

Laurinda Leite

Experiments to Promote Students Conceptual Change on Heat and Temperature. How Do Portuguese text-books include them? / Experimente, um den Wandel der Vorverständnisse der Studenten von Hitze und Temperatur zu fördern. Inwieweit sind sie in portugiesischen Lehrbüchern enthalten?

Zusammenfassung

Die Unterrichtsforschung hat gezeigt, daß Kinder sich verschiedene alternative Auffassungen über die Konzepte „Hitze“ und „Temperatur“ zurechtlegen und daß diese Auffassungen sich im Unterricht als recht resistent erweisen und manchmal sogar noch bei Physikstudenten an der Universität zu finden sind.

Verschiedene Autoren sind der Auffassung, daß Laboraktivitäten ein angemessenes Mittel sind, um in den Köpfen der Studenten einen kognitiven Konflikt zu erzeugen und damit den Studenten helfen, die Grenzen ihrer eigenen Auffassungen zu erkennen. Sowohl durch die Infragestellung der Auffassungen der Studenten als auch der Statusanhebung wissenschaftlich akzeptierter Ideen könnten Laboraktivitäten durch einen Wandel der Auffassungen Lernfortschritte möglich machen. Um das aber zu erreichen, müssen die Labortätigkeiten angemessen strukturiert sein und sich auf die abweichenden Auffassungen der Studenten beziehen. Portugiesische Physiklehrbücher für die 9. Klasse empfehlen Laboraktivitäten bei der Behandlung von Hitze und Temperatur. Dieser Beitrag hat das Ziel, diese Aktivitäten daraufhin zu untersuchen, ob sie die Schlüsselexperimente enthalten, um den Wandel der Auffassungen bei den Studenten in Gang zu bringen.

Die Abhängigkeit der Lehrer von den Lehrbüchern ist in der pädagogischen Literatur gut belegt. Außerdem ist es ziemlich klar, daß es künftigen Lehrern schwer fällt, gute Schülerexperimente zur Thematik Hitze und Temperatur auszusuchen. Deshalb können die Ergebnisse dieser Forschungsarbeit vor allem den noch unerfahrenen Lehrern nützen, da sie den Lehrern nicht nur helfen können, die zugelassenen Lehrbücher und die Labortätigkeiten, die sie im Unterricht machen, kritischer zu sehen, sondern auch ihren eigenen Unterricht zu verbessern, der sich auf den Wechsel der „naiven“ Auffassungen von Hitze und Temperatur bezieht.

Introduction

Heat and temperature is a physics topic that is taught to 9th grade Portuguese students. The learning of this topic bears some difficulties for the students as they usually hold several alternative conceptions (see Brooks *e. a.* 1984; Moreno/Moreno 1989; Driver *e. a.* 1994) which interfere with its formal learning. Besides, research has shown that alternative conceptions on heat and temperature are resistant to teaching and can even be held by university physics students (Caldeira/Martins 1990; Frederik *e. a.* 1999).

Despite the fact that the usual teaching approach leaves students' conceptions almost unaffected, a teaching model based on a constructivist perspective showed to be successful in reducing students' alternative conceptions on heat and temperature (Thomaz *e. a.* 1993).

The students' learning difficulties referred to above may be due to the fact that the concepts heat and temperature are not distinguished from each other in everyday life. Besides, students' alternative conceptions may be reinforced by individual sensorial experiences of feeling hot and cold. The agreement between students' conceptions and their everyday lives and experiences prevents students from feeling the need to change the alternative conceptions and increases the resistance of the latter to teaching.

Several authors (Gunstone/Champagne 1990; Gunstone 1991; Hodson 1993; Millar 1998) believe that laboratory activities are an adequate means to create a cognitive conflict in students' minds and/or to help students to perceive the limitations of their own conceptions. For this purpose, „the less likely the phenomenon is, the stronger the impression it makes” (Millar 1998, 30) and the better it succeeds on both making the status of students' conceptions become lower and raising the status of the scientifically accepted ideas (Hewson *e. a.* 1998). Thus, surprising lab activities would be a way of creating better conditions for learning by conceptual change to occur. However, to succeed in doing so lab activities need to be adequately structured and related to the content of students' alternative conceptions.

As far as the structure of the laboratory activity is concerned, Gunstone and Champagne (1990) suggested the P-O-E (Predict-Observe-Explain) format while Silva and Leite (1997) emphasised the reflective dimension and suggested the P-O-E-R (Predict-Observe-Explain-Reflect) format. The latter format explicitly adds a metacognitive dimension to the former. This dimension focuses on the analysis of the evolution of conceptions as well as on the methodologies used to construct

knowledge both in everyday life and in school. It is supposed to promote students' methodological change that was pointed out by Gil-Perez and Carrascosa-Alis (Gil-Perez/Carrascosa-Alis 1985) as a necessary condition for conceptual change to take place.

As for the content of the alternative conceptions on the differentiation between heat and temperature, the main alternative conceptions reported in the literature (Brook *e. a.* 1984; Moreno/Moreno 1989; Gale 1993; Jara-Guerero 1993; Driver *e. a.* 1994) are the following:

1. Heat and temperature are the same;
2. Things may be inherently hot or cold;
3. Heat is a fluid so that heating means increasing mass;
4. Heating always means raising temperature;
5. Temperature is a non-intensive quantity.

As „in teaching, there is not necessarily one way of doing things” (Loughran 1996, 3), it is hard to put forwards concrete ideas about experiments that textbooks should include in order to promote students' conceptual change. However, as Brook *e. a.* stated, „students need to learn to differentiate between sensory experience and scientific fact” (Brook *e. a.* 1984, 134). Thus, to promote students' conceptual change on the alternative conceptions mentioned above textbooks should include laboratory activities that enable students to perceive that:

1. Heat and temperature are different concepts;
2. Things may seem to be at different temperatures and in fact be at the same temperature; this would make students feel the insufficiency of the senses and the need for the thermometer, in order to obtain reliable measurements of temperature;
3. Heating does not increase mass; heat is not a substance (but it is just a way of measuring energy transferred between systems at different temperatures);
4. Sometimes heating does not mean raising temperature; this is true when a phase transition occurs; to become aware of this is especially important for students to differentiate the two concepts;

5. The temperature of a mixture of substances (or amounts of a substance) is not the sum of the initial temperatures; opposite to mass, temperature cannot be summed up.

The Portuguese physical science syllabus (DES 1995) for the 8th and 9th grades (compulsory education) argues for a constructivist perspective of teaching and learning and for using the laboratory in teaching. It also calls teachers' attention to the existence of diverse types of laboratory activities and stresses the importance of activities that require students to make predictions and, afterwards, test them. These activities „play an important role in the acquisition, construction and adaptation of individual knowledge and ways of thinking... [and]... may also be undertaken to test students' knowledge" (DES 1995, 26). However, as far as the concepts heat and temperature are concerned only two laboratory activities are suggested by the syllabus. Their aim is to lead students to calculate the amount of energy transferred when heating and cooling occur, by using the equation $E = m \cdot c \cdot \Delta\theta$.

Anyway, following the syllabus recommendation, Portuguese textbooks usually include some laboratory activities to be carried out when teaching heat and temperature (Leite 1999a). Thus, the objective of this paper is to analyse Portuguese 9th grade physics textbooks' laboratory activities for teaching the difference between heat and temperature, in order to find out whether or not they may promote students' conceptual change.

The importance of this research lies in two main and related aspects. The first one has to deal with the fact that some research studies (Caldeira/Martins 1990; Thomaz e.a. 1993) have shown that Portuguese students hold alternative conceptions on heat and temperature. The second one has to deal with the fact that teachers are heavily reliant and dependent on textbooks (Chiappetta e. a. 1991; Yore 1991). Therefore, they need to know the different textbooks available in the market in order to select the best one for helping teachers to promote their students' learning and conceptual change. Besides, it is our hope that the discussion of textbooks' laboratory activities done in this paper can help them both to choose appropriate experiments for the teaching of heat and temperature and to structure them according to the conceptual change principles.

Methodology

As it has been explained by Leite (1999b), Portuguese physical science teachers have to choose the textbook to be assigned for their students among those available in the market, whatever the school and the ability of the students. Once chosen, the textbook assigned stands for three years. As 9th grade physics textbooks were chosen on 1997, they will be chosen again on the year 2000. Therefore, no 9th grade physics textbook was edited since 1997. Thus, this research focuses on the last edition of the 9th grade physics textbooks that is, in most cases, the 1997 edition.

As far as it is known, there are 14 grade-9 physics textbooks in the Portuguese market. We decided to analyse the 14 textbooks (Appendix 1) we had access to, including students' activities books and teachers' guides, whenever they exist.

A qualitative content analysis of the parts of the textbooks that deal with the difference between heat and temperature was carried out. Conduction and conductivity were also considered, as they are necessary concepts for changing the second alternative conception referred to above. Thus, the analysis focused on the laboratory activities that fall in the scope of this topic and comprised several dimensions. The first one concentrates on whether or not textbooks include either worksheets or descriptions of experiments. This distinction in formats of presentation of experiments is made because the experiments given under the former format are intended to be carried out in class while those given under the latter are just used to support the presentation of the content (although they could also be done in class). By a description of an experiment we understand something like „If you do... you will find / feel / observe, that...", or „We can prove... by doing... and observing that..." or still we can have a scheme showing the steps of the experiment and the data (that could be) collected. Contrary to a worksheet, a description does not require teacher or students to handle apparatus or to find out answers for questions. However, despite the fact that everything is given to the reader when this way of presenting the experiments is used, a description of an experiment contributes to increasing the cognitive involvement of the student and facilitates the understanding of the concepts. Worksheets integrated in the text can usually be easily separated from the rest of it, as they are written in a different style or presented inside borders, lines or different coloured space or given an identifying heading.

Another dimension of analysis is the content the experiment focuses on. This gives us information about whether or not the experiments included in the textbooks are

related to the content of the main alternative conceptions probably held by the students. Those conceptions were mentioned in the previous section.

The experiments included under the format of worksheets were also analysed with regard to their integration in the texts and the structure of the worksheets. In the former case we wanted to find out whether experiments precede theory or whether experiments are used to confirm the theory presented before them. In the latter case we looked at things like „is there a question/problem to be answered through the experiment?“, „is a prediction asked for?“, „is the experimental procedure given?“, „do data need to be collected?“, „does the worksheet contain instructions for data analysis?“ and „does it promote the interpretation of the results?“. This analysis can give us information about whether or not the textbooks use experiments according to the conceptual change principles. Therefore, we would like to find worksheets that ask an explicit question or present a given problem, ask students to predict what they think will happen and to find ways of testing their predictions, that give students some instructions on what to do for data analysis and interpretation of results purposes, but without telling students exactly how to do them.

The analysis was done twice, with an eight days interval, in order to enhance the reliability of the data.

Results

Content and format of the experiments

Table 1 shows the results of the analysis focusing on the content of the experiments and on the existence of either a worksheet (W) or a description of them (D).

Table 1: Content and format of the experiments included in the textbooks

Content of the experiments	Textbooks													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Hands in water			D			D	D	D					D	
Calibrating a thermometer	D			D	D	D		D	D		D			
											W			
$E = m.c. \Delta\theta$	D		W	D	D	D	W	W			W	W	D	
	W													
T during phase transition							D		D					
Heating/cooling curves		W					W				D		W	
											W			
Feeling hot and cold things	D						D	D						
Thermal equilibrium			W	D	D	D	D		W		W		D	
						W	W				*			
Calculating E					W					W		W	W	W
Conduction	W			D	D	D	D	D	W		W		D	
							W							
Conductivity	D	W	W		D	W	W					W		
		W	W			W								

*One only worksheet

Experiments were found focusing on ten different aspects of the content topic considered in this paper that is, the difference between heat and temperature. They are as follows:

1. *Hands in water*: introducing one hand in cold water and the other hand in hot water and then both hands in lukewarm water, to find out that the senses are not reliable to measure temperature;
2. *Calibrating a thermometer*: using melting ice and boiling water to identify the position of 0°C and 100°C and then dividing the space between these two points.
3. $E = m.c.\Delta\theta$: controlling variables and measuring temperatures when a certain variable (m , c , $\Delta\theta$) is manipulated, in order to confirm/find out how E depends on it;
4. *T during phase transitions*: realising that heating does not increase temperature (I) during a phase transition;
5. *Heating and/or cooling curves*: measuring temperature and graph it over time, to find out how temperature increases/decreases with time;
6. *Feeling „hot” and „cold” things*: realising that things that seem to our senses to be at different temperatures may be at the same temperature;
7. *Thermal equilibrium*: measuring initial (before contact) and final (at equilibrium) temperatures to notice that the latter is in between the initial temperatures;
8. *Calculating E*: measuring $\Delta\theta$ in order to calculate E (using the equation $E = m.c.\Delta\theta$);
9. *Conduction*: noticing that heating one point of a metal leads to increasing its temperature in another point;
10. *Conductivity*: comparing the increase in temperature in certain points of different materials when other points are heated.

The number of experiments per textbook varies a lot from one textbook to the other. While textbook G, for example, includes ten experiments focusing on eight different contents, textbooks J and N include only one experiment. As it is shown in table 1, the most frequent experiments in textbooks are those dealing with the relationship between E , m , c and $\Delta\theta$. They appear in 10 out of the 14 textbooks analysed. Nonetheless, it should be pointed out that only textbooks E and H make it explicit that the equation $E = m.c.\Delta\theta$ does not apply when a phase transition oc-

curs.

The second most frequent experiments are those focusing on conduction. They were found in nine textbooks.

The least frequent experiments are the ones on the constancy of temperature during phase transitions. They appear in two textbooks (G and I) under the form of a description. They are followed by experiments aiming to feel the temperature of „hot” and „cold” things. These experiments appear in three textbooks (A, G and H), under the form of descriptions.

Five of the textbooks (C, F, G, H and M) make reference to the „hands in water” experiment. However, all the textbooks give a description of it instead of any sort of worksheet to guide students to performing the experiment. On the contrary, all the experiments dealing with E calculations (E, J, L, M and N) are presented as worksheets.

While some textbooks (e. g.: G, K and M) include several experiments, being some presented under the form of descriptions and the others presented as worksheets, other textbooks mainly (E, H and M) or only (D) give descriptions. It should also be noticed that textbooks that include only one experiment (J and N) present it under the form of a worksheet.

Finally, the teachers’ guide that accompanies textbook G includes in the activities book two worksheets alternative to the worksheet on $E = m.c.\Delta\theta$. One of them comprises a different version of the same activity and the other one includes an activity on measuring E .

Structure and integration of the worksheets in the main text

Table 2 shows how the worksheets are integrated in the main text and gives some information on their structure.

As far as integration is concerned, less than one half of the worksheets analysed are integrated in the main text. The others appear in the end of the section, the chapter or the textbooks, or are included in the activities book. Textbook G is the only one including activities apart from the main text and that tells (in the main text) the user about when those activities should be performed. As shown in table 2, it suggests the performance of the activities after presenting the content related to them. In the other textbooks, the use of the worksheets given apart from the main text depends on the teacher. He/she can decide whether they should be used before or

after the teaching of the content related to the experiments mentioned in them. Most of the worksheets included in the main text appear after the presentation of the content dealt with in the experiment. Textbook C is, in some way, an exception because it tends to use experiments as a starting point for introducing theory. Thus, its worksheets are in most cases introduced before the concepts or the conceptual relationships.

As regards the structure of the worksheet, seven aspects were considered in the analysis carried out (Table 2). Four worksheets (in textbooks E, F and L) include a sort of problem/question to be answered through the experiment and one worksheet (in textbook L) asks students to make a prediction about the results of the experiment. However, it should be noticed that this worksheet is introduced *after* the relevant content.

Table 2: Integration and structure of the worksheets

Textbook	Experiment	Localisation	Integration in text	Structure of the worksheet						
				Problem	Prediction	Expec. proc.	Data/ results	Data analys.	Interpr./ theory	Follow up
A	$E=mc\Delta\theta$	End textb.	Depends	No	No	Given	Not g.	Partly	Done B	No
	Conduction	End textb.	Depends	No	No	Given	Not g.	Ignored	Done B	Yes
B	Cooling curve	Text	After	No	No	Given	Not g.	Guidel.	Ignored	No
	Conductivity 1	Text	After	No	No	Given	Not g.	Guidel.	Ignored	No
	Conductivity 2	Text	After	No	No	Given	Not g.	Guidel.	Ignored	No
C	$E=mc\Delta\theta$	Text	Before	No	No	Given	Not g.	Guidel.	Ignored	No
	Ther. equilibrium	Text	Before	No	No	Given	Not g.	Ignored	Ignored	No
	Conductivity 1	Text	Before	No	No	Given	Not g.	Ignored	Ignored	No
	Conductivity 2	Text	After	No	No	Given	Not g.	Ignored	Ignored	No
D	—	—	—	—	—	—	—	—	—	—
E	Calculating E	Activ. book	Depends	Yes	No	Given	Not g.	Details	Done B	Yes

F	Ther. equilibrium	Activ. book	Depends	Yes	No	Given	Not g.	Ignored	Partly E	No
	Conductivity 1	Text	Depends	No	No	Given	Given	Done	Done	No
	Conductivity 2	Activ. book	Depends	Yes	No	Given	Partly	Details	Partly E	No
G	$E=mc\Delta\theta$	Activ. book	After	No	No	Given	Not g.	Guidel.	Ignored	No
	Heat/cool curves	Activ. book	After	No	No	Given	Not g.	Guidel.	Asked	No
	Ther. equilibrium	Activ. book	After	No	No	Given	Not g.	Guidel.	Asked	No
	Ther. equilibrium	Activ. book	After	No	No	Given	Given	Done	Done	No
	Conduction	Activ. book	After	No	No	Given	Not g.	Asked	Asked	No
	Conductivity	Text								
	Conductivity	Activ. book								
H	$E=mc\Delta\theta$	Text	After	No	No	Given	Not g.	Guidel.	Ignored	Yes
I	Ther. equilibrium	End section	Depends	No	No	Given	Not g.	Ignored	Ignored	No
	Conduction	Text	Before	No	No	Given	Given	Done	Ignored	Yes
J	Calculating E	Text	Before	No	No	Given	Not g.	Details	Ignored	No
K	Calibr. thermometer	End chapt*	Depends	No	No	Partly	—	—	—	No
		After	After	No	No	Given	Not g.	Guidel.	Asked	No
	$E=mc\Delta\theta$	Text	After	No	No	Given	Not g.	Guidel.	Ignored	No
	Cooling curves	Text**	After	No	No	Given	Not g.	Guidel.	Asked	No
	Ther. equilibrium	Text**	After	No	No	Partly	Not g.	Asked	Ignored	No
L	Conduction	Text								
	$E=mc\Delta\theta$	Text	Partly	No	No	Given	Given	Done	Done	No
	Calculating E	Text	After	No	No	Given	Not g.	Details	Ignored	No
M	Conductivity	Text	After	Yes	Yes	Given	Not g.	Guidel.	Ignored	No
	Heating curve	End chapt.	Depends	No	No	Given	Not g.	Guidel.	Asked	No
N	Calculating E	End chapt.	Depends	No	No	Given	Not g.	Details	Asked	No
	Calculating E	End chapt.	Depends	No	No	Given	Partly	Details	Asked	Yes

Note: * Optional Activity; ** Both in one only worksheet

None of the worksheets asks students to design a complete experimental procedure. However, textbook K leaves some decisions (related to how to settle the apparatus and how to mark the thermometer) to the students. Some worksheets in-

clude data/results of the experiments, totally (e.g.: textbook F – conductivity 1; textbook G – conduction; textbook I – conduction) or in part (e.g.: textbook F – conductivity 2; textbook N – Calculating E). The textbooks that *give* data/results in the worksheets also tend to *do* their analysis and interpretation in the same worksheets.

While several worksheets give guidelines for the students to interpret the data collected, others give detailed instructions, specifying all the steps students need to follow. On the contrary, some other worksheets ignore data analysis. It is worth noticing that this happens with worksheets appearing in the main text, before the theory, as well as with worksheets included apart from the main text.

About one half of the worksheets analysed ignore the interpretation of the results. A few other worksheets ask students to interpret/explain the results obtained. Some others do the interpretation in a final section (*done E*) or start with a presentation of the concepts that are going to be dealt with in the experiment that is, they do the interpretation in advance (*done B*). When data analysis and interpretation are not given in the worksheets, it is usually possible to find them in the main text. But the heating and the cooling curves are an exception insofar as no mention was found to their forms in the textbooks analysed. Finally, table 2 shows that only five worksheets include *follow up* questions that can lead students to think about/plan other experiments.

Discussion of results

As far as content is concerned, Table 3 shows the relationship we think could be established between the experiments found in textbooks and the alternative conceptions referred to above. However, as the integration of the experiments in text as well as their structure are not in agreement with the conceptual change principles, they would need to be reorganised in order to fulfil that aim.

Table 3: Relationship between experiments and alternative conceptions, in terms of content

Alternative Conception	Experiments									
	1	2	3	4	5	6	7	8	9	10
1			√	√						
2						√				√
3										
4		√		√	√					
5							√			

Table 1 together with Table 3 show that none of the textbooks includes experiments related to all the five alternative conceptions mentioned in the introduction section of this paper. However, the whole set of textbooks includes experiments related to the content of all but one the alternative conceptions referred to above. In fact, there is no experiment related to alternative conception number 3 that is, „heating means increasing mass”. It is our belief that an experiment dealing with the conservation of mass during heating would be an important experiment for students to understand that heat is not a substance. Of course, this would require well-chosen laboratory materials, in order to lead students to observe a big increase in volume that they would feel unlikely to correspond to a non-measurable increase in mass.

The most frequent laboratory activities found in the content topic analysed are activities dealing with traditional aspects of heat and temperature that is, setting the equation $E = m.c.\Delta\theta$ and making calculations. In Table 3 these experiments were related to alternative conception „Heat and temperature are the same”. However, most textbooks use it just for setting the equation and do not take the opportunity to explicitly distinguish the meaning given by the students to the concepts involved. Innovative laboratory activities, related to the other alternative conceptions (probably) held by students, are rarely found or not used in such a way as to promote students’ conceptual change. Besides, with the exception of the conductivity experiments (which are often given as worksheets) they are described instead of being presented under the form of a worksheet to be carried out in class. This may be due to market rules that lead the authors to write conservative textbooks because teachers tend to choose those they are familiar with (even though they are in con-

flict with the syllabus recommendations) and to reject the innovative ones (Finley 1999).

As it was previously pointed out, in the majority of the cases there is no sort of worksheet but just descriptions of the experiments. Of course, the use of cookbook type worksheets, to be followed step by step by the students, in a passive (from a cognitive point of view) way should not be generalised, as it happens in the textbooks analysed. Anyway, it is our belief that a worksheet makes teachers feel more compelled to use experiments in their physics lessons than a description does. Also, some of the experiments included in the textbooks have some technical requirements that must be accomplished in order to be successful. One example of them is the „hands in water” experiment. Some descriptions of it do not even make it clear that both hands have to be used simultaneously. Another example is the one on „feeling ‚hot’ and ‚cold’ things”. It requires students to feel and to measure temperature. A usual thermometer cannot be used to measure the temperatures of a stone/brick floor and of a wool carpet. But jelly (or gelatine) and chocolate mousse, for example, can be used instead. However, as descriptions are abbreviated, they skip out more technical details than the worksheets do, taking the risk of not being useful for the students or even for the teachers (especially for the less experienced ones).

A different but important issue relates to the limited use of some experiments. Let us take the case of „temperature during a phase transition”. Experiments on this topic are not only rare in textbooks but also presented as descriptions. Calibrating a thermometer, a much more popular experiment, deals with two phase-transitions. However, this experiment is usually taken just for calibrating purposes, that is to „see” that ice melts at 0°C and water boils at 100°C . It is our belief that more profit could be taken from it if it was also used to clearly show that temperature is constant during the phase transitions involved. Of course, a discussion of the „why” temperature remains constant despite the fact that the system is being heated would help students to perceive the difference between heat and temperature. This could certainly be reinforced by experiments showing that equal amounts of energy can produce different raises in temperature. This aspect can also be brought to discussion when the $E = m \cdot c \cdot \Delta\theta$ is presented or established from experiments (as textbook L does) but care should be taken in order to avoid that the quantitative worries hidden the qualitative ones, as it seems to happen in the majority of the textbooks analysed. Besides, that would prevent students from sticking just to the equation (as they already know they will be asked to solve exercises involving it) and lead them to concentrate on the concepts that is, on the physics of the pheno-

menon. Also, the conditions of validity of the equation should be discussed. It does not apply when a phase transition occurs but this is a neglected aspect in most textbooks.

It could be argued that to undertake the experiments necessary to teach the difference between heat and temperature would take a long time and that time would be even longer if the students were given the opportunity to perform the experiments themselves. We would not agree with the generalised use of teacher demonstrations as this way of performing experiments would prevent students from developing technical laboratory skills and would also be less motivating for them. However, it is our belief that some experiments can be used as demonstrations without any meaningful damage for learning while others must be carried out by the students themselves. As far as the content topic of this paper is concerned, the „hands in water” experiment is a good example of an experiment that has to be performed by the students themselves. Another one would be the one on „feeling ‚hot’ and ‚cold’ things”. Nobody can feel for the students. So, the students themselves must carry out these experiments. However, as far as the measurement of temperatures is concerned, if the teacher feels that she/he cannot spend time enough for the students to both think about and undertake the experiment, then it is possible to find ways of saving time, other than not using experiments. The teacher can perform the experiment more quickly than the students do. More important than manipulating beakers and water or things alike (just to do a single reading in a thermometer, as it happens in some „calculating E” experiments) would be to make grounded predictions about what students expect to happen and, later on, compare them with the results obtained (through a well conducted teacher demonstration), and find explanations for the eventual discrepancies between the two. This means that the P-O-E-R format can be used for the experiment even when the experiment is carried out as a teacher demonstration. Unfortunately, textbooks do not use this format for the experiments.

Besides, the worksheets are often integrated in the text in such a way that the main objective of the laboratory activity is just to illustrate or to confirm what is written in the textbook, before the worksheet or in one of its sections. The inclusion in the worksheet of theoretical information concerning the results is particularly serious in the case of the worksheets given apart from the main text. This way of integrating the worksheets gives the teacher the possibility to decide when and how the worksheet should be used. Nevertheless, the inclusion of that information makes it more difficult for teachers to use the worksheet according to a P-O-E-R or a „find out what happens” format.

Conclusions and implications

Portuguese 9th grade physics textbooks make reference to several experiments related to the difference between heat and temperature. In most cases the experiments are just described and the laboratory worksheets included are never structured according to the P-O-E-R format. It seems, therefore, that although relevant experiments were found in the textbooks analysed, their integration in the text and their structure are not the best ones to promote students' conceptual change.

Let us take the experiment „T during phase transitions” to illustrate how it would look like if used according to the P-O-E-R format. This experiment is related to the alternative conception „heating means raising temperature”. To use it according to the P-O-E-R format one would not start by informing students that temperature remains constant during a phase transition. Rather, one would start by asking them, for example, to sketch and explain a graph, temperature versus time, for a certain amount of water that is heated from room temperature to five minutes after starting boiling. Students holding the alternative conception referred to above would draw a straight line with a positive slope and explain it based on the fact that water is being heated the entire time interval considered. A few students would probably draw the correct graph and some of them would explain its flat part based on the idea of a constant rate of heating while others would explain it correctly. Before being told about which is the correct answer, students should be asked to design an experimental procedure to test their predictions. They could think about either using a thermometer to read temperatures and afterwards to draw a graph or using a datalogging system and getting a real time graph. Whatever the measurement device used, the experimental procedure has to be put into practice and the graph obtained must be interpreted. Then, it needs to be compared to the graph initially drawn and reasons (at conceptual and methodological levels) should be found for the difference between predicted and obtained graphs, whenever they exist. This experiment does not show that temperature remains constant during a phase transition. It only shows that this is true for the case of evaporation of water. The generalisation of knowledge to other substances and phase transitions has to be dealt with by the teacher but it can never be done solely from one or a few experiments.

To look at the diverse suggestions made by the textbooks available may be a way of finding out interesting experiments to be undertaken in physics lessons. However, bearing in mind that there is no perfect textbook (Leite 1999b), teachers need to look at the experiments included in any textbook in a critical way. Maybe they are conceptually and technically correct or maybe not. Whatever the case, are they

structured according to the didactical assumptions the teacher believes should underpin her/his teaching? If this is not the case (as it happens to be in the topic analysed) the format of the experiment, the way it is integrated with the theoretical aspects or the person responsible for its performance can be changed. Of course, this requires not only time and will but also a good theoretical support for doing the analysis and taking decisions. Giving this support and developing analytical and critical abilities is one of the most important dimensions of physics teacher education.

In fact, it is not enough to convince teachers that they should use laboratory activities in their teaching. „If we do practical work 'because science is a practical subject' then, it is almost equally true that we do it 'because science is a theoretical subject'” (Millar 1998, 29). Thus, as far as science learning is concerned, more important than carrying out experiments is what we do with the experiments that is to say, the way we structure and integrate them in the lessons as well as how we elaborate on them. The results of this study indicate that following a textbook does not lead to an appropriate use of the laboratory for teaching science. Therefore, initial as well as in service science teacher education should include a critical analysis of the use of the laboratory for teaching science in order to promote a more rational use of it.

Concepts are not there to be discovered; they have to be reconstructed by guidance. Experiments are just opportunities to feel the need for („new”) concepts and conceptual relationships that have already been constructed by scientists. This is why thinking and discussion play a major role in learning from experiments. Teacher education needs to increase teachers' awareness of this and to help them to find ways of overcoming the constraints that impair the use of experiments according to a constructivist perspective of science teaching and learning.

Note

This paper was written in the scope of the project „Laboratory work in science education” (IIE-SIQE medida 2 (nº 3/98); CEEP/UM (nº C115))

Acknowledgement

The author would like to express her gratitude to the ATEE (RDC 2) colleagues that made comments on an earlier version of this paper.

References

- Brook, A. e. a. (1984): *Aspects of secondary students' understanding of heat: Full report*. Leeds.
- Caldeira, M./Martins, D. (1990): *Calor e Temperatura: Que noções têm os alunos universitários destes conceitos?* In: *Gazeta de Física*, 13(2), pp. 85- 94.
- Chiappetta, E./Fillman, D./Sethna, G. (1991): *A method to quantify major themes of scientific literacy in science textbooks*. In: *Journal of Research in Science Teaching*, 28 (8), pp. 713- 725.
- DES (1995): *Programa de Ciências Físico-Químicas – 3º ciclo do ensino básico*. Lisboa: Ministério da Educação.
- Driver, R. e. a. (1994): *Making sense of secondary science: Research into children's ideas*. London: Routledge.
- Finley, F./Pocovi, C. (1999): *Textbook contributions to science curriculum reform*. In: Castro, R. e. a. (Org.) *Manuais escolares: Estatuto, funções, história*. Braga, pp. 19-33.
- Frederik, I. e. a. (1999): *Pre-service physics teachers and conceptual difficulties on temperature and heat*. In: *European Journal of Teacher Education*, 22 (1), pp. 61-74.
- Gale, C. (1993): *The influence of microcomputer-based laboratories on children's conceptions of temperature and temperature change*. In: *The Proceedings of The Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*. Ithaca.
- Gil-Pérez, D./Carrascosa-Alis, J. (1985): *Science learning as a conceptual and methodological change*. In: *European Journal of Science Education*, 7 (3), pp. 231- 236.
- Gunstone, R./Champagne, A. (1990): *Promoting conceptual change in the laboratory*. In: Heggarty-Hazel, E. (Ed.): *The student laboratory and the science curriculum*. London, pp. 159- 182.
- Gunstone, R. (1991): *Reconstructing theory from practical experience*. In: Woolnough, B. (Ed.): *Practical Science*. Milton Keynes, pp. 67- 77.
- Hewson, P., Beeth, M.; Thodey, R. (1998): *Teaching for conceptual change*. In: Fraser, B./Tobin, K. (Eds.): *International Handbook of Science Education – Part one*. Dordrecht, pp. 199- 218.
- Hodson, D. (1993): *Rethinking old ways: Towards a more critical approach to practical work in school science*. In: *Studies in Science Education*, 22, pp. 85- 142.
- Jara-Guerrero, S. (1993): *Misconceptions on heat and temperature*. In: *The Proceedings of The Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*. Ithaca.
- Leite, L. (1999a): *O ensino Laboratorial de „O Som e a Audição”. Uma análise das propostas apresentadas por anuais escolares do 8º ano de escolaridade*. In: Castro, R. e. a. (Org.): *Manuais escolares: Estatuto, funções, história*. Braga, pp. 255- 266.
- Leite, L. (1999b): *Heat and temperature: an analysis of how these concepts are dealt with in textbooks*. In: *European Journal of Teacher Education*, 22 (1), pp. 75- 88.
- Lougran, J. (1996): *Developing reflective practice: Learning about teaching and learning through modelling*. London.
- Millar, R. (1998): *Rhetoric and reality: What practical work in science is really for*. In: Wellington, J. (Ed.): *Practical work in school science*. London, pp. 16- 31.
- Moreno, J./Moreno, A. (1989): *La ciencia de los alumnos*. Madrid.
- Silva, J.; Leite, L. (1997): *Actividades laboratoriais em manuais escolares: Proposta de critérios de análise*. In: *Boletim das Ciências*, 32, pp. 259- 264.
- Thomaz, M. e. a. (1993): *An attempt to overcome alternative conceptions related to heat and temperature*. In: *The Proceedings of The Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*. Ithaca.
- Yore, L. (1991): *Secondary science teachers' attitudes towards and beliefs about science reading and science textbooks*. In: *Journal of Research in Science Teaching*, 28 (1), pp. 55- 72.

Appendix 1

- A - Cavaleiro, M.; Beleza, M. (1997): *No mundo da Física – 9º ano*. Porto: Edições ASA.
- B - Faria, A. e. a. (1997): *Cfj Física – 9º ano*. Lisboa: Raiz Editora.
- C - Fernandes, M.; Graça, O. (1997): *Física – 9º ano*. Lisboa: Lisboa Editora.
- D - Ferrão, M.; Silva, M. (1997): *Físio-Químias – 9º ano*. Alfragide: Constância.
- E - Fiolhais, C. e. a. (1997): *Física – 9º ano*. Lisboa: Didáctica Editora.
- F - Maciel, N.; Miranda, A. (1997): *Eu e a Física – 9º ano*. Porto: Porto Editora.
- G - Martins, A. (1995): *Física em temas – 9º ano*. Porto: Porto Editora.
- H - Matos, J.; Matos, I.; Pereira, A. (1996): *Física e Química passo a passo – 9º ano*. Lisboa: O Livro.
- I - Mendonça, L.; Ramalho, M. (1997): *Física no mundo em transformação – 9º ano*. Lisboa: Texto Editora.

- J - Morais, A.; Silva, I.; Sousa, L. (1997): *O meu livro de Ciências Físico-Químicas - 9º ano*. Lisboa: Raiz Editora.
- K - Pereira, A.; Souto, A.; Gonçalves, C. (1997): *Eu gosto de Física - 9º ano*. Lisboa: Texto Editora.
- L - Pinto, R. (1997): *Nova Física/Nova Química - 9º ano*. Lisboa: Areal Editores.
- M - Rodrigues, M.; Dias, F. (1997): *Física na nossa vida - 9º ano*. Porto: Porto Editora.
- N - Viegas, C. (1995): *Física - 9º ano*. Lisboa: Editorial O Livro.

LEITE, Laurinda (1999). Experiments to Promote Students Conceptual Change on Heat and Temperature. How Do Portuguese text-books include them? In W. Hörner; D. Schulz & H.-W. Wollersheim (Hg.), *Berufswissen des Lehrers und Bezugswissenschaften der Lehrerbildung*. Leipziger: Leipziger Universitätsverlag, pp. 391-410.