperature using the interpretation of phase transitions. (Experimental)
Adoption stage	8th step - Relation between heat and temperature variation. (Experimental) 9th, 10th, ... - Discussions, tests, problems, etc, that can promote the generalization of the concepts and the appreciation of their range of application.

The discussion that follows should involve all the students and the talk should be transferred to the household situation making the conclusion relevant to daily life.

The awareness stage should take place in one or two period class.

Once in conflict with the existent ideas, students must be motivated to seek new information about temperature and heat. In this interest stage experiments should be provided in which students can visualize the effect of heating air contained in a tube, on its volume and pressure. Using a dynamic model in which the increasing in volume and pressure can be visualized in terms of increasing the mean kinetic energy of each particle, students are asked to interpret the change of temperature between two objects in terms of change of energy.

Only after this should the term heat be given as energy transferred between objects in contact to each other or through a medium, until the thermal equilibrium is reached.

To promote the evaluation stage students should be asked to evaluate the use of these "new" concepts in the interpretation of thermal equilibrium in a day-to-day context.

The introduction of the concept of thermal conductivity appears as a necessity to explain why different sensations do not mean different temperature. This should be done experimentally. Also experiments involving phase transitions should take place in order to promote the development of the trial stage and help the reinforcement of the discrimination between heat and temperature.

The next activities should be used by the teacher as a mean to promote the adoption stage as well as to certificate if it has been accomplished. These activities should involve the quantification of the relation between heat and temperature variations (always through experiments), discussions, problems solving, tests, etc.

RESULTS

The results of this study will be presented having two aspects into account: i) the potentialities of the model for promoting a better understanding of phenomena involving heat and temperature, and ii) the implications of this type of studies on the professional development of the teachers working at the secondary school level.

i) The potentialities of the model for promoting a better understanding of phenomena involving heat and temperature.

As far as the first aspect is concerned the analysis involved an examination of the data, gathered through the pre and post-tests, for evidence of clusters of statements that could reveal the existence of alternative conceptions held by the students. The comparison of data between the two type of classes (experimental and control) provided the baseline to assess the efectiveness of the teaching model.

The pre-test about heat and temperature allowed the identification of students´conceptions which were similar to those cited in the literature and indicated that a large proportion of students, in both cohorts, hold ideas about phenomena related to heat and temperature prior to instruction that were not consistent with accepted scientific explanations. The prevalence of these conceptions in the pre-tests of both cohorts and in post-tests following teaching are presented in table 2.

As can be seen from table 2, before teaching the great majority of students, in both type of classes, did not held the concept of thermal equilibrium. For them, temperature is a property of the materials from which the objects are made and objects in contact for a long time with the same surroundings have different temperature if their material is different. After teaching, the percentage of students, taught according to the model designed, presenting these ideas decreased from 93,8 to 18,7 and 91,7 to 20,8 respectively, while the percentage of the ones taught according to the tradicional model only decreased from 96,9 to 72,7 and 96,9 to 76,6 respectively.

The percentage of students that presents the idea that heat or cold is a kind of substance residing in objects decreased from 31,3 to 6,3 in the experimental classes, while in the control class it remained almost unaffected.

TABLE 2

Students´ conceptions about heat and temperature

students´ conceptions	Experimental classes pre-test (n = 48)	Experimental classes post-test (n =48)	Control class pre-test (n =31)	Control class post-test (n = 30)
	Percentage of students			
. Heat or cold as a substance residing in objects	31,3	6,3	58,1	56,7
. Temperature is a property of the substance from which the body is made	93,8	18,7	96,9	72,7
. Temperature is something that can be transferred	14,6	6,3	19,4	30,0
.Objects in contact for a long time with the same surroundings have different temperature if their material is different	91,7	20,8	96,9	76,6
. The state of hotness or coldness depends on the material from which the body is made	67,7	6,3	66,7	53,3
. Temperature is a measure of a body´s heat	39,6	8,3	29,0	36,6
. Heat is sensation	41,7	14,6	25,8	66,7
. Temperature is a function of heat	29,2	2,1	32,3	32,3

Table 2 presents the results of the analysis of the data of the pre and post-tests applied to the two experimental classes and to the control class.

An interesting situation is the fact that in the control class some ideas appeared reinforced after formal teaching, like the ideas that "temperature is something that can be transferred" (19,4 before and 30,0 after teaching), "temperature is a measure of the body´s heat" (29,0 before and 36,6 after teaching) and "heat is a sensation" (25,8 before and 66,7 after teaching). In this last case the idea that heat is a sensation seems to be an elementary state of the concept, previous to the scientific one.

The last question of the questionnaires was an open question in which students were asked to explain to another person what they meant by heat and temperature. Before teaching none of the students, either in the experimental or in the control class, displayed an scientifically acceptable idea. After the teaching according to the model designed, the percentage of students able to give a correct idea of heat rose from 0,0 to 66,7, while in the control class none of the students was able to do that. Neverthless as far as the concept of temperature is concerned, although no change took place on students´ideas in the control class, the improvement displayed by the students of the experimental class compared with that observed with the heat concept, was less evident. Only 37,5% of the students gave an acceptable idea of temperature. The concept of temperature in microscopic terms seems to be a more difficult one to be assimilated than the concept of heat and it needs more evidence and more time to be learned properly.

Although it is too early to say how successful the model is, the analysis of the data gives some encouraging results.

ii) The implications of this type of studies on the professional development of the secondary school teachers.

. As far as this second aspect is concerned the data were gathered through informal interviews with the teachers and from a written report elaborated by them with the result of their reflection on the work developed during the study.

According to them, this work was very rewarding and highly fruitful. The main aspects pointed out by them as the ones that most influenced the construction of these feelings are:

i) the interchange of experiences between university and secondary school teachers, the latter not being mere performers;

ii) the reading and discussion of studies on students´ideas about heat and temperature made by other researchers in other countries, which allowedfor an awarenessof the implications on the students´thinking and learning processes;

iii) the acquaintance with techniques for the identification of students´ideas,which allowed the development of skills for the elaboration of diagnostic tests and ways of analysing the data gathered;

iv) the implementation of new instrutional strategies for the purpose of promoting conceptual change, that opened new avenues for their performance as teachers;

v) the possibilities for self and hetero observations of their performances, that helped them to improve some aspects of their teaching, which had been undetected before.

CONCLUSION

The teaching model described in this study appeared to be successful in changing many students´ideas about situations related to fundamental ideas about heat and temperature. In particular the ideas that temperature is a property of the substance from which a body is made and that different sensations mean different temperature, changed in the great majority of students taught according to this model, towards the scientific explanation, compared with the ideas hold by the class control´ students taught by the tradicional approach. This change promote the understanding of the concept of thermal equilibrium considered as a key concept for the study of phenomena related to heat and temperature.

The findings reveal an improvement over the usual teaching approach which, as evidenced by the results, left students´own ideas almost unadressed and unaffected. Nevertheless, as research suggests that students´ideas tend to revert to their prior ideas after a period of time, a delayed post-test would be necessary to indicate that the scientific conceptions are retained. This calls for further investigation.

The secondary school teachers found that using the new teaching approach resulted in better learning conditions and better learning outcomes. They also found that the way the study took place, involving them on the research, strongly contributed to their professional development. It helped and motivated them to reflect more accurately on their own practice.

The way the study was conducted substantially strengthen the link between research, theory and practice. It promotes for the university researchers a deep understanding of the problems involved in classroom practice not only through the discussions that took place when elaborating the teaching model and the planning of the strategies used but also when analysing the videorecorded classes. This type of action research proved to be a very useful and efficient activity for in-service teacher education either for secondary school teachers or university teachers involved in teacher formation.

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Apendix 1

Examples of items from the pre and post-tests used to adress students´conceptions related to heat and temperature.

Question 1

At bedsides there are usually woolen rugs where you can put your feet on when getting out of the bed.

1.1 - How do you explain the different sensations you feel when putting your feet either on a floor of stone or on a woolen rug?

1.2 - If you could put thermometers in close contact with the stone of the floor and with the wool of the rug you would expect that :

. the temperature of the stone was higher than the one of the wool

. the temperature of the stone was lower than the one of the wool

. the temperature of the stone was practically the same as the wool

Explain your answer.

Question 2

Two objects made of different materials - one of iron and other of wood were put into an oven at 60^{0} C. After a certain period of time Mary measured the temperature of both. Mary found:

. the temperature of the wood object higher than the temperature of the iron one;

. the temperature of the wood object lower than the temperature of the iron one;

. the temperatures of both objects the same.

Explain your answer.

Question 3

Two spoons, one made of metal and the other made of plastic were dipped in a mug of frozen water.

1.1 - If you felt the hands of the spoons you would feel:

. the metal spoon hotter than the plastic one;

. the metal spoon colder than the plastic one;

. the same sensation in both.

Explain your answer.

1.2 - If you measured the temperature of both spoons you would find:

. the temperature of the metal spoon higher than the temperature of the plastic one;

. the temperature of the plastic spoon higher than the metal one;

. the same temperature in both.

Explain your answer.

Question 4

Imagine you are asked to explain to other person what is meant by heat ant what is meant by temperature.

What would you say?