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What are scientific practices and why are they relevant in science education?

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ABSTRACT

Scientific Practices have been a central theme of recent educational reforms in Science Education in the United States and the interest in this theme has also reverberated in research in Science Education, becoming a topic with international repercussion (Europe, South America, Asia, Oceania and Africa). The objectives of this article are to: 1) To present the concept of Scientific Practices according to the main international theoretical references for the subject; 2) To discuss the eight Scientific Practices and their relevance for Science Education; and 3) to establish possible connections between the idea of Scientific Practices and the discussions exposed in national documents in the area of Natural Sciences. For that, this article is guided by a theoretical-conceptual research, in which the references of Scientific Practices were studied, aiming to identify, know and monitor the development of the theme in a certain area of knowledge. The results of this research point out the main perspectives of conceptualization of Scientific Practices and insert the theme in national educational discussions in Science Teaching; they present reflections about the importance of the eight Scientific Practices for learning in Science and how they can favor the construction of a more contemporary view of Science; and indicate connections between some specific Scientific Practices and discussions exposed in national documents. The discussions in this article seek to contribute to: strengthen debates on the topic nationally; reflect on the relevance of the theme for Science Education; and keep up with the growing interest in research involving Scientific Practices.

KEYWORDS: Scientific Practices. Science Education. Learning.

INTRODUCTION

This paper resulted from some research developed in a Master's program (COSTA, 2021) with the following objectives: I) to identify the main characteristics of publications involving scientific practices; II) to identify what is understood as scientific practices as proposed by the authors of such publications; and III) to identify the context in which research was developed in those publications. The characteristics of the publications mentioned refer to the following aspects: authors, institutions, continents, countries, period of publication, methods, levels of teaching, areas of knowledge, journals, and main references. For a better understanding of the term 'scientific practice', the articles were surveyed to extract aspects expressed by the authors regarding the definition they adopted. The research context provided an image of 'what' or 'who' was related to the scientific practices.

Based on the analysis of articles, we obtained an operational definition of scientific practices, considering common elements among the understandings proposed by the authors in the publications analyzed:

> [...] we understand that scientific practices are similar to the activities developed by scientists to build up knowledge, theories, and models of the world. Students' direct involvement in scientific practices allows them to build up a more complete view of what science is and of the work developed by scientists. In this perspective, not only do students learn about science, but they also have the opportunity to take part in processes of 'doing' science (COSTA, 2021, p. 93).

Within this research context, it seems relevant to emphasize that the theme scientific practices has also been object of study of other investigations. Broietti, Nora and Costa (2019) investigated the potential of the PISA (Program for International Student Assessment) test questions to involve students in specific scientific dimensions, including scientific practices, in another study, Nora and Broietti (2022) reported the results of an investigation in which they identified and analyzed evidence of scientific practices in teacher's actions in chemistry classes, to create a profile of the classes investigated.

The relevance of the theme addressed in this article, is justified by the importance given to scientific practices in science teaching in recent international education reforms such as A Framework for K-12 Science Education (NRC, 2012) and the Next Generation Science Standards (NRC, 2013), which highlight scientific learning objectives or targets that the students must achieve and be able to perform in each school year guided by scientific practices.

The systematic review carried out by Costa (2021) in papers addressing scientific practices in the area of science teaching published in international journals between 2010-2019 on the data bases: ERIC, Scielo, Scopus, and Web of Science provides a general view of the characteristics of those studies, the understandings of scientific practices exposed by the researchers, and the contexts in which the research was developed.

Among the characteristics identified, Costa's (2021) results showed that 40.9% of the publications surveyed were produced outside the United States, including countries such as Spain, England, Brazil, Turkey, The Netherlands, Australia, South Africa, Cyprus, Sweden, Norway, and Finland. This reveals global interest in the theme in research on science teaching and the applicability of the concept of scientific practices into other contexts, making it a theme of collective and global relevance.

Thus, the main objectives of this study were:

1) To introduce the concept of scientific practices, according to the main international theoretical background focusing on the theme;

2) To discuss the eight scientific practices and their relevance for science teaching;

3) To establish possible connections between the idea of scientific practices and the discussions found in national documents in the area of natural sciences.

The discussions proposed seek to strengthen the debate around the theme within the country, to reflect upon the relevance of this theme for science teaching and to keep up with the growing interest in research involving scientific practices.

SCIENTIFIC PRACTICES IN SCIENCE TEACHING: CONTEXTUALIZING THE THEME

In 2012, the National Research Council published a structure for science teaching in basic education named A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC, 2012). The document aimed to set new indicators for science teaching at the elementary and high school levels, which is part of a movement started to strengthen the science teaching national documents in the United States since the mid-1990s. Such indicators involve learning objectives or targets that describe what students must know and be able to do in each school year. The results of recent research on science teaching and learning were also vital in the formulation of that structure, since they contained a review of the existing indicators aiming at revitalizing science teaching.

According to the NRC (2012):

> The overarching goal of our framework for K-12 science education is to ensure that by the end of the 12th grade students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussion on related issues; are careful consumers of scientific and technological information related to their everyday lives, are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (NRC, 2012, p. 1).

That document shows an organization supported by a rich and growing collection of studies on science teaching and learning and is based on three dimensions: I) Central ideas, consisting in specific content and theme areas; II) Scientific practices, presenting activities developed by scientists and engineers to build up knowledge, theories, and models of the world; and III) Crosscutting concepts, which are the main ideas underlying several topics in sciences.

The document discusses the main gaps found in science teaching in the United States such as, 1) the lack of an organization in science teaching throughout the school years; 2) the emphasis on covering a lot of content without considering its depth; and 3) students are not provided with real opportunities of experiencing how science is really developed (NRC, 2012).

Considering the flaws listed above, we observed that these challenges are not only found in the United States. Some national studies have reported similar challenges faced by science teaching, which will be presented later.

A document published by the Brazilian Academy of Sciences (2007), discusses the need for improvement in the basic teaching in Brazil, mainly science teaching. That document emphasizes that science teaching must stimulate logical reasoning, curiosity, and help to educate individuals that are better able to face the challenges of contemporary society. The same document presents some diagnosis and possible problems to be tackled.

Another study in the same perspective is the article put forward by Junges and Espinosa (2020), which questions the role of science teaching in the XXI century, more precisely due to the social and environmental challenges posed by the different socio-scientific issues (QSCs) of this century. In that paper, the authors discuss how students can deal with the scientific dimension of QSCs, interpreting consensus, disagreements, arguments, and statements with scientific content presented by the scientific community or by an individual scientist.

SCIENTIFIC PRACTICES IN NATIONAL RESEARCH

In the Brazilian context, studies related to scientific practices are still relatively scarce. In a search on the CAPES Journal Portal webpage inserting the terms "Scientific Practices" and "Science Teaching", in peer-reviewed journals, only 13 results were obtained (search carried out on 1st June 2021). This demonstrates a field that is still open to investigations. From that search, followed by the reading of excerpts containing the term 'scientific practice' in the respective publications, we observed a diversity of understandings by the authors regarding this term meaning and use. These will be discussed below.

Schiffer and Guerra (2019) adopted the historiographic background of the Cultural History of Science (CHS), which:

> [...] recognizes that science is permeated by values historically built [...], so that its practices are dynamic, historically contextualized, and therefore, change with the time and space in which science is developed [...] (SCHIFFER; GUERRA, 2019, p. 96).

Those authors explained that CHS originated from the critique and epistemological structural analysis of the scientific activity, through the study of scientific practices that constitute the scientific endeavor. Therefore, these practices are not limited to laboratories, for instance, but rather include:

> [...] the language used by scientists [...], theoretical tools [...], the use of communication and dissemination mechanisms [...], ways of constructing the critique and legitimization of the community production [...] (SCHIFFER; GUERRA, 2019, p. 96).

Thus, those authors understand scientific practices as complex and diverse, not only limited to the tasks accomplished in laboratories. Moreover, they consider that:

> Scientific practices are not only understood as the laboratory practice or the in loco practices developed by agents called scientists, but they are also made up by a wide range of activities in different spaces such as the laboratory or the field, and in the dissemination, communication, and legitimation of knowledge. Despite not being unique and universal, scientific practices show some regularity and are basically characterized by the constant process of assessment and critique of the explanations provided by science [...] (SCHIFFER; GUERRA, 2019, p. 98-99).

In the excerpt above, the authors describe the complexity of the term and the different spaces in which these practices can be developed. Other conceptions of scientific practice were also found, as for example:

> [...] scientific practices are not restricted to performance abilities such as the handling of instruments and variables, interpretation of data and graphs, but rather to the association between these performances and the cultural and socio-institutional factors that can produce valid meanings within the scientific community (MOURA; GUERRA, 2016, p. 734).

For those authors, the concept of scientific practices covers other spheres that go beyond what they call "performance abilities". Thus, they highlight the importance of considering the contextualization of such practices in relation to society and culture. Silva, Silva and Kasseboehmer (2019), consider that scientific practices comprise some inherent processes such as creativity, autonomy, and doubt, which are not always understood by students. As a result, "students know little about the nature of sciences, including the scientists' work routine" (SILVA; SILVA; KASSEBOEHMER, 2019, p. 360).

Although those papers do not mention the NRC – National Research Council – documents, we considered that there are points connected to that reference such as the engagement in practices that go beyond the laboratory environment, better understanding of the science nature, and the "scientists' work routine", as well as the reference of that work routine, which are in agreement with some of the scientific practices defined in the NRC (2012).

Variations of the term scientific practices were also found in some national papers. Sasseron (2021), for example, employs the term practices of science. That author refers to the conceptions of scientific activity presented by anthropologists, philosophers, and sociologists to discuss the practices of science focusing on the laboratory work. According to Sasseron (2021), those practices can be transferred to the school reality, mainly when the investigative method of teaching is adopted:

> The development of actions in which concepts, processes, and practices can be worked collectively can be related to ideas that support the activities described by the investigative teaching, that is, activities in which students are engaged with the resolution of a problem, building up work plans, collecting and analyzing data, identifying relevant variables, and building up explanatory models for the situations investigated (SASSERON, 2021, p. 4).

On the other hand, national studies using the term scientific practices without conceptualizing it were also found. In fact, this was observed in most of the publications surveyed in the first search. This revealed the use of this term linked to the common sense. In such context, in this paper, we present a concept of scientific practices adopted in several international studies and that has been the focus of some national studies previously mentioned.

METHODOLOGY

Considering the objectives set for this article, we adopted a theoretical-conceptual methodological approach. According to Miguel (2007), a theoretical-conceptual study:

> [...] is a discussion resulting from literature analysis, raising a series of relevant issues for the planning and conduction of a case study. It is not exactly a literature review, but it presents elements that could lead to this classification, since one of the functions of this study is to identify, learn about, and follow the development of research in certain area of knowledge (MIGUEL, 2007, p. 217).

The development of theoretical-conceptual research might result from conceptual discussions of literature or bibliographic reviews. In this sense, the discussions found in this article result from a broader systematic review of literature developed in a Master's program. The review by Costa (2021) analyzed 44 articles addressing scientific practices in the area of science teaching published in international journals of this area in the 2010-2019 period, which were available in 4 data bases (ERIC, Scielo, Scopus and Web of Science). The issues guiding the search were: 1) What are the characteristics of publications addressing scientific practices? 2) What understandings of scientific practices are expressed in those publications? 3) What were the contexts in which the authors carried out research involving scientific practices?

The systematic review produced significant results regarding the characteristics of those publications, the understandings of scientific practices expressed in those publications, and the research contexts in which those publications involving scientific practices were developed (COSTA, 2021).

SCIENTIFIC PRACTICES AND THE NRC DISCUSSIONS

The NRC is part of the National Academies of Sciences, Engineering, and Medicine of the United States. Those Academies are private, nonprofit institutions that provide specialized consultancy on some of the most urgent challenges faced by the country and by the world. The main aims of the Academies are: to help to structure concrete policies; to inform public opinion; and to advance in the science, engineering and medicine search.

Documents such as the NRC (2012) and the NRC (2013) present greater emphasis on science learning along the school years, focusing on the students and guided by scientific practices, crosscutting concepts, and central ideas. Those documents provide definitions to each of the three dimensions and robust discussions about scientific practices and how students can be engaged in them.

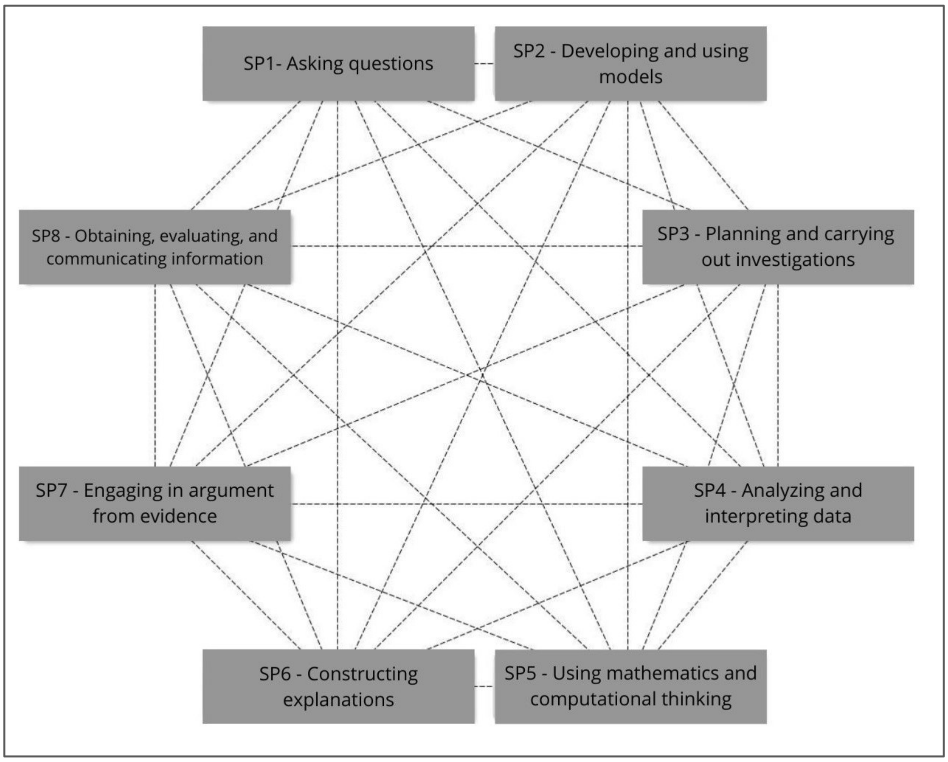
According to the NRC (2012),

> Dimension 1 [scientific practices] describes (a) the major practices that scientists employ as they investigate and build models and theories about the world and (b) a key set of engineering practices that engineers use as they design and build systems. We use the term "practices" instead of a term such as "skills" to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice (NRC, 2012, p. 30).

By articulating scientific practices as the central element of science learning, NRC seeks to specify what is understood as investigation in science and the variety of cognitive, social, and physical practices that it requires. This approach is justified by the fact that students cannot understand scientific practices or fully appreciate the nature of scientific knowledge without experiencing the practices directly.

The eight scientific practices (Figure 1) (SP1, SP2, SP3, SP4, SP5, SP6, SP7, and SP8) are considered essential in science learning by the NRC (2012) and NRC (2013). Our choice to represent these practices in a diagram, in which they are all articulated, shows the association power of scientific practices and their non-linear nature.

Figure 1 – The eight scientific practices



Source: The authors (2023).

NRC (2012) justifies the use of these practices when teaching science since the acquisition of the abilities involved supports better understanding of how the scientific knowledge is developed. Such involvement with these practices favors the appreciation of several approaches used in scientific investigations and help students to become critical consumers of scientific information. This process might also lead students to notice the creativity involved in the scientists' and engineers' work (NRC, 2012).

NRC (2012) emphasizes the importance of using these practices in an interactive way and in combination since they are not considered a linear sequence of phases to be developed in the order presented. The framework is against the trend of reducing scientific practices to a single set of procedures. For the NRC (2012), understanding science as a set of practices implies the development of theories, reasoning, discourse between peers, development of models, inferencing, observing, and testing hypotheses.

This focus on practices (plural) also helps to avoid the impression that there is a specific and unique approach defined for the whole science, that is, an infallible method. The practices described by the NRC derive from those that scientists and engineers carry out as part of their work, favoring the appreciation of scientists' and engineers' skills, as well as the nature of their tasks by the students. Next, we present more detailed discussions about each of the scientific practices and their relevance in science teaching.

THE RELEVANCE OF EACH PRACTICE: A DIALOGUE WITH THE INTERNATIONAL LITERATURE

PC1: Asking questions

Even before starting elementary school, children need to ask questions about things and people around them. When developing and getting engaged in scientific practices, students are led to develop the ability to ask well elaborated questions about the natural world and the man made or designed world (BYBEE, 2011). Rosenshine, Meister and Chapman (1996) proposed that the act of asking questions helps students to evaluate the main ideas discussed and to verify whether they understood the content. Ford (2008) discussed the importance of questioning and its scarcity in textbooks, since they are full of explanations, but rarely expose the questions that had to be answered to reach such explanations. The study put forward by Osborne (2014) confirmed the importance of scientific questioning in science learning. According to that author, questioning prevents students from acquiring a perception that science answers questions that have never been asked.

The scientific practice of asking questions (PC1) is important for all students, even those that do not want to become scientists or engineers, since "the ability to ask well-defined questions is an important component of science literacy, helping to make them critical consumers of scientific knowledge" (NRC, 2012, p. 54).

PC2: Developing and using models

PC2 is relevant in science teaching for constructing an understanding of models and its role in science helps students to build up and evaluate the mental models of phenomena observed (NRC, 2012). In the early years, the idea of models can be introduced by using pictures, diagrams, drawings, and simple physical models, while, later on simulations and conceptual models can be used to introduce investigations or formulate scientific explanations of phenomena (BYBEE, 2011). Models are important in science due to the need for representation of huge phenomena such as the solar system, the moon phases, and/or the depiction of very small phenomena such as the cell or the atom (GILBERT; BOULTER, 2012).

According to Osborne (2014), another important point in scientific practice is that its objective is not only to develop an understanding of science concepts, but rather to develop a type of metaknowledge of science, that is, the knowledge of specific aspects of science and their role in contributing to the process of knowing what we know. Taking that into consideration, the construction of models helps students to understand that the science objective is not the construction of an image that describes precisely all aspects of nature, but rather the elaboration of a map that captures some aspects better than others (OSBORNE, 2014). This confirms the ideas found in the NRC (2012), which explain the importance of discussing the model and the aspects of the phenomenon highlighted by it, as well as the aspects that the model minimizes or obscures, since all models contain approximations, assumptions, and limitations that must be recognized and discussed with students.

PC3: Planning and carrying out investigations

Over the years, students develop deeper understandings and new skills while they carry out different investigations, use different technologies to collect data, focus greater attention on the different types of variables, and clarify the scientific context of investigations (BYBEE, 2011). However, Watson, Swain and McRobbie (2004, p. 40) verified that the number and quality of discussions about empirical results in the classroom were very low, since many considered scientific investigation as "learning and carrying out a set of fixed procedures", which "could be used repeatedly in the same way in different investigations". This is not the PC3 objective.

Carrying out investigations requires the ability of planning, or even drawing, an experiment or observation able to answer some questioning or test a hypothesis formulated by students (NRC, 2012). Developing investigation requires that students identify relevant variables, choose a type of observation, measure, control variables, and make decisions about several factors such as: what measures should be taken? What is the level of accuracy required? What are the instruments needed to carry out this investigation? (NRC, 2012).

The understanding of the word "investigations" in PC3 might be related to the concept of practical activities, in which variables are handled. In other words, situations in which students are actively involved in carrying out a task, which is not necessarily a laboratory task.

PC4: Analyzing and interpreting data

PC4 can be commonly related to PC3 since when students are involved in investigation, data is produced. At a first glance, data might not express its meaning, thus after being collected it has to be presented in a way that reveals patterns or relations (NRC, 2012). Students can use tables to summarize a large amount of data to make it more accessible, use graphs to visually synthesize data, and mathematics to express the relationship between different data, for example. Modern digital tools such as the interactive whiteboard (LÓPEZ; GRIMALT-ÁLVARO; COUSO, 2018) and apps such as GeoGebra (GREEFRATH; SILLER, 2017) can also be used to arrange data in different ways and promote students' engagement with the analyses.

According to NRC (2012), analyzing helps students to extract meaning from the data and identify its relevance to be used as evidence. Therefore, students need to have opportunities to analyze large data sets to identify correlations, seek outstanding patterns, verify whether the data matches their initial hypothesis, recognize when data conflicts with their expectations, evaluate the power of a conclusion obtained from a dataset, and explore the relations between variables. Osborne (2014) exemplifies this scientific practice with a case involving 6th grade students measuring the water boiling point. The purpose of this kind of activity is considered questionable if used to verify a value that was already accurately determined by somebody else in the past. If used as an activity to develop the skill to handle a thermometer, it is also of low value, since reading a thermometer requires little ability. However, given that the students' reading might vary considerably, one could question how to solve this uncertainty and which methods could be used and would be more suitable in this context (OSBORNE, 2014).

PC5: Using mathematics and computational thinking

NRC (2012, p. 65) discusses that "increasing students' familiarity with the role of mathematics in science is central to developing a deeper understanding of how science works". By using mathematics, variables can be numerically represented, the relations between physical entities can be symbolically represented, and results can be predicted. Strategies and tools such as computational theories, computational technologies, information technologies, and algorithms allow scientists to collect and analyze large datasets, to seek patterns and identify relations, which could not be achieved manually (NRC, 2012). Computational methods also enable the visual representation of data and the exploration of patterns using calculations and simulations.

Wilkerson and Fenwick (2016), reported an example of a classroom in the final years of elementary school, where students employed computational thinking to ascribe meaning to a scientific system. Students were organized in small groups to model evaporation and condensation using computer animation and simulation as representation tools. After the groups had created their own simulations, they were presented to the whole class for deeper discussion.

Other examples of this practice are mentioned in NRC (2013) since they create opportunities for the students to use mathematics to represent physical variables and their relations and produce quantitative predictions. Students are also expected to use laboratory tools connected to computers to observe, measure, record, and process data.

PC6: Constructing explanations

Scientific explanations are reports establishing links between the scientific theory and the phenomenon observed to explain relations observed between variables and describe the mechanisms that support possible inferences (NRC, 2012). "Scientific theories are developed to provide explanations aimed at illuminating the nature of particular phenomena, predicting future events, or making inferences about past events" (NRC, 2012, p. 67). According to NRC (2012), the informal meaning of the word "theory" might be an assumption. However, this is not the case of scientific theories about which NRC reports:

> [...] scientific theories are constructs based on significant bodies of knowledge and evidence, are revised in light of new evidence, and must withstand significant scrutiny by the scientific community before they are widely accepted and applied. Theories are not mere guesses, and they are specially valued because they provide explanations for multiple instances (NRC, 2012, p. 67).

That document also addresses the importance of discussing the concept of scientific hypothesis, which is not a theory or an assumption, but rather a plausible explanation for a phenomenon observed that can predict what will occur at a certain point in time. It is elaborated based on existing theoretical understandings and a specific model for the system.

In a study by Weiss *et al*. (2003), those researchers recognized that students usually receive a lot of explanation given by their teachers, but they are seldom asked to construct explanations themselves. However, studies on cognitive science have addressed the value of constructing explanations in learning. Those studies reported that when students are involved in the elaboration of some explanation, they might come up with an unsuitable explanation, which when followed by reading on the topic will produce a contradiction followed by a cognitive conflict, which provokes reflection.

Thus, engaging students in constructing scientific explanations of the world to help them understand the core ideas that science has developed is a central aspect in scientific education. Asking students to demonstrate their own understanding of the implications of a scientific idea, developing their own explanations for phenomena, either based on their own observations, or in models that were developed, involves them in an essential part of a process through which conceptual change might occur (NRC, 2012).

PC7: Engaging in arguments from evidence

Scientists rely on arguments and reasoning to justify their ideas since, in science, knowledge production depends on a reasoning process that requires a scientist to present a justified conclusion drawn about the world. In response to such justified conclusion, other scientists seek to identify its flaws and limitations. (NRC, 2012).

According to Goldacre (2010), identifying “bad science” circulating on the media and being critical in the evaluation of the validity of “scientific” news is a requirement, not only for scientists but for all citizens. The process of becoming a critical consumer of science is fostered by opportunities of using critique and evaluation to judge the merits of any scientifically based argument.

As pointed out by Ford and Wargo (2011), asking students to engage in arguments demands more advanced cognitive competences such as evaluation, synthesis, comparison, and contrast. Therefore, students must construct scientific arguments and show how they are supported by data; identify possible weaknesses in other people’s scientific arguments; discuss the thinking process and the evidence of students’ arguments; recognize that the main characteristics of scientific arguments are data, evidence, and reasons, along with the ability of distinguishing them with examples.

PC8: Obtaining, evaluating, and communicating information

Contrary to the popular view of scientists as people who spend most of their time "carrying out experiments", Tenopir and King (2004) verified that over 50% of the scientists' time is devoted to scientific reading and writing. This fact confirms the ideas put forward by Jetton and Shanahan (2012) that writing and argumentation are core activities in science development.

Communication using writing or speech is another fundamental practice in science and requires that scientists describe their observation accurately and clarify their thoughts, as well as justify their arguments. For this reason, NRC (2012) recommends that students be involved in critical discussion of texts; use words, graphs, tables, and mathematical expressions to communicate their findings or questioning what they are studying; explain the key ideas of scientific texts; and and read texts containing tables and diagrams.

CONECTIONS BETWEEN SCIENTIFIC PRACTICES AND THE DISCUSSION PROPOSED BY SOME NATIONAL DOCUMENTS

This section aims to establish possible connections between the idea of scientific practices and the discussions proposed by national documents, mainly regarding the area of natural sciences. It also seeks to evidence possible implications and relations between scientific practices and the instructions of such documents.

In the National Curricular Parameters – PCNs –, in the section destined to natural sciences, there is some evidence of an approach, expressed as competences and skills, to scientific practice such as:

> Formulating questions from real situations and understanding questions already asked;
> Developing explaining models for technological and natural systems;
> Using measurement and calculation instruments;
> Search for and systematize relevant information to understand the problem situation;
> Formulating hypotheses and predicting results [...] (BRASIL, 2000, p. 11).

Considering the list above, we observed some agreement between the five pieces of evidence highlighted from the competences and abilities presented in the PCNs and scientific practices. The first, for example, resembles SP1: Asking questions; the second is similar to SP2: Developing and using models; the third is close to SP5: Using mathematics and computational thinking; the fourth refers to SP8: Obtaining, evaluating, and communicating information, more specifically, to obtaining information; while the fifth is close to SP3: Planning, and carrying out investigations.

In the Complementary Education Instructions to the National Curricular Parameters (Brasil, 2002), especially those related to natural sciences, general competences in the learning in this area are detailed.

The competence 'representation and communication' includes the recognition and use of symbols, codes and names of the scientific language in their written and oral forms, whose purposes are similar to those of the SP8, that is, obtaining, evaluating, and communicating information, with greater focus on obtaining information. Likewise, the competence ‘analyzing and interpreting texts disseminated by different media can also be related to SP8. On the other hand, analyzing, arguing, and adopting a critical position in relation to science and technology themes is similar to SP7: Engaging in argument from evidence.

Regarding the set of competences related to investigation and understanding, they include the identification of relevant data and information in problem situations, using proper instruments and procedures to measure, quantify, and estimate, use explaining models from different sciences, which take part in the scientific practices present when planning and carrying out investigations, thus presenting connections to SP3: planning and carrying out investigations.

More recent documents such as the BNCC (BRASIL, 2018), also present some similarities to the idea of scientific practices. As regards learning scientific content, that is, in the area of natural sciences, the document instructs:

> [...] throughout elementary school, the area of natural sciences is committed to the development of scientific literacy, which involves the capability of understanding and interpreting the world (natural, social, and technological), but also transforming it based on the science theoretical background and processes. In other words, learning science is not the final objective of scientific literacy, but rather the development of the ability to act in and upon the world, which is highly relevant to the exercise of full citizenship (BRASIL, 2018, p. 321).

The document refers to the conception of scientific literacy adopted, exposing how important it is for the students to have access to the main processes, practices, and procedures of the scientific investigation, beyond the diversity of scientific knowledge. Such investigation process refers to:

> [...] organizing learning situations from questions that are challenging and, recognizing cultural diversity, stimulate the students’ interest and scientific curiosity, enabling them to define problems, survey, analyze, and represent results, communicating conclusions and proposing interventions (BRASIL, 2018, p. 322).

Some relations can be established with the purposes of scientific practices as discussed by NRC (2012), for instance, promotion of appreciation and interest in science and the scientists’ work. Some references, even if indirect, are also observed to scientific practice such as SP3: planning and carrying out investigations; SP4: analyzing and interpreting data, and SP8: obtaining, evaluating, and communicating information.

Regarding the final years of basic education – high school – this phase is expected to “guarantee the consolidation and deepening of knowledge acquired in elementary school” (BRASIL, 2018, p. 464). Even if limited to aspects of the area of natural sciences, the document reinforces attributions of scientific literacy also mentioned in the previous phase. It defines competences and abilities that enable the broadening and systematization of essential learning referring to the conceptual knowledge of the area, social, cultural, environmental, and historical contextualization of such knowledge, and the processes and practices of investigation, and language used (BRASIL, 2018).

As regards investigation processes and practices, the document explains:

> [...] the investigative dimension of natural sciences must be emphasized in high school, putting students in contact with investigation procedures and tools such as identifying problems, formulating questions, identifying relevant information or variables, proposing and testing hypotheses, elaborating arguments and explanations, choosing and using measurement equipment, planning and carrying out experimental activities and field research, reporting, evaluating, and communicating conclusions, and developing interventions from the analyses of data and information about the theme in this area (BRASIL, 2018, p. 550).

Relations can be established between the purposes of the investigation dimension of natural sciences in high school and scientific practices. The list of verbs presented in the document above shows relations with the specific SP such as "identifying problems" and "identifying relevant information or variables" with SP3: planning and carrying out investigation and SP4: analyzing and interpreting data; "formulating questions" with SP1: asking questions; "proposing and testing hypotheses" with SP3: planning and carrying out investigation; "elaborating arguments and explanations" with SP6: Constructing explanations and SP7: Engaging in arguments from evidence; "choosing and using measurement equipment" and "planning and carrying out experimental activities and field research" with SP3: planning and carrying out investigation; "reporting, evaluating, and communicating conclusions" with SP8: Obtaining, evaluating, and communicating information; and "developing interventions" with SP3: Planning and carrying out investigations.

Although some convergence is observed between the proposals of some of the scientific practices and the discussions about the investigation dimension of natural sciences in high school as observed in the BNCC, some weaknesses have been pointed out by researchers in the area of science teaching regarding this curricular document. Authors such as Franco and Munford (2018) mentioned aspects that range from introducing simplistic ideas of science and scientific work, impoverishment of science-related content; predominance of conservatism in relation to the education articulation process, and absence of references from the education and science teaching research areas, which reveals some tension between the authoritarian discourse of the law and the education science discourse.

Due to the flaws listed, it seems relevant to point out that the emphasis on scientific investigation is essential in the construction and communication of scientific knowledge, so that students can broaden their possibilities of action in the world. In such context, we reinforce the importance of deepening the debate about this theme and of associating additional references that can promote scientific investigation and students' autonomy.

FINAL CONSIDERATIONS

Resuming the objectives proposed in this article, as follows: i) to introduce the concept of scientific practices based on the main international theoretical reference on the theme; ii) to discuss the eight scientific practices and their relevance in science teaching; and iii) to establish possible connections between the idea of scientific practices and the discussions found in national documents in the area of natural sciences, we put forward some considerations resulting from this investigative effort.

Scientific practices are considered to be activities that are similar to those developed by scientists to build up knowledge, theories, and models of the world. Direct involvement of students with scientific practices allows the construction of a broader view of what science is and the kind of work that is developed by scientists. When engaging in scientific practices, students learn about science and gain opportunities to participate in the process of "doing" science and acquiring scientific language.

The understanding mentioned above is aligned with the NRC documents and represents the mainstream understanding of scientific practices in the international research on science teaching (COSTA, 2021). However, as already mentioned elsewhere, national studies using the term 'scientific practices' are still scarce, which opens possibilities for research at different levels and in different contexts.

In fact, several questions about scientific practices in the national context still need to be researched and answered such as 'what kind of scientific practices have been developed in science, chemistry, physics, and biology classes in Brazilian schools?' 'Are Brazilian teachers' conceptions of scientific practices the same as those found in the literature?' 'How have teachers been integrating scientific practices in science teaching?' 'How are students engaged in scientific practices in different school subjects?' 'Do scientific practices differ as a function of the methodology adopted?' 'Does the teachers' initial education prepare future teachers to carry out teaching based on scientific practices?' and 'What are the relations between scientific practices and the ideas defended in national or state documents that guide the curricula?', for example.

The idea of scientific practices is inserted in a broader movement that places students in the center of the learning process and make them 'practice' science, considering that in addition to building up knowledge, students must also develop thinking abilities. The use of more advanced abilities to create, evaluate, and analyze is implicit in the engagement of students with such practices. Helping students to develop scientific practices seeks to help them enhance their abilities of critical and creative thinking that can be transferred to any subject, career, or situation in life.

It seems relevant to emphasize the importance of deeper studies establishing positive/negative aspects of scientific practices with the BNCC, since their implementation in basic education institutions is still quite recent and in some Brazilian states, it has not been concluded yet. Therefore, this is a theme to be explored in further studies.

O QUE SÃO PRÁTICAS CIENTÍFICAS E POR QUE SÃO RELEVANTES PARA O ENSINO DE CIÊNCIAS?

RESUMO

Práticas Científicas têm sido um tema central de recentes reformas educacionais de Ensino de Ciências dos Estados Unidos e o interesse por este tema também tem se reverberado nas pesquisas em Ensino de Ciências constituindo-se como um tópico de repercussão internacional (Europa, América do Sul, Ásia, Oceania e África). Os objetivos deste artigo são os seguintes: 1) apresentar o conceito de Práticas Científicas conforme os principais referenciais teóricos internacionais sobre o tema; 2) discutir as oito Práticas Científicas e a sua relevância para o Ensino de Ciências; e 3) estabelecer possíveis conexões entre a ideia de Práticas Científicas e as discussões expostas em documentos nacionais da área de Ciências da Natureza. Para isso, este artigo é orientado por uma pesquisa teórico-conceitual, na qual foram estudados os referenciais de Práticas Científicas objetivando identificar, conhecer e acompanhar o desenvolvimento do tema em determinada área do conhecimento. Os resultados desta pesquisa apontam as principais perspectivas de conceituação das Práticas Científicas e inserem o tema nas discussões educacionais nacionais em Ensino de Ciências; também apresentam reflexões acerca da importância das oito Práticas Científicas para a aprendizagem em Ciências e como estas podem favorecer a construção de uma visão mais contemporânea da Ciência; e, finalmente, indicam conexões entre algumas Práticas Científicas específicas e as discussões expostas em documentos nacionais. As discussões deste artigo buscam contribuir para fortalecer debates acerca do tema nacionalmente; refletir a respeito da relevância do tema para o Ensino de Ciências; e acompanhar o crescente interesse por pesquisas envolvendo as Práticas Científicas.

PALAVRAS-CHAVE: Práticas Científicas. Ensino de Ciências. Aprendizagem.

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