PORTUGUESE SCIENCE TEACHERS' USE OF LABORATORY ACTIVITIES BEFORE AND AFTER THE SCHOOL CURRICULUM REORGANISATION

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Abstract

Since the integration of science in the school *curricula* laboratory activities have concentrated decision makers' and teachers' attention. Nevertheless, a mismatch still exists between the possible contribution of laboratory activities to the teaching and learning processes and the profit that is taken from them in diary classroom practice. This mismatch may be at least partly due to the fact that teachers seldom use laboratory work in their classes and that when they do so they tend to choose closed and teacher centred laboratory activities.
The last two curriculum reforms carried out in Portugal concentrated a great deal of attention in laboratory activities as a teaching and learning resource. The 2001 curriculum reorganisation increased the time of a class from 50 to 90 minutes. The idea was to create better conditions for students to become actively involved in the learning process and to carry out lab activities in the science classes.
The objective of this paper is to analyse whether or not Physical and Natural Sciences teachers are aware of relevant changes in their practices concerning the use of laboratory activities due to the school curriculum reorganisation. Data from 51 Physical Sciences teachers and 61 Natural Sciences teachers indicate that science teaching practices at the third stage of compulsory education may not have suffered such changes. Therefore, it seems that teacher education focusing on their own needs and work contexts is required if the mismatch between curriculum policies and teachers' practices concerning the use of laboratory activities is to be overcome.

Introduction

Since de 1974 Portuguese revolution there have been several curriculum reforms and reorganisations with important implications for compulsory education, in general, and science education, in particular. As far as compulsory education is concerned, since the 1991 curriculum reform it is nine yearlong, starting for children aged six (1st grade) and going up to ninth grade. It is organized into three stages. Although at the compulsory education level the curriculum includes science at every stage, the way science is integrated into it depends nevertheless on the stage. Thus, the first stage is four yearlong, being all the main curriculum areas (including science) taught by a single teacher. The second stage includes a course on science that is taught by a science teacher. The third stage includes Natural Sciences (Biology and Geology) and Physical Sciences (Physics and Chemistry) as two school subjects. The 1991 curriculum reform maintained the previous structure of the third stage with Physical Sciences at the eighth and ninth grades and Natural Sciences at the seventh and eighth grades only. Beyond that it brought changes at the contents and methodologies level. The 2001 curriculum reorganisation brought Physical Sciences back again to the seventh grade and extended Natural Sciences up to the ninth grade. It maintained the contents to be taught but stressed the STS philosophy.
The last two curriculum reforms and reorganisations carried out in Portugal have concentrated a great deal of attention in laboratory activities as a teaching and learning resource. In order to

create better conditions for students to become actively involved in the learning process and to carry out laboratory activities within science courses, the 2001 curriculum reorganisation increased the time of a class from 50 to 90 minutes (Act-Law 6/2001). In addition, it explicitly acknowledges "learning from experiments in the diverse courses and areas, specially, and with a compulsory nature, in science" (Act-Law 6/2001, article 3- d). Thus, the time of a class can no longer be used as an excuse for teachers to not have their students cognitively engaged with the lab activities performed in the science classes.
However, there is some empirical evidence that teachers' practices are resistant to change and hardly influenced by curriculum innovations (Gil & Pessoa, 1994; Martínez *et al*., 2001). To avoid uncomfortable feelings, they tend to find out excuses for not changing their practices, namely those concerning the use of the lab for teaching science. This may be the main reason why international research studies (e,g., Tiberghien *et al.*, 2001) indicate that lab activities performed in science classes continue being closed and teacher centred, as they were decades ago.

Objective

The objective of this paper is to analyse whether or not Physical and Natural Sciences teachers are aware of relevant changes in their practice concerning the use of laboratory activities at the third stage of compulsory education level, due to the 2001 school curriculum reorganisation.

Background of the study

Lab activities in the Portuguese curricula, before and after the curriculum reorganisation

Within the scope of the 1991 school curriculum reform he school, syllabuses for Physical Sciences (DGEBS, 1991a) as well as for Natural Sciences (DGEBS, 1991b) were made available to the teachers. The Physical Sciences syllabus dedicates lots of space to lab activities. It explicitly acknowledges the existence of diverse types of lab activities (including POE activities) and discussed its advantages and disadvantages in terms of students' learning. After arguing for the inclusion of a diversity of types of lab activities in Physical Sciences classes, it discusses how learning from lab activities should be evaluated. The 1991 Natural Sciences syllabuses acknowledges a different approach as it does not discuss the nature and role of lab activities but rather argues for students to attain objectives dealing with hypothesis formulation and experimental testing, design and implementation of investigations, handling measurement instruments and applications of lab techniques. It seems that the Natural Sciences syllabuses was more influenced by an indutivist perspective of science than the Physical Sciences one.
Within the scope of the 2001 Curriculum Reorganisation, Guidelines for Physical and Natural Sciences (DEB, 2001) were developed. This document is supposed to offer some guidelines to the teachers but it does not have a prescriptive nature. Rather, it explicitly calls teachers attention to the need for them to adapt the curriculum to their teaching context, moreover to their students. It does not discuss the diversity of types of lab activities but it argues for the use of diverse types of lab activities and for the investigative nature of the activities carried out as well as for the development of competences that are relevant for citizens and scientists. Hence, it explicitly mentions "hypothesis formulation, prediction of results, observation and explanation" (DEB, 2001, p.133) as well as the development of empirically based arguments. It also argues for experimental activities being "planed by the students from problems to be investigated" (DEB, 2001, p.132) and rejects the idea of recipe-like activities. As far as the lab component is concerned, the existence of a single document offering guidelines for the lab component of the two science courses can give more coherence to the curriculum. In addition,

its acknowledgement of updated ideas about the role of the lab in science can contribute to the students' development of more appropriate views on science and its methods as well as to the improvement of scientific literacy.

Lab activities and school science education

Since the integration of science in the school *curricula* laboratory activities have concentrated decision makers' and teachers' attention (Hofstein & Lunetta, 1982). On one hand they were taken as building blocks of arguments for science teaching. On the other hand they were conceptualized as a mean for developing students' cognitive abilities as well as a powerful teaching resource, namely for teaching science and about the processes of science. Nevertheless, a mismatch still exists between the possible contribution of laboratory activities to the teaching and learning processes and the profit that is taken from them in diary classroom practice (Hofstein & Lunetta, 2004). Analysis of such mismatch showed that opposite to what was thought so far, one cannot think about efficacy of lab-work, taken as a single entity, but rather about the efficacy of each of the diverse types of lab activities (Millar, Tiberghien & Le Maréchal, 2002). Different types of lab activities promote the development of diverse competences and altogether they can contribute to the attainment of the objectives that are attached to the use of the lab for teaching (Hodson, 1994; Séré, 2002). Therefore, lab activities carried out in the classroom should be varied in nature and closed activities should be partly replaced by open activities (investigation type activities) to lead students to develop not only experimental design but also data collection and analysis competences. It should be emphasised that for those students that leave school by the end of compulsory education, to be able to control variables, to select evidence from a set of available data and to build up empirically based arguments is far more important than to be able to accurately perform lab techniques. For them to achieve this competency they need to become familiar with the interplay data-evidence-conclusion which requires them to carry out open activities (Gott & Duggan, 1998; Leach, 1999) that engage students from a cognitive point of view.

Besides, as tacit knowledge seems to play an important role in this process, students need to spend time interacting with different ideas from different people, before, during and after carrying out the lab procedure (Nakhleh, Polles & Malina, 2002), so that they can experience a process similar to the one of the scientists. This may also mean that the slogan "hands-on" science has to be taken with caution. "Hands-on" does not guarantee "minds-on" that is, it does not guarantee that students really understand what they do. Hence, "hands on" may be more useful for some purposes (e.g. accurately perform a lab technique or manipulate an equipment) but may bring a limited added value if conceptual learning is at stake (Hodson, 1994). In this case, a well-structured teacher demonstration may be more profitable (Wellington. 2000), as students can easily follow what the teachers are doing and at the same time be actively engaged with it from a cognitive point of view. Besides, "hands-on" is often considered as a necessary requirement for students to develop positive attitudes towards science. However, as Ausubel, Novak & Hanesian (1980) would argue, meaningful learning leads to intrinsic motivation that is far more important than extrinsic motivation. Thus, "minds-on" may lead to "hearts on" and give meaning to "hands-on". These three "ons" may be the key for success in a lab activities-based science education.

Characteristics of lab practices used in science classrooms

A few research studies have tried to characterise Portuguese science teachers' practices regarding the use of lab activities, before the curriculum reorganisation. A national survey (Dourado, 2001) involving 166 seventh grade Natural Sciences teachers showed that although 82% of the teachers stated that they use lab activities in their classes, the majority seem to use lab activities in only one to six classes per year. Almost all teachers stated that they give lab

worksheets to their students. The worksheets are either prepared by the teacher (49%) or taken from textbooks (44%). It is worthwhile noticing that the majority of the teachers (60%) stated that their students are asked to carry out the lab procedure in small groups. Two other surveys involving 67 (Cunha, 2002) and 77 (Afonso, 2000) Physical Sciences teachers and focusing on post-compulsory Physical Sciences teaching led to some similar results. In fact, it was found that teachers seem to promote low numbers of lab classes a year, and they stated that they take at least 50% of the worksheets from textbooks. These studies have also shown that according to half of the teachers, the lab activities are performed before the introduction of the relevant new concepts. Contrary to what seems to happen at the third stage of compulsory education, the two studies carried out at the secondary school level indicate that Physical Sciences teachers tend to perform the lab procedure themselves with students watching. A recent research study carried out with 87 Portuguese science teachers (stage 2) indicates that apart from a slight increase in the frequency of use of lab activities in science classes, no other relevant modifications occurred in teachers' practices due to 2001 curriculum. This means that the innovations acknowledged by the school curriculum reorganisation did not have a meaningful impact at the classroom level.

This failure of curriculum innovations may be at least partly due to the fact that textbooks, before (Leite, 1999; Figueiroa, 2001; Moreira, 2003; Sequeira, 2004) as well as after (Moreira, 2003; Sequeira, 2004) the curriculum reorganisation, include lab worksheets that are recipe-like. This sort of worksheets do not encourage students to engage into lab procedure planning or into data collection decisions. Besides, those worksheets often give the results to be obtained from lab procedure performance, preventing students from developing data interpretation competencies. In addition, it is worth pointing out that some inconsistencies in the data-evidence-conclusions relationship were also found in Portuguese science textbooks (Leite, 2002; Leite & Figueiroa, 2002), being students asked to draw conclusions from experiments that do not offer them the necessary evidences. This means that if teachers keep on being heavily dependent on the textbook for the lab worksheets used in their classes, students will hardly have the opportunity to develop the lab-related competences acknowledged by the curriculum as relevant for both scientists and citizens.

Methodology

Teachers teaching grades 7^{th} to 9^{th} in schools spread over the country and having at least five years of teaching experience were invited to participate in the study. This condition is needed to guarantee that participants in the study had taught the previous and the actual curricula. The instrument used for data collection purposes was a questionnaire (including close and open questions) that was sent by post to randomly selected junior high schools, after validation with specialists and teachers. A self addressed stamped envelope accompanied the questionnaire for the schools to return it to the researchers. The questionnaire focuses on: teachers' frequencies of use of laboratory activities; the origin of the lab worksheets; how lab activities are implemented; how lab activities are integrated in the teaching sequence.

Fifty-one Physical Sciences and 61 Natural Sciences teachers answered to the questionnaire. The majority of the teachers are female and the samples are heterogeneous with regard to age and teaching experience (table 1).

Percentages per alternative of answers (taken as category) were calculated. The option "others" did not lead to new categories of answers, as no relevant new answers were given by the participants in the study.

Table 1: Characteristics of the sample (%)

Characteristic	**Category**	**Physical Sciences (n=51)**	**Natural Sciences (n=61)**

Gender	Female	72,5	78,7
	Male	27,5	21,3
Age	Bellow 30	9,8	13,1
	30 to 40	54,9	67,2
	Over 40	35,3	19,7
Teaching experience	5 to 10	45,1	55,7
	More than 10	54,9	44,3

Results

Irrespective of the discipline, the percentages of teachers that stated that they did not use lab activities before the curriculum reorganisation as well as the percentages of teachers that do not use them nowadays are very low (table 1). As far as Physical Sciences teachers are concerned, there was a slight increase in the percentages of teachers saying that they use lab activities in 1 to 3 and 4 to 6 classes. In the case of the Natural Sciences teachers, the decrease in the percentage of teachers that said that they were used to perform lab activities in 4 to 6 classes turned into an increase in the percentage of teachers that stated that they use them in 1 to 3 classes. Thus, according to the participants in the study, it seems that a tendency to diminish the number of lab activities carried out in science classes took place due to the school curriculum reorganisation. It is worthwhile pointing out that this tendency is opposite to what should be expected from the curriculum recommendations. In addition, it differs from the tendency found in grades five and six, as the frequency distribution of teachers teaching science to these grades before the curriculum reorganisation compares to the frequency of teachers after it (Leite & Dourado, 2005).

Table 2: Teachers' use of lab activities, before and after Curriculum Reorganisation (%)

Use of lab activities	**Physical Sciences (n=51)**		**Natural Sciences (n=61)**	
	Before	**After**	**Before**	**After**
Not used	6	4	3	8
Used in 1 to 3 classes / year	12	20	23	39
Used in 4 to 6 classes / year	24	33	44	28
Used in 7 to 10 classes / year	25	16	18	18
Used in more than 10 classes / year	33	27	12	7

Almost all the teachers stated that lab worksheets were used in their classes before and after the curriculum reorganisation (table 3).

Table 3: Use and origin of lab worksheets, before and after Curriculum Reorganisation (%)

Lab worksheets	**Physical Sciences (n=51)**		**Natural Sciences (n=61)**	
	Before	**After**	**Before**	**After**
Prepared by teacher	68	43	36	24
Taken from a school textbook	14	21	39	38
Prepared by teacher and students	10	16	7	15
Prepared by the students	2	6	2	10
Not used	0	4	3	3
No answer	6	10	13	10

The origin of lab worksheets preferred by a large amount (68%) of Physical Sciences

teachers, before the curriculum reorganisation, is the teacher him/herself. However, after the curriculum reorganisation this percentage decreased to 43%. On the contrary, Natural Sciences teachers seem to prefer to take the lab worksheets from a school textbook. In addition, physical as well as Natural Sciences teachers seem to seldom involve students in the development of lab worksheets.

These results compare to those found for grades five and six (Leite & Dourado, 2005) and suggest that textbooks maintain an important role in determining the lab activities carried out in the classroom. Bearing in mind the results of textbook analyses given above, they also indicate that students are hardly involved into planning the lab activity and therefore they are not given the opportunity to develop some important types of procedural knowledge like variables control and manipulation, selection of lab techniques, etc.

While the percentage of Physical Sciences teachers that stated that they give their students the opportunity of performing the lab procedure in small groups seems to have increased after the curriculum reorganisation, the percentages of Natural Sciences teachers did not change (table 4). These results are quite similar to those obtained for the second stage of compulsory education, as the number of fifth and sixth grade teachers that stated that they ask students to perform the lab procedure in small groups increased a little bit after the school curriculum reorganisation (Leite & Dourado, 2005). However, no Physical Sciences teachers stated that he/she was used to ask students to carry out the lab procedure individually either before or after the curriculum reorganisation, and 7% of the Natural Sciences teachers stated that they do it after the curriculum reorganisation. As it was argued above, students' hands-on are not required for students' minds to be on that is for students to develop conceptual conceptual knowledge. However, if students are not given the opportunity to carry out the lab procedure, they will not learn how to handle materials and equipments and to accurately perform lab techniques.

Table 4: Performance of lab procedure, before and after Curriculum Reorganisation (%)

Implementation of the lab procedure	**Physical Sciences (n=51)**		**Natural Sciences (n=61)**	
	Before	**After**	**Before**	**After**
By the teacher; students observing	19	10	16	8
By the teacher; students helping	16	16	18	21
By the students in small groups	59	68	53	52
By the students individually	0	0	0	7
No answer	6	6	13	12

As far as the way of integrating lab activities in the teaching sequence, the largest percentages of teachers were found for theory introduced before lab activities (table 5).

Table 5: Integration of lab activities in the teaching sequence, before and after Curriculum Reorganisation (%)

Integration in the teaching sequence	**Physical Sciences (n=51)**		**Natural Sciences (n=61)**	
	Before	**After**	**Before**	**After**
Lab activities before theory	27	20	21	20
Theory before lab activities	53	41	48	42
Theory during lab activities	14	31	16	23
No answer	6	8	15	15

However, a small decrease in the percentages of Physical and Natural Sciences teachers that

said that they use this form of integrating lab activities in the teaching sequence seems to have taken place due to curriculum reorganisation. This result is opposite to the one obtained with a study involving six and fifth grade teachers, as it showed a decrease in the percentage of teachers using lab activities before the theory and an increase in the number of teachers doing it the other way round (Leite & Dourado, 2005).
The percentages of both groups of teachers mentioning that they introduce theories during the lab activities seem to have increased a little with the curriculum reorganisation. This tendency is consistent with the philosophy of the curriculum reorganisation and it compares to the result obtained by Leite & Dourado (2005) with fifth and sixth grade teachers.

Conclusions and implications for teacher education

The results of this study seem to indicate that no meaningful change took place in teachers' practices due to the 2001 curriculum reorganisation, neither in the case of Physical Sciences teachers nor in the case of their Natural Sciences counterparts. In fact, the frequency of use of lab activities did not suffer a relevant increase, lab worksheets, in general, and lab worksheets from school textbooks, in particular, kept an important place, and lab activities continue to serve mainly for the purpose of confirming previously presented concepts and principles. Opposite to what should be expected, the fact that the majority of the teachers ask students to carry out the lab procedure in small groups together with the other results indicates that small group work will hardly result in conceptual and procedural discussions. In fact, bearing in mind what is known about textbooks, most of the lab activities are supported by cookbook-like materials that prevent students from taking decisions about technical procedures as well as about data interpretation.
As it was stated above, the school curriculum reorganisation creates better conditions for open activities to be carried out and it could therefore be expected that some changes in teachers' practices would have taken place. However, it is well known that for teachers' practices to change they would need to feel the need for changing them. The point is that although there was a public discussion of the curriculum, there was nevertheless no well-structured way of explaining innovations to teachers and of making them perceive the educational relevance of the innovations included in the new curriculum. Thus, the mismatch between the results of the study and the curriculum guidelines suggests that adequate in-service teacher education courses focusing on the use of the laboratory for teaching should be organized, so that teachers can reflect upon their usual practices, become familiar with new methodologies and feel-like trying them out with the advice of a more experienced person. The methodology changes that teachers' practices need to undergo may be looked at by the teachers themselves, as too big and teachers may not feel confident enough to try them alone. They may need to be helped to overcome the "fears" that are usually associated with new ways of teaching. To give teachers support for innovative uses of the lab would be a nice way to help them to overcome the challenge of a student's centred use of the lab success. Nevertheless, to effectively move from teacher's centred to student's centred use of the lab is a big challenge that cannot surely be overcome at once. Hence, learning communities of teachers including either experienced teachers or science teacher educators would make teachers' job a bit easier and give more guaranty of methodology change.

Note: This research was funded by FCT, Project POCTI, reference 33352/99 FCT.

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