VIEWS OF A GROUP OF PRE-SERVICE SCIENCE TEACHERS ON THE USE OF EXPERIMENTAL ACTIVITIES IN SCIENCE TEACHING

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Abstract

Teachers often consider experimental activities to be fundamental to the teaching of scientific concepts. However, there are different views about their purpose in science classes; these views are linked to teachers' different understandings of the construction of scientific knowledge. It was analyzed the views of 19 pre-service science teachers (PST) on the use of experimental activities in science classes. These PSTs were enrolled in the subject of science teacher training course of a Brazilian federal university. In their course work, the PSTS were organized into groups and they participated in a pedagogical activity during which they reported their views on two experimental scripts. They answered questions about how they would use these experiments in the future. The activity occurred in two stages: the first was before studying texts on the nature of science with an emphasis on the role of experimentation in the foundation of hypotheses; the second stage was after this. The data analysis was performed using the content analysis technique. The results suggest the importance of debates and deep themes in training courses for science teachers, so that experimental activities are not seen reductively and only as ways to motivate classes or to complement theory, but rather as potential aids in the construction of scientific meaning.
Keywords: *experimental activities, nature of science, teacher education.*

Introduction

Scientific knowledge can be built in different environments, such as a laboratory. In laboratories, scientists make analyses and look for means to explain phenomena. Lab experiments correspond to one of the procedures used by scientists to elaborate their explanations. In school environments, however, experiments are seen as fundamental to natural science classes such as chemistry, physics and biology. However, their use is often linked to proving theories, thus strengthening the idea of a unique and rigid scientific method.

Much research has presented experiments as themes of interest: Hofstein and Lunetta (2003), Mamlok-Naaman and Barnea (2012), Mumba, Mejia, Chabalengula and Mbewe (2010), Reid and Shah (2007) and Toplis and Allen (2012) discussed the context and importance of laboratory work and its role in teaching; Cossa and Uamusse (2014), Antúnez, Pérez and Petrucci

(2008) and Dikmenli (2009) examined teachers' conceptions about experimental activities or laboratory work; Guimarães (2009) and Ferreira, Hartwing, and Oliveira (2010) discussed strategies for the development of experimental activities. Some researchers have pointed out that science teachers often believe in the use of experiments to prove in practice concepts studied in theory (Gonçalves & Marques, 2013; Kang & Wallace, 2005; Silva, Machado & Tunes, 2010). Such an idea may have arisen from the professional training courses themselves or through the planning and development of theoretical and practical disciplines.

Arruda and Laburú (2009) highlighted teachers' answers to the question: *what is the function and importance of experimental activities in science?* They categorized the results in three types: epistemological, which involves understanding the experimental activity as a way of proving a theory and suggests a traditional view of science; cognitive, which involves understanding experimental activities as facilitators of learning concepts; motivational, which involves using these activities to increase interest in learning (p.61). Hodson (1994) also presented categories for the use of experimental activities, including the teaching of laboratory techniques, the development of skills and the creation of "scientific attitudes" (p. 300). These different ways of understanding the purpose of using experimental activities in science teaching created the motivation for this research.

According to Galiazzi and Gonçalves (2004), teachers and students generally present a simplistic view of experimentation based on observations followed by theorization. In this sense, studying the nature of science is a relevant contribution "because this knowledge influences student learning in experimental activity" (Galiazzi & Gonçalves, 2004, p. 327). Deep discussions of this theme with pre-service science teachers is an important action in teacher training courses, given that teachers' conceptions of the use of experiments in science classes will influence how they teach.

Based on all these initial considerations, an educational intervention with pre-service science teachers was designed to assist and promote their reflection on the pedagogical meaning of experimental activities in science teaching.

The present research aims to identify how a group of pre-service science teachers at a Brazilian federal university conceive of the use of experimental activities in science classes. To accomplish that, a pedagogical activity was organized as part of an elective subject in an undergraduate course attended by the pre-service science teachers. This subject focused on the nature of science to help reformulate pre-service science teachers' conceptions about the construction of scientific knowledge.

Two questions emerged as a focus of research: (1) Does the study of the nature of science contribute to the understanding of the role of experimental activities in the construction of scientific knowledge? (2) How do the pre-service science teachers conceive of the use of experimental activities in science classes? The answers to these questions reveal important ideas that can contribute to the planning of pedagogical activities for science teachers.

Theoretical Framework

The discussions with the PSTs were based on the study of the nature of science with contributions from the history, philosophy and sociology of science. This formed a theoretical framework for the elaboration and planning of activities using an explicit and reflexive approach (Abd-El-Khalick & Akerson, 2009). The PSTs had constant opportunities (along with the course's activities) to reflect on their own ideas. Some aspects were commonly discussed, including the dynamic character of science, the historical context in which science has been constructed, the image of the scientist and the relationship between science and society. It is possible to consider that these discussions influence the formulation or reformulation of views regarding the role of experiments in science teaching**.**

In general, teachers understand experimental activities as fundamental to science teaching and they justify this position through different points, such as: the experiments attract the students' attention and are motivators of learning; they help to show in practice what has been studied in theory; they facilitate understanding of the content (Silva, Machado & Tunes, 2010). Such justifications suggest a lack of understanding of the idea that experiments can help students to elaborate and test hypotheses, thus constructing meanings about the phenomenon under study. Experimental activities are part of the process of building scientific knowledge, so there must be a link between theory and practice.

In order to promote this link, inquiry-based experimental activities have been gaining ground in discussions on the role of the experiment in science teaching. Some studies have discussed such activities. Mamlok-Naaman and Barnea (2012) present a case of curricular modifications in Israel in which inquiry-based laboratory activities were included. Furthermore, in their study involving resident scientists (MSc and PhD students) and teachers, Mumba, Mejia, Chabalengula, and Mbewe (2010) discuss the levels of inquiry-based laboratory activities. As Azevedo (2004) argues, "student action should not be limited to the work of manipulation or observation, it must also contain characteristics of a scientific work: the student must reflect, discuss, explain, report, which will give her/his work the characteristics of a scientific inquiry" (p. 21).

From this perspective, students are not limited to the simple execution of a previously established script, but can begin to reflect on the whole process, reporting and arguing about their observations actively by proposing possibilities for resolution of a problematic situation studied. Although there are distinct ways of developing an activity with an inquiry-based character, there is a consensus of their importance in science education.

According to Zômpero and Laburú (2011), besides being used for learning conceptual content, inquiry-based activities allow the development of procedural content. Also, in addition to these two aspects, it is worth mentioning that attitudinal content can also be developed during these activities, since it is possible to encourage the valuation of collective work, for example, by showing the importance of listening and hearing, sharing ideas and making decisions together.

Inquiry-based experimental activities, according to Zômpero and Laburu (2011), have as main objectives the development of students' cognitive abilities, the accomplishment of procedures such as hypothesis elaboration, annotation and data analysis and the development of argumentative capacity. These activities all start from problematic situations by which the students, through the teacher's mediation, may become interested, develop skills related to concepts, procedures and attitudes and actively participate in them.

Methodology of Research

General Background

The research was carried out during an elective subject of a natural science teacher training course at the Federal University of São Paulo in the first semester of 2015 (from March to May). This was in the context of a project developed in the course, called "Projeto Zero", that involved discussing actions and projects based on the collaboration of researchers from different research areas with the aim of improving the quality of basic teacher education. This qualitative research analyzed pre-service science teachers' (PSTs) understanding and knowledge of the nature of science through activities planned with an explicit and reflexive approach (Abd-El-Khalick & Akerson, 2009). It is important to understand PSTs' conceptions about the role of experimental activities in science teaching.

The pedagogical activity was carried out in two stages: the first occurred at the beginning of the course and the second occurred after the PSTs participated in the research and discussed

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texts on the nature of science (the dynamic character of science, the work of the scientist, inquiry-based experimental activities, the social role of science, etc.). The PSTs performed the activity in five groups (indicated by G1 to G5 – G: group) because of the limited amount of material available for the practice.

The group work allowed the sharing of opinions and disagreements. Not only is group discussion considered important in teacher education, it also promotes the understanding that science happens collectively. The results allowed an understanding of how the PSTs construct ideas about the role of experimental activities in teaching.

Sample

The pedagogical activity was carried out by 19 pre-service science teachers (number of PSTs enrolled according to their own interest, because the elective subject was not obligatory). In this university, the natural science teacher training course lasts for four years. In the first half of the course, PSTs take basic and general subjects; in the second half, PTSs select their specialization area from four fields: physics, chemistry, biology, and mathematics. These PSTs' specialization areas were: physics (four PSTs), chemistry (two PSTs) and biology (thirteen PSTs). This classification was random, since the PSTs chose to study the subject according to their interest in the themes studied. Each PST voluntarily participated in the research after signing a written consent form and receiving information about the research goals.

Instrument and Procedures

First stage

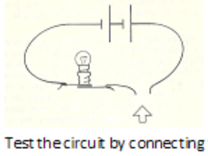
In this stage, two experimental scripts were prepared along with a previously-defined sequence that the PSTs would follow. The first script (experimental activity 1), showed in the Figure 1, focused on materials' electrical conduction and the second script (experimental activity 2) focused on material density. These themes were chosen because they included subjects that comprise the natural sciences curriculum.

Script 1 - The electrical conduction of materials

Objectives
- Experimentally demonstrate the electrical nature of the metals
- Relate the electrical conductivity of the metals to their atomic structures

Materials
- Two batteries – 1.5 V
- Two battery holders
- Four pieces of copper wire, approximately 300 mm in length
- One 2.5 V lamp
- One socket
- Objects of iron, copper, zinc, aluminum, and other metals, and alloys, plastics, rubber, wood, etc.

Procedure
- Mount the circuit as shown in the figure, leaving it open



- Test the circuit by connecting the ends of the wires. If the lamp does not light up, check the connections.
- Close the circuit by placing one of the objects in the location indicated by the arrow. Does the lamp turn on?
- Test the others objects and describe the results.

Figure 1: Excerpt of the script (experimental activity 1).

At the end of each script was the following question (indicated by Q1 - Q: question): *If the group were to teach a science class that involves the theme* [of the experiment], *how would you use experiments in that class?* The objective of the question was to identify how the students understood the experimental class (whether it was a demonstration of the theory, a strategy to attract students' attention, or a proof of the theoretical class).

At the end of the activity, after the two experiments were performed, another question was asked: *For the group, what is the role of experimental activities in science classes?* (indicated by Q3) The aim of this question was like that of the first: the PSTs should express their ideas about the role of experimentation in teaching.

Second stage

In the second stage of the activity, which occurred after the study and discussions of texts on the nature of science, the same experimental scripts were distributed. Since at this stage the PSTs had already discussed the concept of inquiry-based experimental activities, the following situation was proposed to them: *Based on the classroom discussions about the process of constructing scientific knowledge, how can the group turn this script into an inquiry-based activity?* The objective of this question (indicated by Q2) was to identify if the PSTs understood inquiry-based activities as important aids to students' creation of hypotheses, besides instigating logical reasoning and argumentation. At the end of the activity, the question was asked again: *For the group, what is the role of experimental activities in science classes?* The objective of repeating this question from the first stage of the activity was to identify changes in the PSTs' views on experimental activities.

Data Analysis

The groups' answers to the questions in the two steps were analyzed. For this, the content analysis technique was used (Bardin, 2011). This technique involves breaking up a given text into units to identify the different nuclei of meaning that make up the text, then grouping these units into categories. In this research, qualitative analysis was used from the responses produced by the groups. After several readings of the group descriptions, phrases that indicated the PSTs' views on experimentation were selected. From this selection, certain categories emerged from the data of these specific PSTs' groups. Two classes of categories were elaborated - one involving Q1 and Q2 and the other involving Q3. The categories were based on similar meaning in the PSTs' responses, and they were grouped by common characteristics identified.

Results of Research

The first part of the results analysis refers to the questions asked at the end of each script: *If the group were to teach a science class that involves the theme* [of the experiment], *how would you use experiments in that class?* (requested in the first stage) and *Based on the classroom discussions about the process of constructing scientific knowledge, how can the group turn this script into an inquiry-based activity?* (requested in the second stage, after the study of the texts). Q1 indicates the first question and Q2 the second question for each experiment. The purpose of these analyses was to identify if the proposals presented an inquiry-based approach. Table 1 shows the identified categories. The groups were grouped into G1 to G5.

For a better understanding of the categories that emerged from the groups' responses (Q1 and Q2), it was adopted the following description:

Sequential approach - This category is composed of proposals that began with theoretical content that was later developed into an experimental activity (either carried out by the students or demonstrated by the teacher).

Mixed approach - This category is composed of proposals that presented ideas about problematic situations and included discussions of the theme, but also contained some characteristics of the sequential approach.

Inquiry-based approach - This category is composed of proposals that presented problematic situations that encouraged students to elaborate hypotheses about possible solutions. The experimental activity was intended to assist the discussion of such hypotheses.

Table 1 shows the approaches that were identified from the groups' responses for experimental activity 1.

Table 1. Approaches identified in the groups' proposals - experimental activity 1.

Proposal	Experimental activity 1 - Q1 (groups)	Experimental activity 1 - Q2 (groups)
Sequential approach	G1, G3, and G5	No group
Mixed approach	G2 and G4	G1, G3, G4, G5
Inquiry-based approach	No group	G2

Similarly, Table 2 shows the approaches that were identified from the groups' responses for experimental activity 2. There are some similarities between the two tables regarding the data. For example, no group indicated the sequential approach for Q2; instead, the popularity of the mixed approach increased significantly.

Table 2. Approaches identified in the groups' proposals - experimental activity 2.

Proposal	Experimental activity 2 - Q1 (groups)	Experimental activity 2 - Q2 (groups)
Sequential approach	G3 and G5	No group
Mixed approach	G2 and G4	G1, G3, G4, and G5
Inquiry-based approach	G1	G2

The second part of the analysis refers to the general question (Q3): *For the group, what is the role of experimental activities in science classes?* (for both steps). The groups' responses were analyzed and found to contain descriptions of various purposes. Considering Silva, Machado, and Tunes' (2010) study on the role of experiments in science classes, categories were elaborated, as are presented in Table 3.

Table 3. Categories for the general question (Q3).

Category	Description	frequency
Proof of theory	The experimental activity (practical part) proves the theoretical content studied previously.	G1, G3, G5
Skills development	The experimental activity assists in the development of cognitive and procedural skills.	G1, G4
Importance of collective work	Experimental activity values teamwork, as scientists do in the construction of science.	G1, G2
Motivation for learning	The experimental activity facilitates learning and draws the attention of students, making the lesson more interesting.	G1, G2, G3, G4, G5

The responses with the highest frequencies were "proof of theory" and "motivation for learning." It can also be noted that the groups indicated more than one category to explain their ideas.

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Discussion

The analyses, presented in Tables 1 and 2, showed that in experimental activity 1, before the study of the texts, three groups' proposals were classified as sequential (G1, G3, and G5), two groups as mixed (G2 and G4) and no groups followed the inquiry-based approach. After the discussion of the texts, in the second stage of the activity, there was a notable change: no groups had a sequential approach, four groups were mixed (G1, G3, G4, and G5), and one group had an inquiry-based approach (G2). A similar situation can be observed in relation to experimental activity 2. In the first part of the activity, two groups were classified as sequential (G3 and G5), two groups as mixed (G2 and G4) and one group as inquiry-based approach (G1). After the study of the texts, no groups had a sequential approach, four groups were mixed (G1, G3, G4, and G5), and one group had an inquiry-based approach (G2).

The results of the answers for the two experimental activities point to a gradual change in the starting frame, in which the groups that had initially presented a more sequential approach started to think about the activity in a mixed way by considering the importance of discussions on the studied phenomenon and adding research features to proposals. This change evidences a reformulation of the initial ideas after discussing texts, sharing issues that involve the nature of science, and learning of the process of constructing science. Excerpts from the responses of G1 and G5 exemplify these results:

Brief presentation - examples of daily life presented by students and guided by the teacher (observation, hypothesis). Experiment manipulated by students to develop manual skills [...] (G1 - experimental activity 1 - Q1).

Students have to write down the situations in which the lamp lights up. Later they check on a periodic table for common characteristics of materials that can cause the lamp to light ...[...] (G1 - experimental activity 1 - Q2).

In the first part of the activity, G1 presented an account that suggests a sequential approach that emphasizes observation, hypothesis, and a teacher orientation. Experiments would be used for the development of procedural aspects and not for relating to the scientific concept involved. In the second part of the activity, G1 reported a proposal that contains some elements of inquiry, such as the fact that the students stop being spectators and move to a more active position of observing the process, recording their observations, and making comparisons with existing data (properties of elements of the periodic table).

We would use the experiment to demonstrate the difference in density and mass of materials... (G5 - experimental activity 2 - Q1)

[...] *The experiment would become a research activity where students begin to perceive and identify the different characteristics in the most varied types of materials present in nature.*
[...] *Students would answer questions such as: Why do materials have different masses, densities, and volumes? Is there a proportional relationship between these physical quantities? Why does it happen? (*G5 - experimental activity 2 - Q2).

In the first part, G5 presented a sequential approach in their proposal. In the second part, an inquiry-based approach was not clear in the answer, but G5 presented words that suggest a change and highlighted skills such as perceiving and identifying, as well as questions asked of the students.

These changes suggest that the PSTs reflected on the role of experimental activities when considering the nature of science promoted by the course texts and discussions. The groups, in general, included in their proposals characteristics of inquiry-based experimental activities, such as those discussed by Azevedo (2004) and Zômpero and Laburu (2011), such as problematization to involve experiments, the development of important skills like observing, recording, comparing, testing hypotheses, and arguing, and attitudes that give the activity an active and participatory character.

With respect to the general question formulated in the two stages of the activity, it can be observed that the experimental activities had several attributed purposes (Table 3). For example, comparing Tables 1 and 2 shows that G3 and G5 presented proposals in a sequential approach before the texts and discussions on the nature of science and, after that study, presented proposals classified as mixed. G3 and G5 indicated, for Q3, that one of the purposes of experimental activities is proving theory, which seems to agree with a more sequential approach. Such a view was also indicated by Arruda and Laburú (2009) when, in their study of teachers, they identified epistemological, cognitive, and motivational characteristics regarding the purpose of experimental activities in science. Also, Dikmenli (2009), in his research on pre-service biology teachers, identified views about the purpose of laboratory work, including "verifying facts and principles already taught" (p. 6). Kang and Wallace (2004) carried out an analysis with three high school science teachers about the use of laboratory work and indicated similar views: that it is effective in proving "the verity of the scientific knowledge" and "the explanatory power of scientific theories" (p. 148).

The PSTs provided some examples of such ideas:

To approach the student of science, facilitating his/her understanding of the matter, because the lesson leaves the theory and goes to the practice. (G3 - Q3 - stage1)

Experimental activities allow students to interact with the theoretical content applied in the classroom, in addition to facilitating the students' understanding of certain content. (G5 - Q3 - stage 1).

In the second part of the activity, for the general question, G3 mentioned the importance of promoting discussions with students about the phenomena observed, but a proposal of articulation between theory and practice was not clear. G5 pointed out that experimental activities are illustrative in order to facilitate learning:

The experiments serve to bring the student's daily life closer to science, to demonstrate concepts, to promote discussions about observed phenomena, and to help students understand the content studied. (G3 - Q3 - stage 2)

[...] *The experimental activities in classes represent an illustrative way of explaining scientific phenomena; they are for students a means of understanding in a physical and visual way, and thus facilitate learning.* (G5 - Q3 - stage 2).

It is important to highlight that laboratory work helps with skill development, but students need a teacher to guide them, since only executing the procedure without reflecting on the whole process may not lead to the understanding of scientific concepts in students.

In addition, it is interesting to note that all groups indicated that experimental activities are potential motivators of learning, as they illustrate, arouse students' interest, and can facilitate learning. These visions accord with reflections already presented in research on the same theme (Arruda & Laburú, 2009; Gonçalves & Marques, 2013; Silva, Machado & Tunes, 2010, Kang & Wallace, 2004). The motivation to learn is an important product of experimental activities; however, the main objective corresponds to the opportunities for students to construct meanings about studied concepts. In this sense, it is important for teachers to think about the question: Can student motivation be influenced by the way experimental activities are planned and developed?

The result of the activity carried out with the pre-service teachers was that discussion about the role of experimental activities in science classes should be continuous. The process of reformulating ideas did not happen only with a developed activity. This process is dynamic and is the result of other activities that can be carried out during education and in professional training. Ultimately, the pre-service teachers showed efforts to rephrase their views regarding the use of experimental activities in teaching.

Conclusions

The analysis of the responses in the two stages of the activity suggest changes in the PSTs' initial views; the reading of texts and classroom debates contributed to these changes. In this sense, the study of the nature of science and the construction of scientific knowledge created a broader understanding of the use of experimental activities in science teaching. It is emphasized, however, that the PSTs' reformulation of ideas was a gradual process that began in the science teaching course and will continue in their professional careers. The PSTs pointed out several purposes for experimental activities, but they did not indicate a single role. In some of the groups' reports, there was a reformulation of views in the sense of greater articulation between theory and practice. Other reports, however, showed the need to deepen the study of the subject.

The aim of the present research was reached because it provided the PSTs with the opportunity to study and discuss the nature of science and the role of experimental activities in science teaching. An important result of this research is that the discussion about the nature of science can assist in rethinking ideas about the use of experimental activities in science education. A possibility for future studies is to examine how experimental activities are developed in training courses and the trends of approaches to such activities.

Finally, it is possible to consider that discussions about the nature of science influenced the PSTs' views of the role of experimental activities. In this sense, it is necessary for science teacher training courses to develop teaching strategies so that pre-service science teachers can explain their thoughts, learn to construct pedagogical activities with a more inquiry-based character, and reflect on the science that they wish to teach in order to they feel more secure in the planning of their future pedagogical activities.

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