Submitedd: 29/07/2020 Approved: 04/02/2021
ENSAIO • Research in Science Education | 2021 | 23:e24345
DOI | http://dx.doi.org/10.1590/1983-21172021230104

ARTICLE

ANALYSIS OF ASPECTS OF NATURE OF SCIENCE EXPRESSED BY A TEACHER IN INITIAL TRAINING IN THE CONTEXT OF A CHEMISTRY HISTORY DISCIPLINE

Marcondes Medeiros de Lima[1] • Stefannie de Sá Ibraim[2] • Monique Santos[2]
https://orcid.org/0000-0001-5420-5173
https://orcid.org/0000-0001-5724-993X
https://orcid.org/0000-0001-6042-0312

ABSTRACT
Researchers have emphasized the need for teachers to develop their knowledge of nature of science. Therefore, we investigated the views about science of a pre-service teacher, for such, we identified and discussed aspects of nature of science that were expressed by her in a teaching-learning environment of History of Chemistry explicitly involving discussions about science. Based on field notes and the portfolio written by the pre-service teachers, we identified, from MoSSE v.2, the expression of 23 aspects of nature of science related to the context of the historical cases discussed in the discipline. Finally, we emphasize the need for discussions about science and about History of Chemistry to permeate pre-service teacher education, aiming at the development and mobilization of pedagogical content knowledge, and we discuss the potentials and limitations of using MoSSE v.2 as an analysis tool.

Keywords:
Nature of science; Pre-service Teacher Education; History of Chemistry.

ANÁLISE DE ASPECTOS DE NATUREZA DA CIÊNCIA EXPRESSOS POR UMA PROFESSORA EM FORMAÇÃO INICIAL NO CONTEXTO DE UMA DISCIPLINA DE HISTÓRIA DA QUÍMICA

RESUMO:
Pesquisadores têm ressaltado a necessidade de professores desenvolverem seus conhecimentos de Natureza da Ciência. Diante disso, investigamos as visões sobre Ciências de uma professora em formação inicial, para tal, identificamos e discutimos aspectos de Natureza da Ciência que foram expressos por ela em um ambiente de ensino-aprendizagem de história da química envolvendo explicitamente discussões sobre Ciências. Baseado em notas de campo e no portfólio redigido pela professora em formação, identificamos, utilizando o MoCEC v.2, a expressão de 23 aspectos de Natureza da Ciência relacionados ao contexto dos casos históricos discutidos na disciplina. Por fim, enfatizamos a necessidade de discussões sobre Ciências e sobre história da química permearem a formação inicial, visando o desenvolvimento e mobilização de conhecimentos pedagógicos de conteúdo, e discutimos as potencialidades e limitações do uso do MoCEC v.2 como ferramenta de análise.

Palavra-chave:
Natureza da Ciência; Formação Inicial; História da Química.

1 Universidade de Brasília, Instituto de Química, Brasília, DF, Brasil
2 Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil.

ANÁLISIS DE ASPECTOS DE NATURALEZA DE LA CIENCIA EXPRESADOS POR UNA PROFESORA EN FORMACIÓN INICIAL EN EL CONTEXTO DE UNA DISCIPLINA DE HISTORIA DE LA QUÍMICA

RESUMEN:

Los investigadores han enfatizado la necesidad de que los profesores desarrollen sus conocimientos sobre la Naturaleza de la Ciencia. Ante eso, investigamos las visiones *sobre* Ciencias de una docente en formación inicial, para ello, identificamos y discutimos aspectos de Naturaleza de la Ciencia expresados por ella en un ambiente de enseñanza-aprendizaje de historia de la química involucrando explícitamente discusiones *sobre* Ciencias. Basados en notas de campo y el portafolio redactado por la docente en formación, identificamos, desde MoCEC v.2, la expresión de 23 aspectos de Naturaleza de la Ciencia relacionados con el contexto de los casos históricos discutidos en la disciplina. Finalmente, enfatizamos la necesidad de que las discusiones *sobre* Ciencia y sobre historia de la química permeen la formación inicial, con el objetivo de desarrollar y movilizar el conocimiento del contenido pedagógico, y discutimos las potencialidades y limitaciones de utilizar MoCEC v.2 como herramienta de análisis.

Palabras clave:
Naturaleza de la Ciencia; Formación Docente Inicial; Historia de la Química.

INITIAL CONSIDERATIONS

The objectives in teaching science are guided by social demands within specific contexts (Carvalho, 2013). Thus, the fact that scientific and technological questions are more and more present in our society has pointed out the importance of students learning about the processes of construction, divulgation and legitimation underlying the production of scientific knowledge.

In the last decades, numerous researchers (for example, Moura, Camel, & Guerra, 2020; Osborne & Dillon, 2010) have emphasized the need for including discussions on the nature of science (NoS)[1] in the science teaching area, that is, for introducing discussions on the forms of production of scientific knowledge, the way scientists work and the relationships between society and science. Students are thus expected to be able to learn *about* science in such a way that their capacity to think critically about social matters that run through science is mobilized and/or developed (Allchin, 2013).

Considering this, we point out that the discussion about NoS in class is conditioned to the teachers' knowledge *about* science, since teachers cannot teach something that they do not know (Shulman, 1986). Researchers who have investigated views *about* science in teachers (for example, Guerra-Ramos, 2012; Hanuscin, 2013; Lederman, 2007) pointed out that many teachers have inadequate views.

Guerra-Ramos (2012), for example, identifies teachers' points of view and discusses the impact they have on the way they plan and conduct their teaching. The author highlights the fact that teachers conceive science as being linear, universal and detached from theoretical conceptions and interpretations, that, for them, science teaching is based on simple procedures and directions of construction of knowledge, independent of the objective of the investigation and the major area of study. As a result, the teachers end up contributing to the students' non-theoretical and linear view of science (Gil Pérez, Montoro, Alis, Cachapuz, & Praia, 2001).

We emphasize that in many cases the teachers' inadequate views *about* science result in difficulty in teaching science in a more authentic way, that is, involving various scientific practices, opportunities to evaluate the colleagues' ideas critically, etc. (Osborne & Dillon, 2010). However, during initial teacher training, in general, there are few opportunities for pre-service teachers to participate in discussions on the NoS, to learn scientific concepts from their contexts of production, among other actions that make it possible to learn *about* science (Justi & Mendonça, 2016; Marques, 2015). Thus, when these teachers graduate, they tend to reproduce the model of teaching science they experienced.

Considering the need to include discussion *about* science in teacher training courses, some authors have adopted a line of teaching based on the list of principles of the NoS (for example, Hanuscin, Akerson, & Phillipson-Mower, 2016), which has been largely divulged by Lederman and collaborators (Lederman, 2007; Lederman, Abd-Al-Khalick, Bell, & Schwartz, 2002). Thus, such studies have focused only on the teachers' ideas related to the principles made explicit in the list, namely: scientific knowledge is provisional, has an empirical character, is driven by theories, is a product of human inference, creativity and imagination, and is influenced by the cultural and social context, there are differences between observation and inference and between scientific theories and laws.

This view of teaching based on lists of principles has been criticized, for example, for not considering the existence and the particularities of various sciences (Irzik & Nola, 2011; Matthews, 2012) and for contributing little to the understanding of issues present in society involving science (Allchin, 2011, 2013).

Betting on an alternative approach to lists of principles, researchers (for example, Allchin, 2013; Erduran & Dagher, 2014; Justi & Erduran, 2015; Matthews, 2012) have supported that teaching the NoS should not be *declarative*, but rather *contextualized* and *integrated*, respecting the complexity of scientific activities, or based on similar characteristics between (for example, Erduran & Dagher, 2014).

To this end, Allchin, Anderson and Nielsen (2014) recommend working with investigative activities and contemporary and/or historical case studies. In this study, we focus on historical cases because the study presented was conducted within the history of chemistry (HC) course. According to Allchin (2013), historical cases are those that involve the students engaging in historical issues. These topics must be analyzed not from knowledge available today, but under the light of knowledge that was accepted in the historical context relevant to the issue analyzed in order to understand how ideas have evolved over time.

The introduction of elements related to the history of science in the teaching of science has been reported in various studies in the literature (for example, Allchin et al., 2014; Justi & Mendonça, 2016; Martins, 2006; Oki & Moradillo, 2008). In general, the authors indicate that the introduction of the history of science may: (i) contribute to understanding how ideas develop over time, (ii) enable discussing on how data are understood and theories are formulated, (iii) contribute to understanding how scientific controversies are solved, (iv) favor discussions on the influences of social contexts in the scientific environment, and (v) allow discussions on the role of women in the development of science. Thus, these discussions my contribute to students building a broader view *about* science, learning not only about its products, scientific knowledge, but also about its process of construction, divulgation and legitimization (Matthews, 2012).

In order to contribute to discussions about NoS in teacher training courses and to promote discussions on advancing teachers' knowledge of NoS in initial teacher training, the contributions of the history of chemistry teaching-learning context and about how to analyze ideas *about* science expressed in the teaching context, we seek to answer: What aspects related to the nature of science are expressed by a pre-service chemistry teacher during a course on the history of chemistry? How are aspects related to the Nature of Science expressed by a pre-service chemistry teacher based on the history of chemistry teaching-learning context?

METHODOLOGICAL ASPECTS

This study adopts the principles of qualitative research (Merriam, 1988) because we are concerned with understanding aspects expressed by means of reflection, questioning, critical assessment and others. Furthermore, our results are expressed through descriptions and citations of data collected in the research environment: a class made up of 27[2] pre-service chemistry teachers (PSCT) enrolled in the history of chemistry course.

Specifically, we conducted a case study (Yin, 2001) since we investigated the portfolio of Ana[3], one of the PSCT in that class. Therefore, this study is limited for the time being and allowed the identification of what aspects of the NoS stand out and are characteristic in Ana's portfolio and how she expresses these aspects. We have chosen to analyze Ana's portfolio because she demonstrated commitment to the quality of her work and participated actively in class discussions. Additionally, in other moments of her initial training, she took courses that discussed the teaching of chemistry, such as chemistry teaching practice, chemistry didactics and fundamentals of the teaching of chemistry.

DATA COLLECTION CONTEXT

This study is part of a broader research project with the goal of analyzing views *about* science of pre-service teachers in the HC teaching-learning context.

Data were collected in the first semester of 2019 in 100-min classes held once a week in the history of chemistry course at a public federal university. In general, the course dealt with discussions of elements related to the HC, making explicit aspects such as experimental procedures; trial and error processes related to the production of scientific knowledge; the role of women in science; reflections on scientific-technological contributions; the recognition of the role of the researchers involved and the relationship of science with society, culture, economy and politics. In this way, the PSCT had opportunities to reflect on how scientific knowledge developed in specific historical moments and the influences of other contexts (for example, culture, economy and politics) on scientific production. Additionally, discussions were conducted on how to work with the HC in elementary education.

On that occasion, the principal author of this paper worked as a course monitor and participated in all face-to-face meetings and made field observation notes. We also collected Ana's portfolio. Specifically, the portfolio was built up by participating in eight activities relative to elements related to the HC discussed in class and the reading material made available by the teacher trainer. In general, in each activity, the PSCT should present and justify which elements of the previous class and of the texts they considered important and present their reflections, questions and criticisms relative to their understanding of science. Figure 1 presents the elements related to the HC, core materials, which should be consulted by pre-service teachers and complementary materials - texts or videos provided by the teacher that would be consulted depending on the students' interest.

Figura 1. Elements related to the history of chemistry discussed in class and materials used during the history of chemistry course.

Activity	Elements related to the History of Chemistry discussed in class	Core materials	Complementary materials
1	Discussions on alchemy dealing with the existence of other points of view besides the European one and the development of technical procedures at that time.	Alfonso-Goldfarb (1987a)	Not made available
2	Discussions on the work by Robert Boyle dealing with the social context of the time and the efforts made by scientists to form an area of knowledge.	Alfonso-Goldfarb, Ferraz, Beltran and Porto (2016)	Alfonso-Goldfarb (1987b) Anunciação, Neto and Moradillo (2014)
3	Discussion on the controversy involving authorship of the "discovery" of oxygen, dealing with the contributions made by Scheele, Priestly and Lavoisier.	Vidal, Chelone and Porto (2007) Filgueiras (1995)	Not made available
4	Discussions on work by Dalton on the constitution of matter, the existence of controversies in science and the contributions of new evidence to lend support to the existing theoretical models. Discussion on the context of the discovery of cathode rays, Thomson's proposition of an atomic model, the contributions of peer discussions and the role of analogies in science.	Oki (2009) Lopes and Martins (2009)	Leal (2001) Chagas (2011) Bortolotto *et al.* (2012) Lopes (2009) Carvalho (2010)
5	Context of the proposition of the existence of X rays and the work by Becquerel discussing credibility in the scientific community and the influence of beliefs and theoretical models in the interpretation of the phenomena investigated.	Martins (1990)	Martins (1998) Martins (2004)
6 and 7	Discussions on Marie Curie's work and life dealing with the challenges imposed to the scientist by the society of the time, the psychological characteristics of the scientist and the problems faced by scientists in the study of a new phenomenon.	Noëlle (2016)	Leroy (1943) Pugliese (2007)
8	Teaching proposals for the introduction of the HC and aspects of the NoS in elementary education	Not made available	

THEORETICAL AND METHODOLOGICAL REFERENCES

The data analysis tool used was the second version of the MoSSE v.2 (Model of Science for Science Education proposed by Santos, Maia and Justi (2020). In general lines, MoSSE v.2 allows a holistic view of science and makes it easy to articulate aspects of the NoS, given that it considers science as being broad, made up of complex activities and may be analyzed from various areas of knowledge.

MoSSE v.2 covers different areas of knowledge, such as: (i) Philosophy of Science (PhS), which investigates what science is and its importance; (ii) Psychology of Science (PS), which seeks to understand the scientist's behavior and mental processes; (iii) Anthropology of Science (AS), which deals with the study of the relationship of human beings with scientific knowledge; (iv) Sociology of Science (SS), which studies Science as a social practice; (v) Economics of Science (ES), which investigates the transformation of scientific knowledge as a commercial product; and (vi) History of Science (HS), which studies the transformations of scientific ideas and their production over time. The NoS aspects related to each of the areas mentioned, as well as a description of each one is given in Figure 2.

Figura 2. Characterization of the NoS aspects related to the areas of knowledge adapted from Santos, Maia and Justi (2020, p. 595-601) (continued)

Areas of Knowledge	NoS Aspect	Characterization of the NoS aspect
Philosophy of Science	Epistemology	Reflection on the whole, that is, about the nature of science and its objectives, values, criteria, processes and scientific and/or epistemological practices Thus, it is an aspect that allows reflections on the limits and reaches of the construction of scientific knowledge.
	Ethics	Ethical and moral values that guide scientific and/epistemological practices or that serve as a basis in decision-making in the respective area.
	Logic	The way of thinking and reasoning related to the construction of scientific knowledge.
Psychology of Science	Complexity	How a scientist may have difficulty in understanding something due to its complexity during the process of production and use of scientific knowledge.
	Creativity	A scientist's capacity to devise, produce and/or invent something new, as well as to innovate based on something that already exists in the processes of production and use of scientific knowledge.
	Fallibility	How each scientist identifies and handles errors in the process of production and use of scientific knowledge.
	Uncertainty	How each scientist handles uncertainties[4], more precisely, how he/she becomes aware, takes a position and, when it is possible or necessary, makes decisions regarding them.
	Motivational influence	Influences that a scientist's intrinsic and/or extrinsic motivation may suffer and/or exert in processes of production and use of scientific knowledge.
	Intelligence	A scientist's intellectual characteristics related to how a scientist understands, relates to and makes choices concerning some specific knowledge in the process of production and use of scientific knowledge that allows seeing a scientist as having "regular" intelligence, that is, not out of the ordinary (a genius).
	Limitation	How a scientist may face difficulties, or even find it impossible to continue the process of production and use of specific scientific knowledge due to strong internal and/or external factors.
	Non-linearity of thought	How a scientist's thought does not change linearly along the processes of production and use of scientific knowledge.
	Objectivity	How a scientist can think and act directly, that is, focused on an objective in the processes of production and use of scientific knowledge.
	Personality	A scientist's individual characteristics[5] that can explain his or her behavior in a certain situation in the processes of production and use of scientific knowledge.
	Rationality	How a scientist can think and act rationally, that is, how a scientist can relate thoughts following some logic in the processes of production and use of scientific knowledge.
	Representation	A scientist's capacity to express an idea verbally, visually, mathematically or in some other form (for example, by thinking of and/or producing analogies and models in the processes of production and use of scientific knowledge).
	Subjectivity	How a scientist's ways of thinking and/or acting relates to his or her own previous conceptions, which can be different from those of another scientist and not necessarily grounded on some explicit logic.

Areas of Knowledge	NoS Aspect	Characterization of the NoS aspect
Anthropology of Science	Incommensurability	Aspects involving the concept of culture[6], resulting ideas that there is not a good or bad, better or worse culture, there are different cultures. Therefore, scientific knowledge can be constructed, interpreted and valued in different ways, according to different cultures.
	Cultural influence	Influences[7] that culture may suffer and/or exert in relation to certain scientific knowledge. Thus, individuals that express different cultures may interpret the same phenomenon in different ways.
Sociology of Science	Acceptability	How knowledge is produced, divulged, evaluated, revised and validated by scientists in order to be accepted as being scientific.
	Credibility	The *status* that scientists, institutions, awards (such as the Nobel Prize) and/or Science itself may have in the face of the scientific community and/or society.
	Fallibility	How scientists deal with errors in the academic community, either their own or someone else's, in the process of production of scientific knowledge.
	Uncertainty	How scientists become aware as a professional group, take a position and/or when it is possible or necessary, make decisions in the face of uncertainty as a professional group.
	Sociopolitical influence	Influences that the society, where scientists are inserted, and politics (local or global) may suffer and/or exert in the process of production of scientific knowledge. For example, how social and political issues illuminated by different postures influence the development of research on certain subjects and/or research performed interferes with the social and political environment.
	Interaction among scientists	Different ways scientists interact, for example, partnerships, contributions, disagreements, and disputes in the process of production of scientific knowledge.
Economics of Science	Access to knowledge	Exclusiveness of access to scientific knowledge and its implications for the monetary value aggregated to it; or who can use this knowledge directly or indirectly.
	Applicability	Interest from institutions that are involved in the processes of its production and/or application of scientific knowledge in its usage.
	Competitiveness	Competition between institutions along the processes of production, development and/or application of scientific knowledge aiming at filing patents and having innovation acknowledged.
	Financing source	Various institutions, including universities, research centers, industrial laboratories, government agencies, spin-off companies, among others, responsible for supporting scientific research.
	Financial investment	How investment in processes of production and application of scientific knowledge is gradual and depends on the results of the processes and on social, political, environmental factors and others.
	Productivity	Interest of institutions involved in processes of production, development and application of scientific knowledge in productivity in terms of financial return of the investment.
	Divulgation	Interest of institutions involved in processes of production and application of scientific knowledge in its divulgation aiming at obtaining financial support and/or mercantilization and commercialization.
	Viability	Process of evaluation to define and/or justify investment in scientific research.

Areas of Knowledge	NoS Aspect	Characterization of the NoS aspect
History of Science	Historical Influence	Influences that the historical context may suffer and/or exert on processes of production and use of specific scientific knowledge over time.
	Multiplicity	Various narratives and/or different interpretations of the same historical event in relation to a given piece of scientific knowledge.
	Non-linearity	Non-existence of a single path of development of scientific knowledge, including the recovery of ideas presented in previous studies, unexpected events and changes in the research of some given scientific knowledge that have taken place over time.
	Progressivity	Process through which certain scientific knowledge is produced, divulged, evaluated, revised and validated gradually over time. It thus becomes evident that knowledge is not constructed in single steps and that the processes of production of scientific knowledge require time to take place.
	Impermanence	Occurrence of changes in some scientific knowledge over time with some ideas being abandoned in favor of new constructions, which is a consequence of the process being dynamic, non-linear and progressive.

The aspects of the NoS related to each of these areas of knowledge can be used as well-defined categories in the analysis of the data collected in teaching contexts with the objective of investigating the view of science in individuals involved in such contexts. For this reason and considering their amplitude, we have chosen to use MoSSE v.2 as a data analysis tool.

DATA ANALYSIS PROCEDURES

Using the characterizations of the aspects of the NoS defined in MoSSE v.2, we identified signs of expression of aspects of the NoS in Ana's portfolio related to each of the areas of knowledge. When the same aspect was identified at different moments of an activity in the PSCT's presentation, we considered it a repetition of the idea and classified it only once. We point out that we made triangulation of evaluators (Cohen, Manion, & Morrison, 2011), that is, analysis was performed independently by the authors and the results were compared and discussed later until an agreement was reached.

Based on this analysis, we indicated the aspects the PSCT expressed more frequently during the course or in the same activity, as well as the relationships between the context of the activity and the expression of certain aspects.

RESULTS AND DISCUSSION

All the NoS aspects identified in Ana's portfolio are indicated in Figure 3. The first two columns give the areas of knowledge and the NoS aspects related to each area, respectively. The other columns give the number of times each aspect related to the eight activities (A1 to A8) was expressed. The last column gives the summation (**Σ**) of the number of times each aspect in the portfolio was expressed. Finally, we point out that the blanks indicate that the aspect was not expressed in the activities.

Considering the scope of this paper, only the results for the aspects expressed by Ana with a great frequency (in bold) are discussed, namely: (i) those identified in the records of four or more activities; and (ii) those identified more than once in the records of the same activity and which we considered to be more significant to her. In relation to the areas of Anthropology and Economics of Science, although these aspects were not expressed frequently, we discussed the most frequent one in the records to give the reader an idea of how aspects in these areas can be expressed.

Figura 3. Aspects related to the areas of knowledge identified in Ana's portfolio records.

Area of knowledge	**NoS Aspect**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**∑**
Philosophy of Science (PhS)	**Epistemology**	1	1	1	2	2	2	3	2	14
	Logic	1	1							2
Psychology of Science (PS)	Creativity				1					1
	Motivational influence						1	2		3
	Intelligence				1	1				2
	Limitation						2			2
	Non-linearity of thought				1	1				2
	Objectivity						1			1
	Personality				1	1	1	1		4
	Rationality	1								1
	Subjectivity	1	2							3
Anthropology of Science (AS)	**Cultural influence**	1			1					2
Sociology of Science (SS)	Acceptability				1					1
	Credibility				2	1	2			5
	Sociopolitical influence	2	1		3	1	3	2	1	13
	Interaction between scientists		1	1	1	1		1		5
Economics of Science (ES)	**Access to knowledge**						1		1	2
	Applicability								1	1
History of Science (HS)	**Historical Influence**	1	1			1	1		1	5
	Multiplicity				1					1
	Non-linearity				1					1
	Progressivity			1			1			2
	Impermanence		1		1					2

Relative to the Philosophy of Science, Ana expressed the epistemology aspect in the records of the activities present in her portfolio (Figure 3) and, during the course, this aspect was the most frequently identified in the expression of her ideas. We observed a greater occurrence of this aspect in A7, based on Ana's reflections on the construction of scientific knowledge as a whole and the importance of understanding this process as a teacher, as shown in the excerpt below:

> **I think it is very important for us future teachers to be able to understand how the process of evolution and construction of science takes place**, because if we are not familiar with it, we will pass on an incorrect idea of science and we will not succeed in explaining **the humanity of this science constructed by human beings** who are often considered uncommon. (ANA, A7, our emphasis)

Besides reflecting on the nature of scientific knowledge, Ana also emphasizes its importance for teachers, pointing out that a lack of knowledge of the NoS may result in inadequate teaching of science. This note is echoed in the literature on the importance of training of teachers of Science closer to the reality (for example, Justi & Mendonça, 2016; Martins, 2006; Oki & Moradillo, 2008). Thus, she seems to value this knowledge in the teaching of science, contrary to the view that they are less important than the scientific concepts, a view shared by many teachers (Maurines & Beaufils, 2012).

Based on the field notes, in one of the last classes of the course, when the historical case of scientist Marie Curie was discussed, we identified that Ana stated that: "Things from the first semester is making sense now because now I understand how science is made". This note is evidence that at the end of the course Ana had a broader view *about* science and that, as a result, she made more records on reflections on the limitations and reach of scientific knowledge, which may explain the greater frequency of the epistemology aspect. Additionally, Ana seemed to acknowledge the deficiencies in her training in terms of the distancing of learning about scientific concepts and the context of production of these concepts, corroborating the limitations in teacher training found in the literature (for example, Justi & Mendonça, 2016; Martins, 2006; Oki & Moradillo, 2008).

Regarding the NoS aspects related to the area of Psychology of Science, many of them, nine out of 13, were identified in nearly all activities, except for A3 and A8 (Figure 3). In the records from A6 and A7, we characterized the aspect of motivational influence when, for example, Ana acknowledged the motivations of scientist Marie Curie when she reported that Mrs. Marie Curie continued her work despite all difficulties. "Marie Curie was courageous and intelligent. She remained strong in the face of all difficulties and achieved her objectives" (A6). In A7 Ana looked back at Marie Curie's intrinsic motivations and pointed out that the extrinsic motivations derived from the support given by Pierre Curie, her husband, and pointed out that his support was fundamental for her achievements, considering that he made a point of acknowledging his wife's work. Thus, Ana recognized the personal motivation of scientists in the production of scientific knowledge and the continuity of their work. Additionally, she pointed out that the contribution of external motivation for scientists to remain on the path of research, giving signs that she does not see scientists as "geniuses" or "individuals who work in isolation", a view about science that is recurrent among teachers and students (Bomfim, Reis, & Guerra, 2016; Gil Pérez *et al.*, 2001; Guerra-Ramos, 2012).

The limitation aspect appears twice in A6. First, Ana discussed the precarity of Marie Curie's working conditions, acknowledging that it made the scientist's production difficult, but did not prevent her from conducting her investigations:

> The working conditions in which she conducted her experiments were precarious. Her laboratory was "adapted". It was a room with glass-pane windows that the director of the School of Physics where Pierre worked allowed her to use. Some time later, they started working in a hangar lent to them. It had nothing to regulate the temperature; it was very hot in the summer and the temperature fell drastically in the winter, and it hardly provided shelter from the rain. Despite these conditions, she continued to work hard. (ANA, A6).

Later she reflected on the difficulties related to the fact of her being a woman in an environment dominated by men, pointing out that for the scientist to have her work acknowledged she needed to make an effort greater than other scientists of her time did. As shown in Figure 3, the personality aspect was expressed by Ana in four activities (A4 to A7). In A4 and A5, we observe the overlapping of the aspects intelligence and non-linearity of thought. Ana expressed the personality aspect when she discussed how the characteristics of Thomson and Marie Curie contributed for them to make choices that determined the process of production of knowledge. For example, in A4, she pointed out that the way Mr. Thomson related to knowledge was a determinant for him to develop his studies on the atomic theory:

> During his investigation of atomic models, Thomson did not stop; he always read and included new theoretical trends of the time in his work and accepted new ideas pacifically. This greatly helps the evolution of science. (ANA, A4).

For Ana, the scientist's personality traits such as being open to new ideas and eager for knowledge resulted in intelligent choices in the production of knowledge on the structure of matter. In this very excerpt, Ana also expressed the aspect of non-linearity of thought when she reflected on how Thomson's personality contributed for him to include new ideas in his studies and think over his propositions.

Still in the area of Psychology of Science, we observe the expression of the subjectivity aspect in the records from the first activities (A1 and A2), when Ana assumed that the scientists' theoretical conceptions influenced the production of scientific knowledge. This was identified when she commented on the work by Paracelsus, for example:

> [...] Paracelsus managed to link religion to 'science' when he said that the creation of the universe could be seen as an alchemical process of separation and from this, the following processes should be understood in a 'chemical" manner. [...] The relationship with belief still has strong links to the explanations of the studied phenomena, even if laboratory tests are carried out, it is not possible to understand natural phenomena "rationally" and independently as yet. (ANA, A2).

In this excerpt, Ana acknowledged that Paracelsus' association with religion limited his way of constructing scientific knowledge and pointed out that this type of relationship is still present in conceptions of contemporary scientists. In this way, based on this episode of the HC, and the studies of iatrochemistry, she presented reflections on the contemporary process of production of scientific knowledge, pointing out that this process does not follow empirical-inductive logic (Gil Pérez *et al.*, 2001).

Considering the area of Anthropology of Science, the aspect cultural influence was observed at two moments, A1 and A4. In the core material and the class related to A1, various forms of thinking about matter in pre-history and in antiquity were discussed. From that, Ana pointed out that:

> All theories are related to the **historical** context where each 'philosopher' lives and this shows that the construction of knowledge and the explanation of phenomena are directly connected to the **culture** and the **society** the thinker belongs to. (ANA, A1, our emphasis).

We can see that Ana realized that the way of thinking about matter is related to the culture of the time where this knowledge was constructed. This excerpt also brought to light aspects of sociopolitical influence (SS) and historical influence (HS).

Regarding the Sociology of Science, the aspects credibility, sociopolitical influence and interaction among scientists were the most frequent in Ana's records.

We identified the expression of the aspect of credibility in the records from A4 to A6 (Figure 3). For instance, in records from A5 and A6, Ana presented discussions on the acknowledgement of Becquerel's work related to the "discovery" of radioactivity. In both, she pointed out that Becquerel's work was not sufficient to conclude that he had "discovered" radioactivity, because although he had been the first to observe the phenomenon, he failed to interpret it. She also pointed out that Marie Curie contributed more significantly to the understanding of this phenomenon but had greater difficulty to have her contributions acknowledged because of her being a female scientist at a time when women hardly had any, or no space in society. At the end of the records from A6, Ana attributed Becquerel's ease to have his work accepted due to the fact that he belonged to a family influent in scientific circles.

> The case of the discovery of radioactivity is close to that of the discovery of oxygen. Because Becquerel and Lavoisier were both very influent in the scientific community and in society itself for political reasons, they won major awards in science. The difference is that Lavoisier deserved the award for all the contributions that he had made. In contrast, Becquerel won an award, although he did not explain the

> phenomenon that he had observed and had simply "paraphrased" studies published earlier. It is evident that this happened because he belonged to a family of scientists and that his father and grandfather had been great scientists, for which reason he was rather influential in the scientific community. Even though Marie Curie's contributions to radioactivity were much more decisive, she needed to justify herself and fight to deserve a [Nobel] prize. [...] The study of this historical event led me to reflect on all the fights Marie Curie had to put up for us [women] to have a greater space in the scientific community today. It is clear that even today science is still dominated by males. However, the space has become broader and more 'egalitarian'.[8] (ANA, A6).

In this case, Ana pointed out the difficulties Marie Curie had to face to develop her work and conquer her space in the academic world. We found her thoughts to fit the credibility aspect because she discusses the impact of the lack of status of the scientist in the academic community of the time more emphatically, even though she related it to the cultural and social context of the time. She also discussed the impact that Becquerel's family status had in academic circles. Thus, in this excerpt, the aspects of limitation (PS) and sociopolitical influence overlap. Furthermore, Ana drew a parallel with the contemporary world, acknowledging the influences of a chauvinist and patriarchal society even today. However, she also acknowledges the progress made in this respect and points out the importance of scientist Marie Curie for the recognition and expansion of the possibilities of participation of women in science.

Now, the sociopolitical influence aspect was identified 13 times in almost all activities in the portfolios, with the exception of A3 (Figure 3). For instance, in A6 Ana discussed the social interferences in the context of the discovery of radioactivity by those responsible for the use of this knowledge to make weapons due to the war context of the time:

> [Science] is not neutral, **apolitical**. It suffers **social interferences** and its evolution follows the context of the time. For example, at the time of the studies on radioactivity, **political issues** became gradually tenser and resulted in two World Wars. That period saw a need to hide radioactive elements because their potential for chemical weapons was already known and, unfortunately, shortly later, scientific knowledge was used to make an atomic bomb. (ANA, A6, our emphasis).

In this and other records from A6, we can observe that Ana reflected on the influence of society on the production of knowledge, both from the perspective of the access of scientists to means of divulgation of scientific knowledge and the scientific community and of the influence of the production of knowledge on society, considering that she pointed out how knowledge on subatomic particles influenced and changed the context of war in the world. Thus, Ana pointed out the relationships between science and society, demonstrating that she did not conceive science in a neutral and isolated way, that she did not have a salvationist view of science.

The last aspect related to the area of Sociology of Science, interaction among scientists, was observed in records of more than half the activities, with one occurrence per activity. For instance, Ana showed she understands this aspect when she discussed the discovery of the chemical element oxygen and acknowledged Lavoisier's contributions, but she pointed out that: "Lavoisier was always surrounded by scientists who helped him and participated together in the construction of Chemistry (A3). This note led her to point out that it was inappropriate to attribute the title of "father of chemistry" to Lavoisier, considering that his work was related to other studies at that time and whose authors should also be acknowledged. Once more, Ana seemed to reflect on the fact that scientists do not work alone and even when the knowledge produced is novel, it is related to other studies conducted and discussed at the time.

Regarding the Economics of Science, we identified only two aspects in the records of the last activities (A6 and A8). For instance, in the latter, when Ana reported on a teaching proposal for the insertion of the HC and other aspects of the NoS in elementary education, she expressed ideas on the aspect of access to knowledge when discussing the relationship between development of research on radiation and the context of war:

> Another important factor was the decisive issue of use of this knowledge acquired in wartime. **Whoever had knowledge was one step ahead in the war**; the discoveries were gradually more present and the progress was greater and greater. (ANA, A8, our emphasis).

This excerpt was so classified because, based on the elements related to the history of science on the existence of subatomic particles and radioactive elements, Ana reflected on the value that scientific knowledge may acquire, so that the power of subjects and nations may be related to who can pay for knowledge or have access to it.

Finally, in terms of History of Science, all the aspects were identified in Ana's records. This can be justified by the fact that our data were collected in a teaching-learning context of the HC. Additionally, we point out that the aspect of historical influence was identified in a large part of the records of the activities, very often together with the aspect of sociopolitical influence (SC).

In general, we identified historical influence when Ana presented reflections on the influences of the context of the time on the production of scientific knowledge, recognizing that they are closely linked to their historical contexts of production. For example, in records on A2, Ana discussed the impact of religion on the explanations given at the time for natural phenomena; in records on A5 and A6, she attributed part of the challenges faced by Marie Curie to patriarchy; in records on A8, when reporting the objectives of her teaching proposal for elementary education, she pointed out the interference of the context of war on the production of scientific knowledge, highlighting the great scientific productions of the time.

Finally, based on the detailed discussion of the results, we expect that the reader has been able to perceive how the characterization of the aspects of the NoS related to the areas of knowledge (Figure 2) can be used as well-defined categories in the analysis of the data collected in a teaching-learning context of the HC, favoring the visualization of the interpretation of these aspects in the data analyzed.

CONCLUSIONS AND IMPLICATIONS

Based on the analysis of mainly the records from the portfolio of one of the PSCT drafted during a HC course, we identified the occurrence of 23 out of 37 aspects of the NoS related to all the areas of knowledge represented in MoSSE v.2, that is, over 60% of the aspects proposed and characterized in the model. This variety of aspects of the NoS indicates that Ana expressed a broad view about science.

Upon analyzing how the aspects of the NoS were expressed in the records of the activities carried out during the HC course, we noticed that the use of different elements related to the HC, the explicit discussions on the characteristics of science made evident by each of them, and the invitations for reflections on learning about science observed in all the eight activities contributed mainly for Ana to:

I. reflect on conceiving science as a social practice, pointing out that scientists form groups with their own rules, behaviors and habits and that during the production of scientific knowledge, there occur disputes and collaborations between group members:
II. perceive the influences of historical contexts on the production of scientific knowledge; and
III. understand the meaning of science today and how it has developed/develops.

Relative to how Ana expressed the aspects of NoS related to the area of Psychology of Science, we point out that their occurrence was favored by discussion of elements related to the HC involving emphasis laid on a scientist, such as occurred, for instance, in the discussions on the works of Thomson, Becquerel and Marie Curie. In this regard, we highlight the need for the teacher trainer to be careful not to depict any scientist as a "genius" or focus on discussions on a single piece of work of such a scientist because this may drive students away from scientific careers and lessen their interest in science (Allchin, 2013; Gil Pérez *et al.*, 2001) because they do not identify any of the characteristics or elements of their personalities with those of the scientists presented (Bomfim *et al.*, 2016). Thus, for a more appropriate discussion of aspects of the NoS present in this area, we need to go outside the traditional boxes with information on scientists presented in didactic books (Porto, 2019). We understand that it is fundamental that characteristics emerge from a context where the production of scientific knowledge is shown with all its challenges, partnerships, etc. (Allchin *et al.*, 2014).

The fact that the aspects of the NoS related to the areas of Economics and Anthropology of Science have been identified few times may indicate that working with historical cases alone is insufficient to generate a broad context of teaching-learning about science. We thus endorse the remarks made by Allchin *et al.* (2014) on the need for the teaching *about* science to also involve discussion based on contemporary research activities and cases. In other words, we consider it important to use complementary approaches for teaching to encompass a greater variety of aspects of the NoS and consequently of areas of knowledge. For instance, we consider that discussions on the commercialization of scientific knowledge (related to the area of Economics of Science) can be more evident in discussions of contemporary cases than of historical cases, in which commercialization of scientific knowledge tends not to be emphasized (maybe because it is more evident in more recent times).

On the aspects related to the area of Anthropology of Science, we point out that maybe their expression is not directly connected to the teaching approach used, but rather to the theme set selected. Thus, for example, in discussions of other types of knowledge besides scientific knowledge, such as traditional knowledge, they may appear.

We highlight that the work with elements related to the HC can contribute to the teaching of science, as also pointed out in other studies in the area (Martins, 2006; Oki & Moradillo, 2008). However, we emphasize that the teaching of the NoS and the Hh in higher education should not occur only in a single course and with a single approach of teaching. It is important that pre-service teachers participate in these discussions during their whole training, both in courses of a pedagogical nature and those focused on chemistry contents, since studies on how these kinds of knowledge were developed are part of these contents and may contribute toward furthering their learning (Matthews, 2012).

Maurines and Beaufils (2012) pointed out that many working teachers consider the teaching of scientific concepts more important than teaching *about* science, and even teachers that consider the teaching of the HC important, face difficulties doing so in the class room. For this reason, we reiterate that the involvement of pre-service teachers in discussions *about* science and the HC in courses such as Organic and Analytical Chemistry, among others, is fundamental for them to be able to learn together about the concepts, their contexts of production, the individuals involved, etc.

Furthermore, Carlson and Daehler (2019) point out that the pedagogical knowledge of the personal content of the teacher reflects the teacher's experiences in teaching, which makes the need evident for pre-service teachers to experience a teaching that is more coherent with what they are expected to do in class. In other words, generally, during the initial training, teachers experience teaching focused on contents outside their contexts of production (Schnetzler, 2019), which can contribute to the results indicated by Maurines and Beaufils (2012). However, we recognize that this implies the fact that teacher trainers must have developed their knowledge about science and have knowledge related to how to teach *about* science, which poses another challenge to be overcome in the training of teachers (Schnetzler, 2019).

Still regarding teacher training, we point out that a limitation of this study is that it has not dealt with aspects related to science expressed by the PSCT when it conducted teaching situations involving elements related to the HC and aspects of the NoS. Although one of the activities of the course was related to the preparation of a teaching proposal for the insertion of the HC and aspects of the NoS in elementary education, just discussions of this nature may not be sufficient for the teacher to be able to work within this approach.

Being so, we endorse discussions present in the literature on the importance of practice courses as curriculum components (Diniz-Pereira, 2016; Pereira & Mohr, 2017), which must aim at familiarizing the future teachers with the reality of teaching classes. We acknowledge the need to offer not only opportunities for future teachers to plan teaching proposals in teacher training courses, but also give them opportunities to perform them. This will enable them to develop and mobilize pedagogical knowledge of collective content (Carlson & Daehler, 2019) - related both to knowledge of the HC and how to teach Chemistry involving the HC - since they will have teaching experiences guided by supervising teachers.

In these contexts, could other research objects be investigated, such as the aspects of the NoS that pre-service chemistry teachers consider when planning and conducting teaching situations involving the history of chemistry? Investigations of this nature could lead to the proposal of science teacher training course guidelines in the approach discussed here.

Considering our experience using the MoSSE v.2 as an analysis tool, we acknowledge its adequacy and indicate that it may be used in future studies that seek to investigate views *about* science in teachers, without the intention of fitting them into pre-defined models, which tends to occur when the analysis is based on questionnaires (Guerra-Ramos, 2012; Moura *et al.*, 2020). On the contrary, we point out that MoSSE v.2 is an adequate tool to characterize the ideas about science in individuals when the investigation is conducted in teaching contexts.

On the other hand, the extension of the analysis tool and the consequent need to understand the meaning of the various aspects of the NoS may make its use by less experienced researchers difficult. Being so, we agree with Santos *et al.* (2020) concerning the use of the tool requiring the researcher to understand the limits and reach of each area of knowledge, as well as the meaning of the aspects of the NoS related to each one.

Finally, we point out that the results presented and discussed here, as well as the reflections on the use of MoSSE v.2 may contribute to the development of other studies in the area by indicating the potentialities and limitations of the analysis tool used. Additionally, based on these results and reflections, it has been possible to shed light on the importance of teacher training focused on the teaching of and *about* science that is more authentic, thus broadening the perspectives of research in relation to the introduction of the NoS in higher education, and also furthering the dialogue in the area of science education on the respective theme.

ACKNOWLEDGMENTS

The authors would like to thank: CAPES and FAPDF, for the financial assistance, and Rosária Justi, for the critical reading of the article and notes that contributed to this production.

REFERENCES

Alfonso-Goldfarb, A. M. (1987a). Algumas reflexões sobre a Genealogia e a Gênese da Alquimia. In *Da Alquimia à Química* (pp. 41-68). São Paulo: nova Stella: Editora da Universidade de São Paulo.

Alfonso-Goldfarb, A. M. (1987b). Robert Boyle e a Introdução do Universo Mecanicista na Química. In *Da Alquimia à Química* (pp. 173-207). São Paulo: nova Stella: Editora da Universidade de São Paulo.

Alfonso-Goldfarb, A. M., Ferraz, M. H. M., Beltran, M. H. R., & Porto, A. P. (2016). Séculos XVII e XVIII: a química em busca de novos caminhos. In *Percursos da História da Química* (pp. 35-59). São Paulo: Editora Livraria da Física.

Allchin, D. (2011). Evaluating Knowledge of the Nature of (Whole) Science. *Science Education, 95*(3), 518-542. doi:10.1002/sce.20432

Allchin, D. (2013). *Teaching the nature of science: Perspectives and resources*. St. Paul: SHiPS Education Press.

Allchin, D., Andersen, H. N., & Nielsen, K. (2014). Complementary Approaches to Teaching Nature of Science: Integrating Student Inquiry, Historical Cases, and Contemporary Cases in Classroom Practice. *Science Education, 98*(3), 461-486. doi:10.1002/sce.21111

Anunciação, B. C. P., Neto, H. S. M., & Moradillo, E. F. (2014). Robert Boyle no Contexto da Transição para a Ciência Moderna: Elementos para uma Análise Sócio-Histórica *Revista Ideação, 29*(1), 165-192. doi:g10.13102/ideac.v1i29.1345

Bomfim, J., Reis, J. C., & Guerra, A. (2016). Problematizando a ideia de gênios isolados: Mayer e Joule no episódio da conservação da energia. *Revista Tecné, Episteme e Didaxis: TED, Extraordinário*, 1264-1270. Retrieved from https://revistas.pedagogica.edu.co/index.php/TED/article/view/4736

Bortolotto, A., Lobato, C. B., Tonetto, S. R., Ferraz, M. H. M., Alfonso-Goldfarb, A. M., & Beltran, M. H. R. (2012). Dissecando a Matéria entre os Séculos XVIII-XX. In *História da Ciência: Tópicos Atuais 2* (pp. 103-130). São Paulo: Editora Livraria da Física.

Carlson, J., & Daehler, K. R. (2019). The Refined Consensus Model of Pedagogical Content Knowledge in Science Education. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science* (pp. 77-92). Singapore: Springer.

Carvalho, A. D. (2010). *A constituição Particulada da Matéria*. (Trabalho de conclusão de curso). Universidade Federal do Rio de Janeiro, Rio Janeiro.

Carvalho, A. M. P. (2013). O ensino de Ciências e a proposição de sequências de ensino investigativas. In A. M. P. Carvalho (Ed.), *Ensino de Ciências por Investigação* (pp. 1-20). São Paulo: Cengage Learning.

Chagas, A. P. (2011). Existem átomos? (abordando Jean Perrin). *História da Ciência e Ensino: Construindo interfaces, 3*, 7-16. Retrieved from https://revistas.pucsp.br/hcensino/article/view/5605

Cohen, L., Manion, L., & Morrison, K. (2011). *Research Methods in Education* (7th ed.). New York: Routledge.

Diniz-Pereira, J. E. (2016). [DCN's para a formação inicial e continuada em nível superior: concepções e desafios.].

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing the Nature of Science for Science Education: Scientific Knowledge, Practices and Other Family Categories*. Dordrecht: Springer.

Filgueiras, C. A. L. (1995). A Revolução Química de Lavosier: Uma Verdadeira Revolução? *Química Nova, 18*(2), 219-224.

Gil Pérez, D., Montoro, I. F., Alis, J. C., Cachapuz, A., & Praia, J. (2001). Para uma imagem não deformada do trabalho científico. *Ciência & Educação, 7*(2), 125-153. doi:10.1590/S1516-73132001000200001

Guerra-Ramos, M. T. (2012). Teachers' Ideas About the Nature of Science: A Critical Analysis of Research Approaches and Their Contribuition to Pedagogical Practice. *Science & Education, 21*(5), 631-655. doi:10.1007/s11191-011-9395-7

Hanuscin, D. L. (2013). Critical Incidents in the Development of Pedagogical Content Knowledge for Teaching the Nature of Science: A Prospective Elementary Teacher's Journey. *Journal of Science Teacher Education, 24*(6), 933-956. doi:10.1007/s10972-013-9341-4

Hanuscin, D. L., Akerson, V. L., & Phillipson-Mower, T. (2016). Integrating Nature of Science Instruction into a Physical Science Content Course for Preservice Elementary Teachers: NOS Views of Teaching Assistants. *Science Education, 90*(5), 912-935. doi:10.1002/sce.20149

Irzik, G., & Nola, R. (2011). A Family Resemblance Approach to the Nature of Science for Science Education. *Science & Education, 20*(7-8), 591-607. doi:10.1007/s11191-010-9293-4

Justi, R., & Erduran, S. (2015). *Characterizing Nature of Science: A supporting model for teachers*. Paper presented at the Conference of the International History, Philosophy, and Science Teaching Group, Rio de Janeiro, Brazil.

Justi, R., & Mendonça, P. C. C. (2016). Discussion of the Controversy Concerning a Historical Event Among Pre-service Teachers Contributions to Their Knowledge About Science, Their Argumentative Skills, and Reflections About Their Future Teaching Practices. *Science & Education, 25*(7-8), 795-822. doi:10.1007/s11191-016-9846-2

Laraia, R. B. (2001). *Cultura: Um conceito antropológico*. Rio de Janeiro: Jorge Zahar.

Leal, M. C. (2001). Como a química funciona? *Química Nova na Escola, 14*, 8-12.

Lederman, N. G. (2007). Nature of science: past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research T education* (pp. 831-880). Mahwah: Lawrence Erlbaum Associates.

Lederman, N. G., Abd-Al-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. *Journal of Research in Science Teaching, 39*(6), 487-521. doi:10.1002/tea.10034

Leroy, M. (Writer). (1943). Madame Curie. In. Estados Unidos da América.

Lopes, C. V. M. (2009). *Modelos Atômicos no Início do Século XX: Da Física Clássica à Introdução da Teoria Quântica.* Pontifícia Universidade Católica de São Paulo, São Paulo.

Lopes, C. V. M., & Martins, R. A. (2009). *J. J. Thomson e o Uso de Analogias para Explicar os Modelos Atômicos: O 'Pudim de Passas' nos Livros Texto* Paper presented at the Encontro Nacional de Pesquisa em Educação em Ciências, Florianópolis.

Marques, R. A. (2015). Formação de professores de ciências no contexto da História da Ciência. *História da Ciência e Ensino: Construindo interfaces, 11*, 1-17. Retrieved from https://revistas.pucsp.br/hcensino/article/view/23020

Martins, R. A. (1990). Como Becquerel não Descobriu a Radioatividade. *Caderno Catarinense de Ensino de Física, 7*, 27-45.

Martins, R. A. (1998). A Descoberta dos Raios X: O Primeiro Comunicado de Röntgen. *Revista Brasileira de Ensino de Física 20*(4), 373-391.

Martins, R. A. (2004). Hipóteses e Interpretação Experimental: A Conjetura de Poincaré e a Descoberta da Hiperfosforescência por Becquerel e Thompson. *Ciência & Educação, 10*(3), 501-516. doi:10.1590/S1516-73132004000300013

Martins, R. A. (2006). Introdução: a História das Ciências e seus usos na educação. In C. C. Silva (Ed.), *Estudos de História e Filosofia das Ciências: subsídios para aplicação no ensino* (pp. 21-34). São Paulo: Livraria da Física.

Matthews, M. R. (2012). Changing the Focus: From Nature of Science to Features of Science. In *Advances in Nature of Science Research* (pp. 3-26). Dordrecht: Springer.

Maurines, L., & Beaufils, D. (2012). Teaching the Nature of Science in Ohysics Courses: The Contribution of Classroom Historical Inquiries. *Science & Education, 22*(6), 1443-1465. doi:10.1007/s11191-012-9495-z

Merriam, S. B. (1988). *Case Study Research in Education - A Qualitative Approach*. San Francisco and London.

Moura, C., Camel, T., & Guerra, A. (2020). A Natureza da Ciência pelas Lentes do Currículo: Normatividade Curricular, Contextualização e os Sentidos de Ensinar sobre Ciências. *Ensaio: Pesquisa e Educação em Ciências, 22*, 1-27. doi:10.1590/1983-21172020210114

Noëlle, M. (Writer). (2016). Marie Curie: The Courage of Knowledge In. França.

Oki, M. C. M. (2009). Controvérsias sobre o atomismo no século XIX. *Química Nova, 32*(4), 1072-1082. doi:10.1590/S0100-40422009000400043

Oki, M. C. M., & Moradillo, E. F. (2008). O ensino de história da química: contribuindo para a compreensão da natureza da ciência. *Ciência & Educação, 14*(1), 67-88. doi:10.1590/S1516-73132008000100005

Osborne, J., & Dillon, J. (2010). How science works: what is the nature of scientific reasoning and what do we know about students' understanding? In J. Osborne & J. Dillon (Eds.), *Good Practice in Science Teaching: what research has to say* (pp. 20-46). New York: Openup.

Pereira, B., & Mohr, A. (2017). Origem e contornos da prática como componente curricular. In A. Mohr & H. G. Wielewicki (Eds.), *Prática como componente curricular: que novidade é essa 15 anos depois?* (pp. 19-38). Florianópolis: NUP/CED/UFSC.

Porto, A. P. (2019). A história e Filosofia da Ciência no Ensino de Química: Em busca dos objetivos educacionais da atualidade. In P. F. L. Machado, W. L. P. Santos, & O. A. Maldaner (Eds.), *Ensino de Química em Foco* (pp. 141-156). Ujuí: Editora Unijuí.

Pugliese, G. (2007). Um sobrevôo no “Caso Marie Curie”: um experimento de antropologia, gênero e ciência. *Revista de Antropologia, 50*(1), 347-385. doi:10.1590/S0034-77012007000100009

Santos, M. A. R., Maia, P., & Justi, R. (2020). Um Modelo de Ciências para Fundamentar a Introdução de Aspectos de Natureza da Ciência em Contextos de Ensino e para Analisar tais Contextos. *Revista Brasileira De Pesquisa Em Educação Em Ciências, 20*, 581-616. doi:10.28976/1984-2686rbpec2020u581616

Schnetzler, R. P. (2019). Apontamentos Sobre a História do Ensino de Química. In W. L. P. Santos, O. A. Maldaner, & P. F. L. Machado (Eds.), *Ensino de Química em Foco* (2ª ed.). Ujuí: Unijuí.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Research, 15*(2), 4-14. doi:10.3102/0013189X015002004a

Vidal, P. H. O., Chelone, F. O., & Porto, P. A. (2007). O Lavoisier que não está presente nos livros didáticos. *Química Nova na Escola, 26*, 29-32.

Yin, R. K. (2001). *Estudo de Caso: Planejamento e métodos*. Porto Alegre: Bookman.

NOTES

1 We have used the terms of/about Science as synonyms of the term Nature of Science.

2 All the teachers in early training were informed about the objectives of the study and gave their written informed consent to participate in the study.

3 We have used a fictitious name to preserve the participant’s identity.

4 Something with results that cannot be foreseen precisely or explained.

5 For example, whether the scientist is honest and incorruptible in a certain situation.

6 Set of beliefs, habits, ways of dressing, thinking, behaving, speaking, eating, walking, praying and others, that is, whatever is passed on, acquired, learned, lived and shared by individuals (Laraia, 2001).

7 According to Santos *et al.* (2020), resulting from postures related to the degradation of the environment, racism, feminism and others.

8 The ideas presented by Ana agree with the historical approach of studies such as those by Martins (1990; 2004), which were among those used as a reference in the discussion of this activity. In these texts, the author discusses the dubious veracity of Becquerel’s work, but not all that is pointed out by Ana and Martins is necessarily absolute truth. Additionally, Ana may have written her portfolio under heightened emotions, since she said at other moments in her portfolio that it was the first time that she studied social issues underlying Marie Curie’s work in depth.

Marcondes Medeiros de Lima

Licenciado em Química pela Universidade de Brasília.

E-mail: marcon_des@live.com

Stefannie de Sá Ibraim

Doutora em Educação pela Universidade Federal de Minas Gerais e membro do grupo de pesquisa REAGIR – Modelagem e Educação em Ciências.

E-mail: stefannieibraim@ufmg.br

Monique Santos

Doutoranda em Educação pela Universidade Federal de Minas Gerais e membro do grupo de pesquisa REAGIR – Modelagem e Educação em Ciências.

E-mail: moniquersqui@gmail.com

Contact:
Stefannie de Sá Ibraim
Departamento de Química – Universidade Federal de Minas Gerais
Av. Antônio Carlos, nº 6627
Belo Horizonte, MG | Brasil
CEP 31.270-901

Publisher:
Ana Carolina Araújo