Representations of “laboratory activity”, “experimental activity” and “practical activity” constructed by master’s degree students

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Abstract

This work aims to identify and analyze how the terms "laboratory activity", "experimental activity" and "practical activity" are differentiated by a group of 26 students of a master's degree course in science education. The research is justified by the recognized polysemy of the terms and the centrality of these activities for science education in school. The thematic content analysis of Bardin was used as a methodology to fulfill the research objectives. The master students’ answers to a diagnostic questionnaire were classified in four categories: "undifferentiated"; "local of the activity"; "student role" and "scientific level". In general, master students’ do not use abstract criteria, theoretical or related to the nature of scientific knowledge, to differentiate the terms. The focus of the statements were, overall, the aspects of the pedagogic practice. The result indicates the need for closer dialogue between research and teaching.

Keywords: laboratory activity; experimental activity; practical activity; teacher training; content analysis

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Contextualization and research question

Experimentation has always been present in discussions about science education. Fensham (2004), analyzing pioneering research of the science education area, asserts that they were made both by researchers from scientific areas and by high schools teachers interested in their practice. He emphasizes that at this time the debates, themes and interests of studies were preferentially those directed at teaching through experimentation, a way to obtain learning.

These aspects about the history of science education show a direct relation between the practice of teaching science and the practice of scientific knowledge production.

Therefore, discussing experimentation in science education, although not new, is part of the constitution and the consolidation of knowledge in the area. In this way, we reach the following research question: how do students in master’s degree courses differentiate the terms laboratory, experimental and practical activity?

The context of this research is a master's degree course in science education, specifically a diagnosis made by one the authors of this article in a discipline she teaches, one of the, first disciplines, that is part of the course. That fact leads to believe that the master’s students (MS) had not yet accumulated the reflections of other curriculum disciplines, but that the representations they have at that moment were based on their own pedagogic practice. In order to make the diagnosis, the students answered the following question: what differences do you see between laboratory activities, experimental activities and practical activities? The answers to this question given by the 26 MS were the empirical material of the research.

The above terms are polysemic and their multiple meanings are related to different ideologies that are present in the history of science education. Thus, the assigned meanings are related to multiple factors, some more local and others more global, and include: the school's material conditions; the curriculum; the representation of science; the nature of social relations etc.

In addition to the distinctive meanings assigned to the same term, it is important to draw attention to the terminology used in different countries. The study of Lunetta (1998) pointed out that the researchers in the USA employ the term "laboratory work" while Europeans prefer "practical work" to denote similar activities. As Hofstein and Kind (2012) cited Hegarty-Hazel (1990): “A precise definition is difficult because these terms embrace an array of activities in schools, but generally, they refer to experiences in school settings in which students interact with equipment and materials or secondary sources of data to observe and understand the natural world.”(p.189)

The researchers cited above conducted a literature review using, interchangeably, the terms "practical work" (common in the UK) and "laboratory work" (common in the USA) and observed that in the last 50 years there have been three major periods concerning different approaches to experimental practices in the USA and the UK:

(1) 1960s to mid-1980s “unfulfilled ideals”,

(2) mid-1980s to mid-1990s “the constructivist influence”,

(3) the last 15 years "the new area of change" (Hofstein and Kind, 2012, p.190).

During the first period ("Unfulfilled ideals") some curriculum changes took place, based on the renewal of science education guided by the logic of scientific production processes (emphasis on empirical method). In this period the educational strategies were supported by cognitive psychology which emphasizes the development of the student’s scientific thinking. The reform of the curriculum, made by the Nuffield Foundation of England marked this period, also influencing other countries of the British Commonwealth and of the world.

The second period, "The constructivist influence", included two challenges. One was to establish a pedagogy that would enable the development of student’s conceptions, and as in the previous period, many practices were focused on the handling of equipment and materials. The other challenge was the development of a theoretical basis to support a new perspective on science education, i.e. constructivism. As pointed out, both challenges were issues that were strongly related to the structure of the knowledge area of science education. In Brazil this period was quite similar.

The third period called "The new area of change" marked a more radical change in the goals of science education due to the recognition of the straight relationship between our lives and scientific and technological knowledge. This relationship became even more evident with the expansion of globalization and agile technological development. In this sense, according to Hofstein and Kind (2012, p.194), "we observed internationally that there has been a high frequency of curriculum reforms. A central point has been to make science education better adapted to the needs of all citizens”. In this period, the practice of science education emphasizes the scientific investigation as a complex cycle, including from research questions to reporting results. The focus on the individual student is shifted to the relationship between the students, using social interactionist approach.

Indeed, the Brazilian context was marked by the international scene and had begun to make changes in its curriculum policies during the three periods that were previously described. During the 1960s, Law 4.024 - Education Guidelines and Foundation, from December 21st 1961, extended science education in the curriculum in order to develop critical thinking through the reproduction of the scientific method in school activities. In the 1970s, under the military regime, a new law was formulated (the Law of Directives and Foundation of Education No. 5692/1971) and science education turned its focus to professionalization.

Despite this new guideline, the schools kept science education focused on preparing students for university life. At that time, the Brazilian Institute of Education, Science and Culture and the Brazilian Foundation for the Development of Science Education played a central role in the production of teaching resources that were supported by laboratory teaching, performing translations and producing adaptations of foreign materials. Other projects introduced were: science clubs, science fairs and the training of teachers for the use of kits for experimental classes.

Brazil restarted a democratization process in 1985 and, in that decade initiated a strong emphasis on the training of researchers. The experimentation in science education became a subject and also a target of criticism. This criticism was because of the stress given to handling equipment in contrast to the investigative capacity of students.

In dialogue with international research based on constructivist theory, the student’s role in learning, especially the ability to progress from common sense to scientific thought, was introduced. Apart from this, many practices persisted in classrooms that focused on experimentation in different forms.

In the mid-1990s there were new changes made in the national education policy (The Law of Directives and Foundation of Education No. 9394/1996), as well as the development of National Curriculum Standards (1996). These educational reforms in the Brazilian educational system were once more related to the international context. There were also conditions set by the World Bank (BIRD) and the International Monetary Fund (IMF) to release credit.

The documents of this period, which are still valid, emphasize the importance of forming critical citizens although this is not very clear throughout the documents. In certain sections of the document, which define the scientific content/curriculum, the main arguments turn to learning based on logic and sequential transmission and only little to an investigative attitude of the students. It is observed therefore that this reform relates to the second and third periods cited by Hofstein and Kind (2012).

Research in science education has been established as a strong area in Brazil since the mid-1990s and, in dialogue with international research, has reformulated experimentation in school through investigative approaches. However, such practices are not widespread in schools, and in general, science education in Brazil is done preferentially by memorization, without an experimental tradition in classrooms. The reasons related to this situation are not only linked to poor infrastructure but also to curriculum decisions that do not introduce experimental activity as a structuring component of science education (Marandino, Selles and Ferreira, 2009).

These aspects, beyond being present in the research of the science education area, also have a strong influence on teacher training and textbooks. This means that there are different kinds of texts, circulating in the schools and universities, carrying different ideologies, institutionalizing the production of science education. These texts were probably appropriated by science teachers and are part of their social horizons.

This does not always determine the teacher's representation of science teaching, since other aspects, as for example the relationship with the students or the material contexts of teaching performance also contribute to compose the elements that give meaning to a social practice.

Given the polysemy of the term, both in policy, curriculum and research, it is not in the interest of this study to determine how the activities in classrooms should be focused on experimentation, laboratory and / or practice. The objective of this study is to understand the way in which MS, in undergoing training, build representations in relation to these activities and, consequently, on the nature of science education and of science itself.

Methodology

The methodology used was thematic content analysis of Bardin (1977). The procedures used in this methodology can be quantitative and/or qualitative. In this research we chose the qualitative aspects, in order to understand the meanings involved in students’ answers to a diagnostic questionnaire. For this, the "record unit" of the study is the sentence containing reference to the terms that we are analyzing. The steps in the analysis (categorization, inference, description and interpretation) are not a sequence to be followed, but imply adjustment processes involving back and forward movements. The following items explain the steps of the research.

Floating Reading

"Floating reading" represents one of the first steps of the thematic content analysis, which enables the initial contact of the analyst with the documents to be analyzed in order to get "impressions and guidance" (Bardin, 1977). At this stage, the analyst begins to formulate guiding questions and creates categories of analyses through the location of themes recurring in the documents.

Development of Units of meaning

Empirical data were initially identified through an electronic search conducted by the Microsoft Word program tools. Keywords used were: "laboratory", "experimental activities" and "practical activities". This procedure allowed us to develop a " units of meaning " based on the identification of words associated with these keywords, and subsequently gather record units that refer to the same sense cores. Thus, the results of the "units of meaning" in the categories for the classification of statements, are presented in Table 1.

Descriptive and interpretative synthesis

The organization of data in "units of meaning" requires an exhaustive reading of the data in order to understand the relationship of words that structure the statement to the particular social practice. This involves the interpretation of the theoretical constructs about science education from what was said by the MS student. From these units of meaning it is possible to organize themes for the discussion of the empirical data.

Findings

Units of meaning

From the exhaustive reading of the data and supportive research texts in science education, we organize the way in which teachers differentiate the laboratory activities, experimental activities and practical activities, in the following four categories: "undifferentiated" (4); "local of the activity" (9); "student's role" (8); "scientific level" (10). It is important to know that some teachers used more than one criterion and therefore the sum of the number of statements in each category do not match the total number of participants. The table below describes the units of meaning with an illustrative example.

Table 1: Units of meanings: categories

Units of meaning	Example
Undifferentiated	I do not see much difference between laboratory activity, experimental activity and practical activity. All are held to be a practice in teaching that will require a techno-scientific knowledge that is more far-fetched and more laborious. (MS10)
Local of the activity	Laboratory activities refer to any experiment or practice in place which is conducive to their realization (MS01)
Student's role	Activities of small laboratory experiments in which students will put into practice what he/she saw at school. (MS06)
Scientific level	Laboratory activities would have a more accurate character and must follow a set of rules to be realized (MS02)

These units of meaning were derived from the answers of MS and are not mutually exclusive, because the criteria used to define the "laboratory activity" were not always the same as the ones to define "experimental activity" and/or "practical activity". In the example below, this characteristic is evident in the formulation given by the MS.

Laboratory activities involve precision instruments and measurements, as well as more controlled conditions. Experimental activities can be done outside the laboratory, closer to the students, but with some kind of instrument. Practical activity could be, for example, carried out without tools and without much methodological accuracy, i.e., a practical activity constructed with pupils. (MS15).

In the answer above we mainly noted terms associated with the scientific level of the activity, by which a representation of science based on technical accuracy can be assumed instead of a building process. This can also be identified from the relationships made by a student, because the presented line of argument assumes that the lower degree of accuracy of the activity will be the result of the (level of) participation by the student. By the other hand, in order to explain what experimental activity is, the MS use as a criterion just the local where the activity can occur.

Units of meaning give us an overview of the main directions related to the subject and, from these, we made a new reading of the data in order to produce more broad thematic categories, which we will use to build a synthetic interpretation of the data.

Description

The statements classified as "undifferentiated" are the following identified affirmatives: "are synonymous; there's no difference; these terms are mixed; I do not see much difference." Three of the four answers use the idea that all activities facilitate student learning as a (main) criterion. In general, these MS do not see epistemological differences for different activities, showing little reflection about the nature of scientific knowledge in the teaching of science education at school.

The statement classified as "activity of the location" used the following terms for laboratory activities: "suitable place; place specifically prepared; physical laboratory space". The practical activities were associated with the following terms: "different natures; other places; non-formal spaces; room or multidisciplinary laboratories". In case of experimental activities associated terms were: "room environment; laboratory; room or multidisciplinary laboratories; alternative places; classroom". Generally, these kinds of answers indicate that the idea of laboratory activity does not occur in school environments or are linked to the specific context of academic research.

The statements classified as "Student's Role" gave centrality to the student's active role when they referred to the "experimental activities" by the terms "like dialogue, interaction, knowledge of trading". On the other hand, the "laboratory activity"-category was practically not related to the active role of the student, pointing to a view of science where the laboratory activity is a use of an existing method to be followed.

The statements classified as "Scientific level" presented the level of technical and methodological refinement of each activity as criteria. They described the activities of more specific techniques and laboratories, using terms such as, for example, "more rigid (accuracy) character; rules; Chemistry and Physics; controlled; technical procedure". The experimental activities in this category are associated with the words: "investigative character; daily; playful; cheap materials". As for the practical activities, we identified: "without instruments; any practice; movie; game". Such answers refer to a scientific representation of knowledge production and application of the scientific method and specific procedures.

In this category, several MS attribute a more scientific nature of the activity to the methodological accuracy and experimental evidence. These attach to "dialogue, interaction and negotiation of knowledge", a lesser degree of methodological rigor. These statements also bring to light a relationship between the level of interaction that the student will have with the activities and the degree of specificity of activity.

Interpretative summary

Differences or indifference guided by the notion of the empirical scientific method

In general, the answers of MS point to a representation of science education based partially on the apprehension of methods and techniques, i.e. regarding an operational scientific work. Indeed, the kind of activity to be developed by the students in the classroom was related to assumptions about the production of scientific knowledge. The representation that laboratory activities are purely mechanical tasks without space for dialogue prevailed. These representations seem to disregard the relationship that the work in the laboratory has with the community of peers. Disregarding the active role of the scientist, they do not consider the processes of research that have been included from the literature search to the communication of the research results, all of it referring to the subject of study. Some answers indicate a possible lack of philosophy and sociology of science rather than knowledge based on the scientific work stereotypes.

Many answers were based on the correlation between the degree of science in some activity and the interaction level, in other words, the student's role in the learning process. According to these answers the sense is that the greater the degree of specificity of the activity, the less autonomy the student will have in its development. This view is rather curious because the formation of a scientific culture requires the development of autonomy in questions of production processes, responses and conducting activities. The meaning attributed to the production of scientific knowledge returns to the approaches identified with the teaching by rediscovery, typical of the period between the 1960s and 1980s (Unfulfilled ideals). These kinds of ideas were used in particular to describe "laboratory activities" while a closer sense of the typical constructivist approaches of the 1980s and 1990s (The Constructivist Influence) would describe "experimental activities" and / or "practical activity". Below we illustrate these senses from some excerpts from answers given by the MS.

The first example provides evidence of the representation in a science based on technique and logic. The MS10 chooses not to differentiate between the terms once they consider that both have the same function; to "be a practical teaching". According to the example (MS10), see bellow, the result of any of these practices is "an elaborate technical and scientific knowledge" and "efficient." The nomenclature applied in their answers indicates a view of science as a technique, a simple mechanical action, resembling the educational representations present in the period called "Unfulfilled ideals" (Hofstein and Kind, 2012). These were strongly guided by the empirical method and by the representation that it is possible to learn scientific content by repetition of the scientific method. Applying the method is understood as "to do science", excluding all cultural aspects related to scientific production.

I do not see much difference between laboratory activities, experimental activities and practical activities. All are held to be a practice in teaching that will take a more far-fetched techno-scientific knowledge. The practice leads to efficiency. Through the errors it is possible to redo and have adjustments. (MS10)

The second example illustrates this thematic synthesis where the MS’s representation expresses an affinity for the empirical science and the activities performance by the students do not have "methodological rigor". The representation, which combines methodological rigor to measuring instruments and control conditions, indicates the representation of knowledge production as a method and not in the methodological design process and negotiation with the community of peers.

Laboratory activities involve precision instruments and measurement, as well as more controlled conditions. Experimental activity can be done outside the laboratory, closer to the students, but with some kind of instrument. Practical activity could be, for example, carried out without tools and without much methodological rigor, i.e. a practical built on pupils. (MS15)

The two examples used to illustrate this thematic were mobilized to demonstrate that approaches identified with periods ranging from the 1960s to mid-1990s (Unfulfilled ideals and the Constructivist Influence) still strongly guide the repertoire of these MS who are largely, science teachers. This fragment of reality we investigated indicates that the paradigmatic turn in the scientific vison and its teaching, which is being built in the academic field, was still not appropriate by these MS.

Differences or indifference guided by pedagogical objectives

Another set of responses can be considered as belonging to this thematic. It includes pedagogical criteria and learning objectives as meaning an element construction for the "laboratory activity", "practical activity" and "experimental activity". It will be possible to observe in the examples, that there is an emphasis on the student’s role in learning and the proximity to ideas that circulated in the first and second periods described by Hofstein and Kind (2012).

Nevertheless, the fact of the central argument being the process of knowledge construction indicates that MS know that science taught and made in schools should be invariably different to the science produced in academic contexts. This difference does not lead to science education unrelated to academic science, but a practice that hybridizes educational and scientific objectives.

In the first example, the criteria used to describe differences between the "experimental activity" and "practical activity" was "cognitive conflict". This approach, which is very strong in teaching experimentation in science, recognizes the student's role in the construction of knowledge; however, it individualizes this process and disregards the role of language in this process. Despite this difference, the MS believes that both practices "require the participation of the students". On the other hand, the sentence about "laboratory activity" was made in an inaccurate way by the verb “can be”, "can be activities that only demonstrate theories studied in the classroom."

Another differentiation criterion can be identified by the words "demonstration" and "to demonstrate theories", indicating the representation that laboratory activity would be more related to scientific knowledge than the others.

I understand that the experimental and practical activities require the participation of students with the difference that the experimental activity should generate a conflict in the student to seek answers to the observed, while the practical activity can only be demonstrative. Laboratory activity can be activities that only demonstrate theories studied in the classroom. (MS09)

According to the second example, the principal issue is not differentiation. This example varies from the others in two aspects (i) it indicates the difficulty to rigorously define a nomenclature; (ii) it brings centrality to the work of the student and the student's self-reflection process with regard to the learning process. Regarding the first aspect, the representation was constructed by the recognition of the semantic field, in other words, they don’t see much differentiation in the meaning of words. The literature of the area, as presented earlier in this article, indicates that the terms "laboratory activity" "practical activity" and "experimental activity" are synonyms. Although used as differentiation criteria of physical space in the answers, they demonstrated that the development activities could occur in any kind of space. Thus, the strongest sense is limited by the teaching practice in pedagogic goals that will be drawn regardless of how the activity is named. Besides this, the centrality in self-reflection is explicit in this answer: "our students realize when stimulated" demonstrating understanding that the process of building knowledge should also be aware of the student.

The differences between laboratory activities, experimentation or practical activities are more in the environment in which they operate than the very semantic context. (...) It is necessary to break free of certain labelling that the teacher himself imposes. By giving the necessary approach to the experiential moments of the student, it is possible to obtain three types of activities. Non-formal spaces teach science, such as exhibitions and historic sites. The practical activities exist with or without labelling. Our students realize this when stimulated. (MS11)

This thematic axis exhibits similarity with respect to the student's central role in teaching and learning processes. Thus, we affirm that for some teachers what is at issue is the pedagogical objective, i.e., what will be developed in learning with the student.

Following are some conclusions based on the study we developed with this group of teachers who are in an educational training process.

Conclusions/Implications

In Brazil, the terms "practical activity", "experimental activity" and "laboratory activity" as stated by Marandino, Selles and Ferreira (2009) may be confused. It is important to understand that the experimental activity has an active and a practical feature, but not all activity developed in the classroom can be considered as experimental activity for the simple fact that it occurs in a science lesson. The practical, experimental or laboratory activities in science classes should ensure typical characteristics of scientific culture. Thus, practical activity in science class can’t be watching a video, as some MS said.

Laboratory activities also vary widely according to the specific academic science. In this sense, nuances exist between the various epistemological bases that support the production of knowledge in the sciences, which should be considered in teaching and learning science. For example, knowledge production in biology may also involve field work to collect material; the construction of zoological and botanical collections; screening work etc. These activities are not more or less scientific than biochemical analyses, for example, because there are many ways to produce scientific knowledge. However, people still have a picture of scientists as white European men wearing lab coats and carrying test tubes.

Our research participants showed little emphasis on epistemological aspects in their answers, indicating directions based on concrete aspects, practical and from common sense. This feature of the answers indicates a greater use of knowledge built in other areas, such as in teacher performance.

This feature reveals the necessity to think of training teachers to establish a dialogue between the most current theoretical perspectives of science education and knowledge circulating in different sources of training for our students in elementary/ school. This dialogue involves bringing not only the analysis of academic texts, but also educational policies, texts of major media and school materials and various materials that talk about science to training practices and to then rethink the way we build on science and ways of teaching.

Finally, we wonder if the key is the name given to the activity or the directions of science and science education that they produce.

References

Bardin, L. (1977). Análise de conteúdo. Lisboa: Edições 70.

Barolli, E.; Laburú, C. E.; Guridi, V. (2010). Laboratorio didáctico de ciencias: caminos de investigación. Revista Electrónica de Enseñanza de las Ciencias, Vigo, v. 9, n. 1, p. 88-110.

Fensham, P. J. (2004). Defining an identity: the evolution of Science Education as a field of research. Dordrecht: Kluwer Academic Press.

Hofstein, A., and Kind, P.M. (2012). Learning in and from science laboratories. In B.J. Fraser, K.G. Tobin, and C. J. Mc Robbie (Eds.), Second international handbook of science education (pp. 189-207). Dordrecht, the Netherlands: Springer.

Lunetta, V.N. (1998). The school science laboratory: historical perspectives and contexts for contemporary teaching. In K.G. Tobin and B. Fraser (Eds.), International handbook of science education (pp. 189-207). Part
I. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Marandino, M., Selles, S.E., and Ferreira, M.S. (2009). Ensino de Biologia: histórias e práticas em diferentes espaços educativos. São Paulo: Cortez.