

Teaching Science in The Laboratory: A Study on Portuguese School Science Teachers' Perspectives

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ABSTRACT

Laboratory activities may serve diverse educational purposes and be used in different ways. The educational advantages taken from laboratory activities depend strongly on the ways they are performed. Teachers' conceptions on the best ways to carry out laboratory activities may influence the potential taken from them. This paper aims at finding out how teachers' representations of practices regarding laboratory activities compare to their perspectives on a possible ideal form of implementing them. Data were collected through an online questionnaire from 159 teachers belonging to schools all over the country. Almost all participants stated that they were used to include laboratory activities in their classes. Besides, most teachers stated that the way they would implement laboratory activities would not change if there was no constrains to putting laboratory activities into practice. Thus, most teachers do not feel the need to change their practices regarding laboratory activities. In addition, teachers that would do things differently did not express theoretically grounded reasons to do so. Hence, research results suggest that pre-service and in-service teacher education must deal with the pros and cons of the diverse ways of using laboratory activities as well as with an analysis of possible strategies to overcome the main constrains face by teachers in Portuguese schools.

CONTEXT OF THE RESEARCH

Laboratory activities are a teaching resource that has concentrated educationalists' attention for a long time (Abrahams, 2011) even though for reasons that depend on the interest of the moment or on the prevailing conceptions about what teaching science is. In fact, in the late nineteen century, laboratory activities were used to argue for the inclusion of science in the curriculum. By the turn to the twentieth century, Armstrong saw them as a way to give students' the opportunity to acquire first-hand knowledge. By mid-twentieth century, they were conceptualized as a way to promote the development of science process skills. By the last decades of the twentieth century, they laboratory activities were seen as a tool to help students to reconstruct their previous ideas. More recently, it has been argued that they should be used to foster the integration of conceptual and empirical knowledge (Abrahams, 2011), based on an interplay between theory (or ideas) and evidence (or observables) supported by empirically based argumentation (Gott & Duggan, 2007). Besides, it is acknowledged that they should be used in such a way as to help students to bridge the gap between school science and contemporary issues (Gott & Duggan, 2007; Llorens-Molina, 2010).

Despite the long history of laboratory activities as an educational tool and the large amount of publications, including several books (Woolnough & Allsop, 1985; Woolnough, 1991; Wellington, 1998; Leach & Paulsen, 1999; Psillos & Niederer, 2002; Abrahams, 2011) focusing on them, a lack of consensus still emerge in different domains of the laboratory activities issue, starting with the terminology used to address them. In fact, as it was discussed in a previous paper (Leite & Dourado, 2013), several different words (e.g., practical work, laboratory

work, experimental work, investigations), that have different meanings, have been used to address laboratory activities in an undifferentiated way. This type of terminological issue is common when several researchers or research groups work simultaneously on the same issue, from different epistemological backgrounds. It happened, for instance, in the alternative conception research area (see Abimbola, 1988). Even though it does not necessarily suggest a lack of conceptual rigor from the researchers' side, it may have negative implications for students learning, as it may impair readers' awareness of the educational powers and limitations of each set of activities that should, in rigor, be associated with each of the different terms. This is why terminology clarification is a necessary requirement for an appropriate use of this valuable educational resource.

Within an educational context, laboratory activities can be defined as tools that enable indoor reproduction or simulation of natural facts and phenomena (or part of them) through conventional laboratory equipment and/or reusable everyday materials (Hodson, 1994; Abrahams, 2011; Leite & Dourado, 2013) that students and/or the teachers handle to produce data. Hence, laboratory activities are practical activities but it should be stressed that not all practical activities are laboratory activities. For instance, paper and pencil or computer modelling problem-solving activities are practical activities but they are not laboratory activities.

The ultimate goal of using laboratory activities in science teaching is not only to help students to learn how to interpret and explain facts and phenomena (Abrahams, 2011) but also to do it as scientists do (Ogborn et al, 1996). However, a set of intermediate and diverse objectives can be achieved through laboratory activities (Hodson, 1994), including conceptual, procedural, metacognitive and affective objectives. It should not be expected that a single laboratory activity would be able to lead to the fulfilment of such a variety of types of objectives. Rather to achieve such a demanding goal several laboratory activities, with different focus, should be performed. Thus, to enable the attainment of all of those objectives, a set of differentiated laboratory activities, each of them structured according to the requirements of the main type of objective to be achieved through it, should be performed (BERG, 2014; Leite & Dourado, 2013). As it has been argued before (Leite & Dourado, 2013), for instance: if attaining the main objective requires control and manipulation of variables to be done then an experimental laboratory activity may be required; if attaining the main objective involves problem-solving, then worksheet free laboratory investigation may be needed.

However, research suggests that teachers may have got used to the idea that laboratory activities are non-dissociable from science teaching, look at them as a single entity and often lack an appropriate methodological background on the best ways to using them. A consequence of this is that "Students' experience of practical work as implemented could lead to a surface approach to learning rather than deeper learning for understanding." (Sani, 2013, p. 1016). The point is that research suggests that the nature of the activities promoted by the syllabuses depend on the syllabuses' authors (Ferreira & Morais, 2014; Šorgo & Špernjak, 2012) and that textbooks (Park & Lavonen, 2013) and teachers' practices (Abrahams & Reiss, 2012; Sani, 2013) are pervaded by receipt-like laboratory activities that lead straight to the right answer. The popularity of worksheet-based laboratory activities leading to the right answer may lie on the fact that those activities are perceived as being less risky for teachers, that feel afraid of failing in the laboratory classes (Cossa & Uamusse, 2015), and for students who want to get credits for what they have done (Carlo, Mazzaro & Page, 2006). Nevertheless, research suggests that even though teachers resist to new ways of doing laboratory activities, with appropriate training, they gradually overcome their resistance and reluctance and develop willingness and motivation to practice them differently in everyday science classrooms (Kim & Chin, 2011).

Another issue that is worth raising is that laboratory activities may integrate the teaching and learning sequence in different ways (Leite & Dourado, 2013). In fact, the laboratory activities can be inserted at the beginning, the middle or the end of the teaching sequence, depending on whether it is aimed to be a starting point for conceptual learning, whether it is to facilitate conceptual knowledge reconstruction or procedural and conceptual knowledge integration or whether it is to reinforce previous conceptual learning, respectively.

Laboratory activities can have different levels of openness. The level of openness relates directly to the cognitive demands imposed to students (Tamir, 1991), so that the higher the level of openness of the activity, the higher the level of students' demands. Consequently, the higher the level of openness, the deeper the learning that

should be expected to take place. However, there is some empirical evidence that teachers' activities are low demanding (Ferreira & Morais, 2015) for students, which according to BERG – Biology Education Research Group (2014), may be due to teachers' intentions for using them. Their attention is often focused on the hands on part of laboratory activities, based on the argument that students need to perform the laboratory procedure to learn better. However, even though hands-on are important to develop handling capabilities as well as a few technical skills (BERG, 2014; Woolnough & Alsop, 1985), developing those types of skills is hardly relevant unless they are integrated with cognitive reasoning issues (Abrahams & Reiss, 2012). Handling is far less important for meaningful learning than thinking is. As BERG (2014) emphasizes, "practical work isn't just 'doing', it also involves 'thinking about doing'." (p.178). Thus, if conceptual learning is to take place, then it is far more important that students' are cognitively engaged into the activity (have minds-on) than that they handle equipment or materials (have hands-on), without being aware of what they are doing or of what it is relevant for. For this process to be successful, it can be argued that students should also have their hearts-on (Leite & Dourado, 2013), as positive affective involvement would facilitate cognitive engagement. Unfortunately, research suggests that teachers' naïve beliefs about laboratory activities are reflected into their practices (Kang & Wallace, 2005) leading them to often use laboratory activities unthinkably (Toplis, 2012) and to fail to explicitly promote the link between the laboratory activity and the related theory (Chopra, 2017). In addition, research focusing on teachers' practices and representations of practices suggests that teachers' practices regarding laboratory activities are teacher centred and aiming at confirming, empirically, previously taught concepts (Abrahams, 2011; Leite & Dourado, 2007; Ramalho, 2007). This may explain why students' motivation towards laboratory activities decreases along the school path (Abrahams, 2009) and why some of them expect the laboratory to be the place to learn practical skills as well as to illustrate theory taught in lectures (Hanif et al, 2009).

As assessment practices determine what is important to learn (Abrahams & Saglam, 2010; Carlo, Mazzaro & Page, 2006), students' assessment procedures need to be consistent with the aims settled for laboratory activities (Hodson, 1992) as well as with what is in fact valued (Abrahams, Reiss & Sharpe, 2013). As it was argued elsewhere (Hofstein & Lunetta, 2004; Leite, 2005), there is a variety of learning issues that can be assessed when laboratory activities are at stake. This variety is as larger as higher is the level of openness, being investigations the type of activity that offers a larger variety of learning issues to be assessed (Leite, 2005). Besides, there is a variety of assessment tools that can be used (Doran et al, 2002) to assess students' learning from laboratory activities. The traditional laboratory reports are only one of them. They can be useful when open activities are used, as they assume a shape and role similar to the one of a scientific research paper in which all the decisions, procedures, data and conclusions are registered. However, they can be a waste of time when well-structured worksheet-based activities are under question, as to prepare the laboratory report students would need to transcribe (copy) the information and instructions given in the worksheet and to add the right answer only. On one hand, making copies is not what some researchers (e.g., Ellis, Taylor & Drury, 2007) talk about when they argue for writing for learning science. On the other hand, "the majority of students find one way or another to come up with the "right answer". While most of them rely on perseverance to achieve their goal (i.e., redoing or fixing the procedure), many take the alternative route of copying or manipulating data." (Carlo, Mazzaro & Page, 2006, p.1366).

Therefore, more authentic assessment techniques need to be adopted (Hodson, 1992; Gott & Duggan, 2007), especially for summative purposes as it seems that the nature of summative assessment influences school practices with regard to using the laboratory with direct practical assessment favouring laboratory activities (Abrahams, Reiss & Sharpe, 2013). Of course, this may be a challenge for educational managers, as direct assessment in the laboratory is costly. It can also be demanding for teachers, as they themselves may feel the need of training, so that they can find the best assessment practices and to design activities that match their teaching context and their class conditions (Yip & Cheung, 2005) and that are more transparent to students (Ottander & Grelsson, 2006).

Teachers' conceptions are one of the key factors that may influence their teaching practices (Kang & Wallace, 2005) namely in what concerns the use of laboratory activities. Besides, teachers' work conditions may also condition their practices. In fact, teachers often complain about the conditions they have to include laboratory

activities into their teaching practice. They mention laboratory unavailability, inexistence of a laboratory technician, shortage of equipment or reactants, lack of time, and even student's lack of interest on them. The worst part is that instead of finding valuable ways to overcome challenges to laboratory classes' impairments, some teachers opt for the easiest alternative – do not put them into practice.

In summary, teachers' conceptions on the best ways to carry out laboratory activities may influence teachers' practices as well as the potential they take from laboratory activities. Their practices are often inconsistent with what specialists argue for and they mention several factors that impair them from using laboratory activities or from using laboratory activities, as they should be. However, as far as it is known, there is no research on how schoolteachers would like to use laboratory activities if there was no constrain.

RESEARCH QUESTION

A few research studies on teachers' practices or representations of practices are already available. However, as teachers' practices are often limited by factors that they see as constrains to the way they can teach, this study aims at answering the following question: how do Portuguese Natural Sciences teachers' representations of practices regarding laboratory activities compare to a possible ideal form of implementing them?

RESEARCH METHODOLOGY

To attain the objective of the study, a questionnaire focusing on what teachers do and on what they would like to do (if there was no constrain) with regard to using laboratory activities in their junior high school natural sciences classes was designed. The questionnaire was inserted into Google Docs so that it could be answered online. In the first page there was an explanation about the overall aim of the study, as well as about the anonymous nature of the questionnaire and participants could decide on whether they were willing to proceed or not.

The target population was Natural Sciences (a school subject that encompasses biology and geology themes) teachers that were teaching in Portuguese public junior high secondary schools (grades 7 to 9) during the academic year of 2014/15. Due to the large dimension of the population, a sample was drawn. To do so, it was taken into account that data would be collected through an online questionnaire meaning that a large percentage of invited teachers could not reply. Besides, as the contacts of individual teachers were not available, it was decided to contact them through the school Director. Afterwards, it was decided to contact the Director (using the school e-mail address) of all the junior high schools included in the ministry of education official schools database and to ask to him/her to collaborate in the study. Those that accepted were asked to ask four Natural Sciences teachers, with at least three years of teaching experience, to answer to the questionnaire. The objective of this requirement was to ensure that the research participant teachers had a minimum teaching experience at this school level and therefore had a quite good overview of the syllabuses as well as about the possibilities and the constrains associated with putting them into practice with regard to laboratory activities.

The school Director should make the questionnaire web link available to teachers selected and willing to participate in the study so that they could fill it in. According to McMillan and Schumacher (2010), it should be noted that filling in an online questionnaire is a volunteer action that can be accepted as good alternative to informed consent statement signature.

The effective participants in the study are 159 teachers. Due to the anonymous character of the questionnaire, the number of schools they come from is not known. An analysis of data given in table 1 shows that all teachers have more than five years of teaching experience, that is two years more than the minimum required. Besides, it shows that the least experienced group is very small. This is consistent with the fact that, in the recent years, the admission of new teachers has been very rare, due to demographic reasons. A consequence of this is that all but one teacher are over thirty years old. Besides, table 1 shows that the number of male teachers is very small when compared with the number of their female counterparts. The prevalence of female teachers is consistent with what happens in school in several countries (Kelleher, 2011) as well as with what was found in other studies (e.g., Dourado, 2001; Nunes, 2011). As far as teachers' academic background is concerned, all of them have graduated as teachers through a *Licenciatura* (the required 5 years qualification before the Bologna process) and

about 27% (43 out of 159) have taken further post-graduation studies. This means that all of them are fully qualified to be teachers and that some of them even have additional qualifications.

Table 1: Characteristics of the sample (%)
(N=159)

Variable	Categories	f	%
Gender	Female	140	88,1
	Male	19	11,9
Age (years)	Less than 30	1	0,7
	30 to 40	49	30,8
	41 to 50	81	50,9
	More than 50	28	17,6
Professional Experience (years)	5 to 10	4	2,5
	11 to 20	87	54,7
	21 to 30	57	35,9
	More than 30	11	6,9
Higher academic degree	<i>Licenciatura</i>	116	72,9
	Specialization	10	6,3
	Master	32	20,1
	PhD	1	0,7

RESEARCH RESULTS

Table 2 shows that all but one percent of the teachers stated that laboratory activities have been performed in their classes over the last three years. However, teachers are almost divided between a mean of less than and more than six activities a year in each of the classes they taught.

Table 2: Teachers' mean use of laboratory activities over de previous 3 years
(N=159)

Use of laboratory activities		Percentage
Do not use		1
Use	1 to 3 times a year	14
	4 to 6 times a year	37
	More than 6 times a year	48

Comparing these frequencies with data obtained in other studies it can be stated that these data are similar to those obtained for Physics and Chemistry, for example (see Leite & Dourado, 2007). Besides, by comparing them with the syllabuses laboratory requirements, it can be argued that whatever the grade level, the syllabus requires more than six activities to be done. Therefore, performing less than six activities a year in each class is not too much.

About a quarter of the 157 teachers that stated that they use laboratory activities in their classes mentioned that they were fully satisfied with the way they use them (table 3). The other three quarters were not fully satisfied with the way laboratory activities are carried out, being 2% fairly satisfied and 27% moderately satisfied only.

Teachers that stated that they were fully satisfied put forwards arguments that are related to the objectives that can be attained through laboratory activities. They argued that laboratory activities:

- i) promote students' conceptual learning
"Students internalize concepts much more easily" (P8)
- ii) promote students' procedural learning
"They improve students' laboratory material handling skills and develop their data analysis competences" (P43)
- iii) increase students' motivation to learn
"Students show enthusiasm every time a laboratory activity is performed." (P13)
- iv) develop students' critical thinking
"They foster students' critical thinking." (P158)

Table 3: Teachers' level of satisfaction with the laboratory activities used in their classes

(N=157)

Level of satisfaction	Percentage
Fully satisfied	26
Quite satisfied	45
Moderately satisfied	27
Fairly satisfied	2
Unsatisfied	0

Most teachers that were quite satisfied put forwards positive and/or negative arguments. The positive arguments compare to those used by the fully satisfied teachers. The negative arguments compare to reasons reported in the literature for teachers to not use laboratory activities. They are as follows:

- i) students do not engage into the activities
"Students do not look at these classes seriously." (P29)
- ii) good laboratory conditions are not available
"There is not a real well equipped laboratory in our school." (P31)
- iii) the class time is too short
"I am not fully satisfied because for some activities, the duration of the class (45 min) is insufficient." (P39)
- iv) the syllabus is too long
"The only reason for my [moderate] satisfaction is the great length of the syllabus." (P71)
- v) the class is too large
"There are too many students in a class." (P128)

Moderately satisfied teachers mentioned negative aspects mainly. Those aspects compare to the ones previously presented. Finally, teachers that were fairly satisfied mentioned negative reasons only. Their reasons compare to reasons found in other studies for not performing laboratory activities, namely:

- i) lack of laboratory
"I cannot perform more laboratory activities because there is no sciences laboratory in my school." (P1)
- ii) shortage of laboratory material
"There is shortage of laboratory material in schools." (P11)
- iii) insufficient discipline workload
"The number of hours per week is very low." (P41)
- iv) shortage of training
"I have inappropriate training to perform laboratory activities consistent with the syllabus." (P41)

An analysis of the reasons above suggests that most teachers would like to have better conditions to use laboratory activities differently. However, comparing the way teachers state that they use laboratory activities with their perspectives on the ideal ways of using them it can be noted that, in each case, teachers mention a variety of ways with quite similar percentages (table 4). It can also be noted that there is a slight reduction on the percentages of teachers in the categories involving the option *after* teaching the content and a *slight* increase on the percentages of teachers in the categories involving the *before* option. This means that most teachers that stated that they use laboratory activities after teaching the content are happy with that approach and would not perform them differently if they had no constrains to their teaching practices relative to laboratory activities. However, a few teachers that use them *after* teaching the content would like to in traduce them *before* teaching it. They are used to introduce the content before the activity because, as P59 stated, they feel that "introducing the theoretical content before the activity helps the majority of the students to understand better the objectives of the activity and to consolidate conceptual learning". However, they would like to start with the activity because, as the same teacher stated, "to suggest problems to be solved through laboratory activities fosters inquiry, requires several types of knowledge to the used and stimulates students' autonomy".

Table 4: Teachers' use of laboratory activities and their perspectives on the ideal way of using them (%)
(N=157)

Laboratory activities versus concept teaching	Real use	Ideal use
Before	1	11
During	34	29
After	14	6
Before or during or after	27	29
Before or during	7	11
Before or after	4	8
During or after	13	6

Besides, the percentage of teachers that use and would like to perform the laboratory procedure either before, or during or after teaching the content remains almost unchangeable (table 4). For these teachers, the decision “depends on the content to be taught and on the activity itself” (P67). This may mean that teachers that believe that laboratory activities can be performed at any moment of the teaching and learning sequence do it because they believe it is the best for their students and that they can overcome the constraints they face in their daily life practice. In fact, laboratory activities should be performed at different stages of the teaching and learning sequence, depending on the main objective to be achieved (Leite & Dourado, 2013). However, a few teachers that are used to introduce laboratory activities at any moment of the teaching and learning sequence would like to introduce them before theory, because, as P9 stated, it would “enable students to interiorize concepts more easily”. In addition, a few teachers that are used to introduce laboratory activities during theory presentation, they would like to use them before theory because, as P31 stated, “It enables the teacher to guide the students towards the formulation of questions that would be answered, with increased motivation, during the presentation of the content”. Hence, a few teachers, with different practices, seems to believe that students would benefit if laboratory activities were introduced before the content.

Table 5 shows that there is not too much difference between the tasks that teachers stated that are carried out before the implementation of the laboratory procedure and the tasks that would be performed in the ideal situation of having no constraints. However, there is a slight reduction in the percentages of teachers that stated that the teacher “Teaches contents related to the laboratory activity”, “Does scientific and pedagogic preparation for the laboratory activity”, and “Selects laboratory materials and Provide information on safety and handling rules”. In fact, as P11 mentioned, some teachers are used to “Start by introducing theory so that students can understand what they are going to do and what they should conclude from the laboratory activities”. It is worth noting that this is what a few of them would like to do under ideal conditions: “Introduce the theory related to the issues to be studied in the lab, so that students can have the theoretical foundations underlying the activity to be carried out.” (P11). However, a few other teachers would like to do it differently, as P18 stated: “Would not introduce the content before the activity; students would be asked to reach conclusions and to discover by themselves. It would be much more interesting even though most students are not used to work on this way” (P18).

Also, there is a reduction in the percentage of teachers that would ask students to “Read and analyse the laboratory worksheet” (table 5). On the contrary, there is a slight increase in the percentages of teachers that stated that they would like to give students the chance to “Design the laboratory worksheet”, “Do bibliographic search” and “Carry out predictions”. This may mean that only a reduced number of teachers would like to give more autonomy to students or to conduct more students' centred activities. P1, which gives students the opportunity to become familiar with the laboratory worksheet in advance in order “[...] to develop the activity without wasting time”, may illustrate this group of teacher. In fact, this teacher stated: “Ask students to design the worksheet. I think that it would be educationally more valuable and the classes would not be receipt-based”. This argument may mean that P1 that trusts students' abilities to learn in a student centred environments.

Additionally, it should be noted that the percentage of teachers that did not answer increased in 19% (from 8% to 27%) from the actual practices to the ideal situation. This means that more than a quarter of the participants may not be aware of what they would like to do before the implementation of the laboratory activities. This is a very intriguing result, as experienced teachers should have an idea about the way they would like to use a key

educational resource like laboratory activities.

Table 5: Tasks carried out before starting the implementation of the laboratory procedure (%)
(N=157)

Responsible person	Action	Real way	Ideal way
Teacher	Teaches contents related to the laboratory activity	31	27
	Does scientific and pedagogic preparation for the laboratory activity	13	10
	Selects laboratory materials	20	16
	Provides information on safety and handling rules	24	19
	Provides information on learning assessment criteria	9	8
	Prepares for teamwork	12	11
	Does a prior trial of the laboratory experiment	3	3
	Asks questions on the activity to be carried out	8	8
Students	Read and analyse the laboratory worksheet	29	24
	Design the laboratory worksheet	4	10
	Do bibliographic search	3	6
	Carry out predictions	1	3
	Practice the handling of laboratory materials and equipment	2	1
	Solve exercises	6	4
Do not answer		8	27

Comparing what teachers stated that is done during the implementation of the laboratory procedure with what would be done (table 6), it can be noted that, in the majority of the laboratory activities, there would be about 20% less teachers guiding students and also about 20% less explaining to students, if there was no constrain to their implementation. This means that during the laboratory procedure, teachers would like to give more responsibility to students: “Would give a more central role to students.” (P3). Consistently, more teachers would like to have students performing the laboratory procedures in small groups or individually (table 6). However, there is no evidence that teachers would ask students to engage more strongly into the activity, as they did not mention that they would ask students to carry out conceptual/cognitive tasks.

Table 6: Tasks carried out during the implementation of the laboratory procedure (%)
(N=157)

Responsible person	Action	Real way		Ideal way	
		None/few	Majority/All	None/few	Majority/All
Teacher	Guides students	18	82	36	64
	Explains issues to students	27	73	45	55
	Asks questions to students	11	89	13	87
	Observes students working	11	89	8	92
Students	Observe teacher’s laboratory procedure performance	98	2	99	1
	Help teacher to perform laboratory procedure	89	11	92	8
	Carry out laboratory procedure in small groups	32	68	23	77
	Carry out laboratory procedure individually	94	6	80	20

Besides, some teachers are not confident on students’ motivation to engage into learning from laboratory activities. This statement can be illustrated by teachers like P40 that was used to guide students in all the activities because he/she believes that “only with guidance students succeed on performing the activities and getting aware

of the interactions between the activity and the relevant theory”. This teacher would reduce the number of activities in which guidance is provided but only “In an utopian situation in which students are engaged and interested in learning and in which schools have good laboratory conditions”. Also, P157 stated that he/she explains and would explain content issues to the students in all activities because “students are very immature, have no rules, and have their interests focused on other places than the school. Therefore, they need explanations to recall previously acquired knowledge.”. Underlying these teachers’ answers is the perception that students are not motivated (even) to perform laboratory activities which is in disagreement with teachers who state that students enjoy all laboratory activities.

Finally, it should be mentioned that teachers whose students perform (only) the majority of the activities individually would like to have their students performing all the activities individually. To illustrate this, we take P69 o stated that: “as someone said ‘learning by doing’ leads to a deeper understanding of the phenomena”. This statement seems to be strongly influenced by a hands-on conception of using the laboratory for teaching science, which can be negative in terms of students learning achievements, as it was discussed above.

Table 7 shows that, after the laboratory procedure, a few teachers would do things differently, if there was no constrains. In fact, the percentage of teachers that, for the majority of the laboratory activities, would “Remind students about laboratory activity related contents” as well as the percentage of teachers that would ask students to “Discuss on the laboratory activities” previously carried out increased slightly. Besides, the percentage of teachers that stated that they would teach new contents increased 11%. However, this may mean that teachers would like to teach either the new content related to the procedure previously performed or another new content not related to the previous activity. Their answers are not too clear about that, as shown by P20’s answer: “Laboratory activities may be a starting point for approaching new issues.”.

Table 7: Tasks carried out after the implementation of the laboratory procedure (%)

(N=157)

Responsible person	Action	Real way		Ideal way	
		None/few	Majority/All	None/few	Majority/All
Teacher	Reminds students about the activity related content	27	73	22	78
	Teaches new contents	76	24	65	35
Students	Prepare the laboratory report	40	60	25	75
	Discuss on the laboratory activities	11	89	8	92
	Solve problems	61	39	36	64
	Plan new laboratory activities	94	6	61	39

Larger percentage increases were found in two tasks that teachers would ask students to do. One of them relates to laboratory report preparation (15% increase). Teachers stated that they use and would continue to use laboratory reports because “They promote the development of a bridge between theory and practice; laboratory reports (besides being assessment instruments) they lead students to systematize their learning achievements” (P19) or “The elaboration of a laboratory report is an assessment and a consolidation tool.” (P158). These teacher’s answers reveal a deficit of knowledge laboratory learning assessment techniques and/or of critical thinking on laboratory reports potential and limitations. As argued above, laboratory report is a traditional laboratory assessment tool whose educational usefulness depends on the type of the activity that is at stake. It can be useful for investigation like activities (not based on a worksheet) but may be a waste of time for receipt like activities as their laboratory worksheets give all the information to students.

The action whose percentages are different has to do with asking students to solve problems (25% increase). Solving problems in the basis of a laboratory activity to be performed or related to the activity performed would be good for students to develop problem-solving competences or to perceive the usefulness of the newly acquired knowledge, respectively. With regard to this, teachers that ask and would like to ask students to do problem-solving, stated that they do it “so that students learn how to think scientifically; learn with experimentation” (P9) and because “ a laboratory activity serves to lead to a conclusion, that is to solve a given problem.” (P112). These results raise some concern, as there is some empirical evidence that teachers often do

not differentiate the concepts of exercise and problem and also that problems are seldom used in the classrooms as well as in the textbooks.

Finally, the largest increase (33%) was noted for “Plan new laboratory activities” related to the majority or all activities performed. P54 that do not ask students to plan laboratory activities, stated that he/she would like to having them doing it for all the activities because “It is important and having the chance to plan new activities would be interesting for the students but it would require much more time for each activity.”. Similarly, P64, stated that “if the syllabus was not so long, it would be possible to ask students to plan new activities and to present problem to be solved through laboratory activities.”. This would be nice, as it would provide opportunities for students to develop procedural competences and to better integrate their knowledge. However, it seems hardly consistent with the reduced ambition shown by teachers in the previous phases.

CONCLUSIONS AND IMPLICATIONS

Almost all participants stated that they were used to include laboratory activities in their teaching practice, even though about half of them seem to use laboratory activities once in two months in each class. However, only about a quarter of the participants mentioned that they feel a moderate or lower level of satisfaction with the laboratory activities they put into practice. Besides, as far as the stage of the teaching and learning sequence in which laboratory activities are introduced is concerned, teachers stated a variety of possibilities that compare to the ones they would introduce them if they had no constraints to putting laboratory activities into practice. The only important difference has to do with the ‘before’ stage, as 10% more teachers would like to introduce laboratory activities at that stage than they were actually used to do. In addition, the percentages of teachers that do and would like to do things in a certain way before, during or after the implementation of the laboratory procedure are quite similar. Exceptions are that: i) a few less teachers would like to give guidance and explanation to students; ii) a few more teachers would like to have students performing the laboratory procedure individually, writing laboratory reports and solving problems after the laboratory procedure. These results suggest that teachers do not feel a strong need to change their practices regarding the introduction and implementation of laboratory activities. Besides, teachers that would do things differently did not express theoretically grounded reasons to do so. Some changes that they would like to do may not even be the best ones, as they would reinforce practices based on doing *for habit*, irrespective of the nature of the activity that is at stake. An example of this is the use of and belief in laboratory reports, which has powers and limitations, as discussed above.

Hence, pre-service and in-service teacher education must deal with the possible ways of using laboratory activities for teaching science in order to help them not only to overcome the temptation of continuing to use the frequent excuses reported in the literature (see Cossa & Uamasse, 2015) to not perform laboratory activities, but also to continue performing them as usual. Training should include a discussion on the potential and limitations of the diverse ways of using laboratory activities as well as on the best ways to carry them out in order to counteract what Kang & Wallace (2005) called teachers’ naïve epistemological beliefs about laboratory activities. Besides, it should help them to find ways of overcoming constraints faced in particular school contexts, for instance by doing laboratory activities (safely but) in places other than the conventional laboratory and or with non-conventional materials. Teachers and prospective teachers may need to perceive that motivation is important but that motivation in itself is not a learning outcome (Hanif et al, 2009). Nevertheless, it is possible to structure and use laboratory activities in such a way as to both increase students’ learning achievements and develop students’ positive attitudes (Tarhan & Sesen, 2010; Toplis, 2012).

Finally, curriculum developers and educational authorities need to find ways of fostering changes namely by fighting the *right answer syndrome* and promoting more realistic school laboratory practices that, as Ogborn et al (1996) would put it, may help teachers to lead their students to explain science as scientists do. As Abrahams, Reiss and Sharpe (2013) have emphasized, laboratory related learning assessment guidelines might need to change in order to foster teaching changes. Doing laboratory activities costs time and money. Therefore, they cannot be done just because ‘they are a part of science’ or because ‘science is a practical subject’. They need to be done because and when they have a meaningful role to play in the specific educational context each teacher is immersed at the moment, so that teachers can help their students to better master the scientific explanations of real facts and phenomena.

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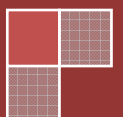
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