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Initial Teacher Training: Contribution to an Appropriate Use of the Experimental Work

Alcina Figueiroa, J. António Moreira*

Centro de Estudos Interdisciplinares do Século XX (CEIS20), Universidade de Coimbra, Portugal
*Corresponding author: jmoreira@uab.pt

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Abstract The renewal of conventional science teaching practices, particularly regarding the use of Experimental Work, has been a concern of official documents and experts, due to the lack of fitness and motivation on the part of teachers who use it. Since no one teaches in a scientifically accepted way what is unknown, it is essential to provide future teachers with didactic and scientific updates, in order to apply correct pedagogical-didactic practices, of experimental nature. This study included 12 future teachers of the 1st cycle of basic education (primary education) and aimed to investigate whether these students were correctly planning experimental activities which should assist in an internship context. The planning of these activities was based on the planning chart used in the Training Program of Experimental Science Education, promoted by the Portuguese Ministry of Education. The results showed that these future teachers acquired in the initial training classes the necessary skills to correctly design and plan experimental activities that would develop in the internship. It seems necessary to include "spaces" in the initial teacher training preparation in order to achieve adequacy in activities of an experimental nature.

Keywords: *initial teacher training, internship, science teaching, experimental work*

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1. Introduction

There have recently been profound changes in the field of education, with implications for initial teacher training. Many of these changes result from commitments made by the Bologna process [3,4]. This change of educational paradigm required a restructuring, pedagogical and curricular adaptation in the development of skills in teacher training profile [8], i.e., concerning professional qualification of teachers [2]. Thus, the process of becoming a teacher began to focus on the acquisition and development of various kinds of knowledge (scientific, pedagogical, didactic, organizational, practical technical), from professional know-how knowledge to learning the teaching process [2,18].

Some changes are necessary in the development of those kinds of knowledge, in training profile and in the concerning professional qualification of teachers. Therefore, in the context of initial teacher education, one should provide future teachers with didactic, pedagogical updates that include not only the theoretical aspect but also the practical side in order to provide them with a broad, consistent range of professional knowledge and opportunities to acquire and develop skills [2]. In this sense, the future teacher can "experience different methods and techniques from those already observed in his former student curriculum and consequently extend the repertoire of experiences that may transfer to teacher performance" [[9] p. 52].

One of the essential skills of teaching practice and, thus, indispensable to develop in future teachers, it is the preparation for the experimental nature of science teaching [5,15] and especially, given the difficulties that teachers have often demonstrated in this domain [12,15,22]. It is within this context that I intended to investigate if a group of 12 future teachers of the 1st cycle of basic education (primary education), after the initial training lessons, in the scope of Science Teaching, adequately planned experimental activities that were given to students in an internship context.

2. The Experimental Work – Experts' Point of View

The demands of contemporary society, in its multiple facets, require citizens to live in various levels of scientific and technological qualification so that they are able to responsibly act in problem solving and decision making [6]. In this context, one of the goals of science education, in elementary education, has been not only the personal training of individuals, but also their preparation for effective, responsible participation outside the academic context [14].

However, this preparation of citizens implies a scientific training which, in turn, demands that we make available to students educational situations that promote critical thinking, which naturally cannot fail to have an impact on science teaching [17]. This way, one must include, in classroom practices, conducive research situations [17] to scientific methodology learning that help the developing of problem-solving skills (knowledge, reasoning, communication, attitudes) that constitute the foundation of a scientific education [6].

One of the best ways to provide students with research situations is to conduct experimental activities, given the diversity of investigative attitudes that are included [5], [12] such as: questioning, predicting, planning, observing, recording, arguing and concluding [13]. However, despite this universal nature evidenced in experimental work [15], this will be more advantageous in the educational process if it enjoys from a proper and reasoned use [16].

Regarding the structure for performing experimental activities (Table 1), take, as an example, the proposal of [13] used in the Training Program of Experimental Science Education (PFEEC) and subsequently by other researchers [7].

Table 1. Main Stages Included in the Planning Chart (adapted from [12])

BEFORE TRIAL		
Exploration Context (EC) (presentation of a contextualized situation)	*Problem Question* (PQ) (question to which the answer will perform the activity)	*Prediction* (P) (students' previous ideas)
TRIAL		
Undertaking the activity (U) (procedures and materials)	*Study Variables* (V) (measured variable; changed variables; controlled variables)	*Reporting of results* (recording the results after observation)
AFTER TRIAL		
Interpretation results (IR) (explanation of results)	*Conclusion* (C) (answer to question problem)	*Learning Assessment* (LA) (placement of new questions)

Therefore, the experimental activity starts with the presentation of a problematic situation (context of exploration), preferably known on the everyday lives of students and that is part of their experiences. From this contextualized situation, one formulates a question (problem question) for which an answer is sought: what one wants to know about the topic under study. Students are asked to express their point of view on the subject (prediction), so that they explain and justify the ideas they already have and that may (or may not) turn out to be confirmed by the experimentation.

Once identified and registered the previous students' ideas, one will move on to the planning stage of the activity to be undertaken. This step includes outlining the procedure itself (*what do we do to get the answer to the question problem*), selecting the required materials (*what will we need*) and defining the variables to be studied, ex:, making a *controlled trial* [13]: "*what we will measure*" (depending variable selected), "*what we are going to change*" (independent variable in analysis); "*what we keep*" (controlled independent variables).

Then, by performing the activity, the student observes the phenomenon or event and records the results, being able to test their predictions and compare them with the observations. Resorting to dialogue, one takes the student to compare the obtained results with their initial ideas, being able to build a new explanation if the results contradict these initial predictions (verification).

To finish up, we draw a conclusion about the content in question - the answer to the question problem (conclusion). It is vital that each activity will conduct an assessment of the intended learning and may include the placing of new questions on the explored theme.

Summing up:

- One of the best ways to develop the scientific competence of students, to deal with scientific subjects and to participate with practical and rational interventions, is conducting experimental work, given the multiplicity of investigative actions that are contemplated [13];
- The period of Supervised Practice Education (internship) can decisively contribute to the acquisition and development of necessary skills to adopt more appropriate and innovative pedagogical-didactic practices in the use of experimental work [20].

3. Methodology

The 12 participants in the study were attending the last year (2nd year) of a course for future teachers of the 1st cycle of basic education (primary education) in a higher education private institution. The lessons included in the initial training, as curricular units, focused on Science Education courses (Pedagogy and Didactics of Science and Pedagogy and Didactics of Science and Mathematics), in a set of 30 hours, based on *Didactic Scripts* (http://www.dgidc.min-edu.pt/), used in the Training Program of Experimental Science Education (PFEEC).

I approached contents inherent to experimental work, aiming to develop essential skills in students that would help them to correctly develop practices with experimental activities. Each of eight trainees designed two experimental activities while the remaining four, due to their participation in other projects, were only able to plan one activity (Table 2).

Table 2. Items Considered in the Planned Experimental Activities

Intern	Year	Activity I	Activity II
E1	2nd	Materials and objects - absorption	Air - weight
E2	1st	Water - floating	Air - pressure; space
E3	4th	Water - dissolution	----------------
E4	2nd	Air - space	----------------
E5	4th	Water - water quality	pH - acids and bases
E6	2nd	Water - state changes	Combustion - oxygen
E7	4th	Electricity - conductivity	--------------
E8	3rd	Water - floating	Air -compressibility
E9	4th	Electricity - conductivity	--------------
E10	4th	Water - dissolution	Air - pressure, space
E11	4th	Static electricity	Electricity-conductivity
E12	3rd	Water - dissolution	Electricity-conductivity

As for the structure for performing experimental activities (20 activities), we took, as an example, a planning framework proposed by [10] (quoted by [13]) and designated as a planning chart. This planning chart includes the different stages needed for the development of experimental activities. The planning charts built by the interns were subjected to an analysis.

4. Results

Almost all steps were contemplated in the planning chart produced by the future teacher participants (Table 3). The only exception was seen in the "*Learning Assessment*" (LA). It was necessary to constitute the subcategory "*not included*" (LA4), because half of the planning charts (50%) presented no proposal to review the learning.

Table 3. Summary of Key Features in the Planning Intership (*n*=20)

Categories	Subcategories	f
Exploration Context (EC)	EC1: Focused on topic(s) to explore through activity	18
	EC2: Extended to other program topics	2
Problem Question (PQ)	PQ1: Taking only into account the *Context of Exploration*	6
	PQ2: Having in regard the articulation with the scientific context	14
Prediction (P)	P1: Examples of possible predictions of students	13
	P2: Box / table to record predictions	9
	P3: Suggested predictions for students to point out	2
Undertaking the activity (U)	U1: Tasks to carry out to obtain necessary data	19
	U2: Suitable material to the activity	19
	U3: Guidance on data to observe/record (frame and/or text)	20
	U4: Precision/accuracy in language giving objectivity	9
Study variables (V)	V1: All possible variables	17
	V2: Some of the possible variables	3
	V3: With language precision and scientific correction	10
Interpreting results (IR)	IR1: The obtained recorded results	10
	IR2: It also allows the comparison of the predictions with the results	10
Conclusion	C1: Direct response to Problem Question	14
	C2: Expanded response plus more info	6
Learning Assessment (LA)	LA1: With applicability in everyday life	4
	LA2: With curriculum content	4
	LA3: With applicability in everyday life and the curriculum content	2
	LA4: Not included	10

These are the following features at each step of the planning charts:

Exploration Context (EC)

Almost all the planning charts (90%) included an "*Exploration Context*" focused only on the topic on which the practical activity was based on EC1. As an example, I refer to a conversation about the possibility of drinking water (or bathing) from different sites (ponds, rivers, fountains, tap, bottled, ...) to explore the topic "water quality".

However, only a few planning charts (10%) presented exploration contexts that were also extended to other program topics (EC2). Included in this type, there is, for example, the history of the "Water Droplet" regarding the water cycle and the properties of water, when, in fact, the subject to explore was the solubility of substances in water.

The "*Exploration Context*" took various forms of presentation: the presentation of a story, drama or to read a text. However, most interns preferred the projection of images, followed by the viewing informational videos.

Problem Question (PQ)

To formulate the "*Problem Question*", most trainees (70%) chose to introduce concepts and/or terms that would direct an activity to the corresponding phenomenon (PQ2). For example: "Does the weight of the object ...?"; "What is the effect of temperature ..." (as in Table 4).

Table 4. Examples of Problem Questions Included in the Subcategory PQ2

Examples
"Does the weight of the object (potato) influence its fluctuation?" E2-I
"What is the effect of temperature on the physical state?" E6-I
"Why do the bodies in the water appear lighter?" E8-I

In the least chosen form (PQ1 - 30%), the language used in the given questions focused only on a case by case scenario, namely that of the “Exploration Context". For example: "which of the papers absorbs..."; "which of the two liquids...?".

Prediction (P)

The presence of the P1 subcategory ("*examples of possible students’ predictions*") stands out (65%) in relation to each of the other sub-categories: P2 ("box/table to record predictions"- 45%) and P3 ("*predictions’ suggestions for students to point out*"- 10%).

Table 5 presents an example of the forms used by the interns to diagnose students’ predictions.

Table 5. Ways to Ask Students for Their Predictions (inserted in subcategory P3

Record your ideas in the following table: We anticipate that... rubbing the object attracts the other because ...	Mark with X
… it’s stronger	
… it produces energy.	
… it’s smaller.	
… it’s thinner.	
… it’s thicker.	
… it’s longer.	

Undertaking the activity (U)

"*Undertaking the activity*" (U) breaks down into four subcategories are related with the "*tasks to do* ..." (U1), with the *"tools ..."* (U2), with the "*data to observe and record* ... "(U3) and with the" *precision /accuracy in language* ... "(U4). All of these items, with particular emphasis on U1, U2 and U3, show quite high percentages (95%, 95% and 100%, respectively) compared with others in different stages of planning.

The "*guidance on data to observe /record*" (U3) is provided in two ways, namely in text and / or chart / table (see the example in Table 6), being the only subcategory present in all of the 20 planning charts.

Table 6. Example of a Table for Recording Observed Data

Records / Objects	Weight	Found that …	
		float	do not float
Very heavy potato	________ g		
Heavy potato	________ g		
Light potato	________ g		
Very light potato	________ g		

Study variables (V)

The "*Study variables*" (see Table 7) are a key feature in the context of experimental work.

Table 7. Examples of Variables Defined in the Planning Charts

Problem Question	Variable	Examples
Does the size and thickness of the object influence in the attraction?	Dependent variable (under analysis)	"The attraction that the balloon and pen apply after being rubbed in small, large, thin and thick papers"
	Independent variable under analysis	"The objects that will be attracted." "Papers of different size and thickness."
	Independent variables to control	"Balloon" "The woollen cloth" "Pen"

It seemed that, for each of the three produced subcategories, the definition *of "all possible variables*" (V1) is what it is present in a greater number of planned activities (85%), followed (50%) by the "*accurate definition of language and scientific precision*" (V3).

In the case of V2 ("*some of the possible variables*"), although the interns (15%) defined the three types of variables (measured variable; changed variable; controlled variables), a complete discrimination wasn't always shown, especially in controlled variables (2 planning charts) and changed variable (1 planning chart).

Interpreting results (IR)

An equal number of interns selected one of two identified formats: one focusing on "the obtained registered results" (IRI) (Table 8) and the other enabling the "comparison of the predictions with the obtained results" (IR2).

Table 8. Example of Interpretation of Results Focused on the Obtained and Registered Results (IRI)

We found that …
-Temperatures of the various samples are approximate (17°C and 18°C)
- Samples 1 and 6 are acidic. - Samples 3, 4 and 7 are neutral. - Samples 2, 5 and 8 are basic. - Samples 1 and 6 show a pH value less than 7. - Samples 3, 4 and 7 show a pH value equal to 7. - Samples 2, 5 and 8 show a pH value higher than 7.
-A base and an acid should not mix.

In some cases, the interns left a box containing two spaces: a space for the placement of predictions and another intended to record the results, thus allowing students to compare predictions and results.

Conclusion (C)

When preparing the "Conclusion" (C), there were two scenarios the conclusions included: "Direct response to Problem Question" (C1), with a dominant presence (70%) (see Table 9 for an example), or "Extensive answer with more info" (C2).

Table 9. Example of Conclusion with Direct Response to PQ (C1)

Problem Question	Conclusion
"What materials are good conductors of energy?"	"In carrying out the activity we can see that not all materials are good conductors of energy. After all the observations, we may assume that materials such as copper, iron, aluminum, coal, etc., are good conductors of energy and materials like rubber, porcelain, string, stone, wood, glass, etc. are not good conductors of energy."

In the case of C2 (conclusions "*with extensive answer with more info*"), one included more information in addition to the response to the *Problem Question*. Take as an example the case that Table 10 exposes.

Table 10. Example of *Conclusion* with Direct Response to Problem Question (C2)

Problem Question	Conclusion
"What will happen to each of the candles in the containers?"	"The different space of permanence in contact with air and oxygen influences the time of candles combustion. The smaller the amount of air and oxygen, the lesser time the candles remain lit. The candle that is in direct contact with air does not extinguish there is always oxygen fuelling her." E6-II

Learning assessment (LA)

The following three types were identified in "Learning assessment": i) establishing connections with the "applicability in everyday life" (LA1 - 20%) (Table 11), ii) taking into consideration the "applicability of curriculum content" (LA2 - 20%), iii) contemplating the "applicability in everyday life and with the curriculum content" (LA3 - 10%).

Table 11. Learning Assessment Example Focused on the Applicability in Everyday Life (LA1)

Programmatic topic	Example
Dissolution	"Margareth went to the doctor who prescribed her some pills for headaches. However, Margareth cannot swallow them. What do you think she can do to solve the problem? " E12-I

Despite the considerable absence of the "*Learning Assessment*" in half of the planning charts, some interns still chose to put it on their lesson planning chart.

To sum up, the items most focused on the procedural aspects of experimental work show considerably higher percentages than most items requiring a high conceptual involvement or the ones dealing with the assessment of students' capabilities in doing experimental work.

Thus, summing up, Figure 1 shows at each step the dominant presence of the following aspects:

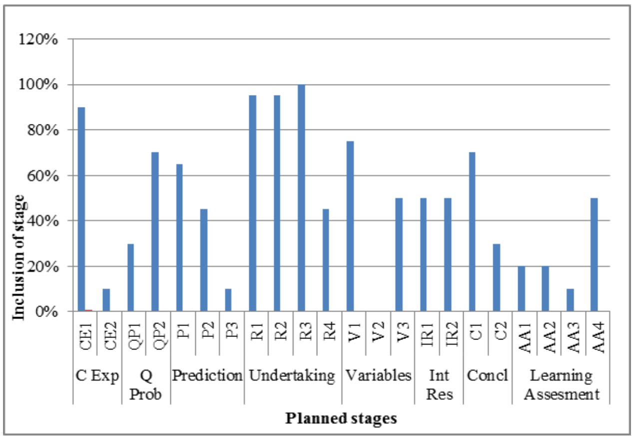

Figure 1. Overview of the Key Characteristics Identified in the Planning of Activities

Context for Exploration (CE1): focuses on exploring the theme (90%);

Problem Question (PQ2): articulates with the physical phenomenon to explore (70%);

Prediction (P1): examples are presented of possible predictions of students (65%);

Undertaking (U1, U2, U3): information is presented, respectively, about *tasks to be done* (95%), *material to be used* (95%) and *data to observe / record* (100%);

Variables (V1): all possible variables to study / analyze (75%) are defined;

Interpreting Results (IR1): in equal numbers - the data obtained is taken into consideration and the comparison of predictions and outcomes is provided (67.8%);

Conclusion (C1): gives an answer to the Problem Question (50%);

Learning assessment (LA2): not in the Planning Charts (50%).

5. Discussion

Considering the obtained results, most interns seemed to show a qualified professional preparation, being able to apply the provided guidelines in the curricular units focused on science education in relation to the process of designing and planning of experimental activities. This was expected, considering that the inicial teacher training is an oportunity to acquire and develop skills [2,5].

All interns were able to draft the planning chart for the activities intended to be developed with students. In these 20 planning charts that were analysed, the interns showed some understanding of the preparation process of each of the stages and could integrate them but bearing in mind that there was some fragility pointed out for the component "*Learning Assessment*".

This may constitute some evidence that, despite being aware that evaluation is an important part of the teaching and learning process (mentioned in the class grid planning) it is not, however, being considered here as an inseparable part of any activity, which, in turn, may have to do with the way one structures the experiential activities given to pupils, which is not always the most appropriate to the desired learning [1].

Although most interns provided appropriate lesson plans, it was noted more security and ease in the design of the items that provide greater procedural involvement by students (for example: U1, U2, U3) and some difficulty in the formulation of the aspects that require greater conceptual involvement (for example: IR2, C2, LA1). Such procedure was expected, at least in part, if we consider the opinion of experts, quoted above [1,15], in which teachers tend to focus on the procedural aspect - "*hands on*" - in detriment of the conceptual aspect - "*minds on*".

6. Conclusions and Implications

The results indicate the following:

All interns were able to draft the planning chart for activities intended to be developed with students;

The majority of lesson plans were well structured, presenting articulation and sequentiality between the different steps and scientific appropriate language to the chosen topic. However, it was noted some language inaccuracies and/or sentence construction, which, in no way, alter its meaning and correctness (for example, R4, V3);

The revealed superficiality in planning some steps is more noticeable on items that require greater conceptual involvement, such as IR2, C2, LA, LA3. This finding suggests that the activities that interns will develop with students, based on these planning charts, will possibly also experience a reduced degree of openness **[11]**.

The "*Learning Assessment*" (LA) was the most absent step in the planning chart;

The lessons performed during initial training seemed to have contributed to develop, in this group of future science teachers, the essential skills in the conception/planning of experimental activities.

The conclusions of this study reinforce the need of a good initial training, taking into account not only the multifaceted nature of teaching activity, but also the difficulties that teachers often have in the use of experimental work [22].

Since teachers are direct intermediaries in the educational process, it becomes necessary to include in initial teacher training, similar to what was done in this study, "spaces" of awareness to deal with in the most appropriate manner with the experimental work in science classes that are going to teach in the future. In fact, there is a tendency for teachers to teach students through the methods they used while they were students themselves [19]. Future teachers can, thus, become more able to deal with the processes of design and structuring experimental activities.

On the other hand, the strong socializing power of the workplace [8] may exert a less favorable influence on future teachers, which makes it advisable to adapt the education of teachers to create opportunities and provide resources to improve the quality of their performance.

If "... the quality of teaching and learning outcomes is closely linked with the quality of the educators and teachers' qualifications ..." [4], then we must continue to invest in training future teachers, so that they develop the necessary skills to the adoption of more appropriate practices associated with the design and structuring of the experimental activities.

This whole range of considerations may be considered from the ideology that [[21], p. 37] argue regarding the training of teachers and that translates into principles, such as: i) improving the pedagogical-didactic content knowledge; ii) integration of theory and practice; iii) creating opportunities for the trainee teacher to question their own conceptions and practices. In this framework, the initial teacher training can be particularly valuable, in the sense that it can provide an opportunity to experience innovative appropriate resources and strategies, transferring them to teacher performance [2].

References

[1] Abrahams, I., & Reiss, M. (2010). Effective practical work in primary science: the role of empaty. *Primary Science*, 113, 26-27.

[2] Cachapuz, A. (2009). O Processo de Bolonha e a formação de professores: dilemas, realidades e perspetivas. *Revista Brasileira de Formação de Professores*, 1 (2), 104-117.

[3] Diário da República – I Série n° 60 (24-03-2006). Decreto-Lei nº 74/2006 de 24 de Março. Lisboa: Ministério da Educação, 2006.

[4] Diário da República – I Série nº 38 (22-02-2007). Decreto-Lei nº 43/2007 de 22 de Fevereiro. Lisboa: Ministério da Educação, 2007.

[5] Dillon, J. (2010). Effective practical science. *School Science Review*, 91(337), 36-39.

[6] Figueiroa, A. (2007). As Actividades Laboratoriais e a Explicação de Fenómenos Físicos: uma investigação centrada em manuais escolares, professores e alunos do Ensino Básico. Tese de Doutoramento (não publicada). Braga: Universidade do Minho.

[7] Figueiroa, 2012 Figueiroa, A. (2012). *Trabalho Experimental em contexto de Prática de Ensino Supervisionada.* Trabalho de investigação de Pós-Doutoramento (não publicada), Universidade de Aveiro.

[8] Flores, M. A. (2010). Algumas reflexões em torno da formação inicial de professores. *Educação,* 33 (3), 182-188.

[9] Formosinho, J. (2001). A formação prática de professores. Da prática docente na instituição de formação a prática pedagógica nas escolas. *In* Campos, B. (org.). *Formação profissional de professores no ensino superior*. Porto: Porto Editora, 46-64.

[10] Goldsworthy, A., Feasey, R. (1997). *Making Sense of Primary Science Investigations.* Hatfield: ASE.

[11] Gunstone, R. (1991). Reconstructing theory from practical experience. *In* Woolnough, B. (Ed.). *Practical Science.* Milton Keynes: Open University Press, 67-77.

[12] Harlen, W. (2010). The royal society's report on primary school science. *Primary Science*, 115, 25-27.

[13] Martins, I.; Veiga, L.; Teixeira, F.; Tenreiro-Vieira, C.; Vieira, R.; Rodrigues, A., & Couceiro, F. (2007). *Educação em Ciências e Ensino Experimental*. (2ª edição). Lisboa: Ministério da Educação – DGIDC.

[14] Martins, I. *et al.* (2011). A Química nos primeiros anos de escolaridade em Portugal. A dissolução em líquidos e o trabalho investigativo. *Educació Química EduQ*, 8, 35-43.

[15] Millar, R. (2010). Analysing practical science activities to assess and improve their effectiveness. The Association of Science Education. University of York.

[16] Millar, R. & Abrahams, I. (2009). Practical work: making it more effective. *School Science Review*, 91 (334), 59-64.

[17] Pereira, S.; Rodrigues, M.; Martins, I. & Vieira, R. (2011). Pre-school science education in Portugal: teacher education and innovative practices. *The Journal of emergent science*, (1), 23-31.

[18] Ponte, J. (2006). Os desafios do Processo de Bolonha para a formação inicial de professores. *Revista da Educação, 14* (1), 19-36.

[19] Porlán Ariza, R., & Martín Del Pozo, R. (2004). The conceptions of in-service and prospective primary school teachers about the teaching and learning of science. *Journal of Science Teacher Education*, 15 (1), 39-62.

[20] Vieira, R. (2010) (Coord.). O programa de formação de professores do 1º ciclo do ensino básico – ensino experimental das Ciências. Aveiro: Universidade de Aveiro.

[21] Vieira, R., Tenreiro-Vieira, C., & Martins, I. (2011). A Educação em Ciências com Orientação CTS: Atividades para o Ensino Básico. Porto: Areal Editores.

[22] Woodley, E. (2009). Practical work in school science – why is it important? *School Science Review*, 91 (335), 49-51.