Epistemological Beliefs about the Nature of Science of University Professors in Physics Teacher Undergraduate Courses

EDVCATIO PHYSICORVM
SCIENTIAE AD ASTRA
QVO NON ASCENDAM?

ISSN 1870-9095

Gabriela Kaiana Ferreira, **José Francisco Custódio**
Departament of Physics, Federal University of Santa Catarina.

E-mail: gabriela.kaiana@ufsc.br

(Received 30 March 2023, accepted 25 August 2023)

Abstract

Epistemological beliefs refer to individuals' beliefs about knowledge and knowing. In teacher education, especially Physics teachers, epistemological beliefs can be used to help characterize the conceptions of university professors about the Nature of Science and to develop a more refined understanding of how these conceptions influence the teaching and learning of the Nature of Science in education courses. In this study, we aimed to highlight the epistemological beliefs of university professors and their influences on teaching activities in disciplines with content associated with the Nature of Science taught by the professors. From the analysis of the interviews, we conclude that there is a lack of articulation of teaching on the Nature of Science with topics from the teaching area and Physics contents; there is no homogeneity and consensus on what to teach on the Nature of Science, and an update/renewal is necessary for the debate on the Nature of Science in the Physics teachers' education.

Keywords: Nature of Science, Physics teacher education, Epistemological beliefs**.**

Resumen

Las creencias epistemológicas se refieren a las creencias de los individuos sobre el conocimiento y el saber. En la formación docente, especialmente en los profesores de Física, las creencias epistemológicas se pueden utilizar para ayudar a caracterizar las concepciones de los profesores universitarios sobre la Naturaleza de la Ciencia y para desarrollar una comprensión más refinada de cómo estas concepciones influyen en la enseñanza y el aprendizaje de la Naturaleza de la Ciencia en los cursos educativos. . En este estudio, nuestro objetivo fue resaltar las creencias epistemológicas de los profesores universitarios y sus influencias en las actividades de enseñanza en disciplinas con contenidos asociados a la Naturaleza de la Ciencia impartidas por los profesores. Del análisis de las entrevistas, concluimos que existe una falta de articulación de la enseñanza sobre la Naturaleza de las Ciencias con temas del área de enseñanza y contenidos de Física; no hay homogeneidad y consenso sobre qué enseñar sobre la Naturaleza de la Ciencia, y es necesaria una actualización/renovación del debate sobre la Naturaleza de la Ciencia en la formación de profesores de Física.

Palabras clave: Naturaleza de la Ciencia, Formación de profesores de Física, Creencias epistemológicas.

I. NATURE OF SCIENCE

Discussing aspects of scientific activity is fundamental in teachers' initial and continuing education [1, 2, 3, 4, 5, 6, 7, 8, 9]. This is supported by the evidence indicated by some studies that the epistemological conception adopted by teachers largely defines their attitudes in classrooms, especially when it comes to learning and knowing. Positions marked by inadequate conceptions imply reproducing an idea of empirical-inductivist, aproblematic, ahistorical, accumulative of linear growth, inductivist, elitist, decontextualized, and socially neutral Science [10].

Among the justifications for accepting and reproducing this type of conception by teachers, Gil-Pérez *et al.* [10] mention the lack of incentive and critical reflection on the Nature of Science (NOS) in initial education courses and the experience of education restricted to the passive transmission of strict and immutable knowledge, which is a frequent practice in the specific disciplines of the courses in Science and Technology. If, therefore, both justifications originate in the education of this professional, it is necessary to question: *What views about the NOS are disseminated in Science teacher education courses? What beliefs about the NOS are shared by the university professors in Science teacher education courses?*

Gil-Pérez *et al.* [10] suggest that an acceptable view of scientific work can be constructed by refusing ideas of the scientific method and naive empiricism, reflecting on the role of divergent thinking in research, seeking global coherence, and understanding the social character of scientific knowledge. *But how to build with the (future) teachers adequate, updated, renewed, or informed views on NOS? What is the effectiveness of discussions about the nature of scientific knowledge, which occur in teacher education*

courses, to incorporate more appropriate, updated, renewed, or informed views about NOS? In the education of Physics teachers, such questions remain open.

One obstacle in building more acceptable views about Science seems to lie in the time devoted to discussions on the topic in education courses is intended to discuss NOS aspects [11]. Ferreira and Custódio [12] showed that inserting topics related to the Nature of Science is still very low and is present in discipline syllabi that represent only 4.65% of the total credit hours. Moreover, they showed that of the small part of the credit hours destined to the debate on the Nature of Science in Physics teacher undergraduate courses, 3.39% is in disciplines that deal with the Disciplinary Knowledge of History, Philosophy, Epistemology, and Sociology of Sciences and Physics, 0.94% in disciplines focused on Pedagogical Knowledge, and 0.32% in disciplines related to the Disciplinary Knowledge of Physics. This shows, together with the low prominence of the topic, that there is still a greater focus on the disciplines of History and Philosophy of Science and little emphasis on contributions to teaching and the production of didactic material about NOS.

In Science Education framework, there is a set of recommendations on how to map and assess the views of students and teachers [13, 14, 15, 16, 17, 18, 19]. There is also a diversity of theoretical-methodological approaches that guide the studies, reflections, and investigations developed to insert the debate of the NOS in teaching and to guide teacher education [17, 19, 20, 21, 22, 23, 24]. Nevertheless, little (or no) attention has been given to the influence of the beliefs about the NOS of university professors in constructing undergraduate students' views about scientific work.

Thus, we aim to identify and characterize the epistemological beliefs about the NOS of university professors who educate Physics teachers and how these beliefs influence the teaching action.

II. EPISTEMOLOGICAL BELIEFS

Personal epistemological beliefs refer to *beliefs about knowledge and knowing* [25]. In the educational context, an adequate understanding of how they manifest can contribute to the intellectual epistemological development of individuals in classrooms [26]. This is because teachers' epistemological beliefs greatly influence their pedagogical practices and the selection and proposition of tasks. The experience and involvement of students with these activities, guided by the teachers' epistemological beliefs, imply, consequently, the construction of students' personal epistemological beliefs. These, in turn, act directly on the student's motivation, their more general beliefs about learning and education, and the selection of their strategies for learning [26].

In Physics, teachers' personal epistemological beliefs are quite traditional and stable [27, 28, 29, 30]. They may represent obstacles to inserting new themes in classrooms, such as the NOS, if it is necessary to adopt curricular and instructional practices related to their teaching that oppose the individuals' personal beliefs.

Among the obstacles that interfere with the implementation of the History and Philosophy of Science (HPS) for the learning of scientific concepts and about the NOS, Höttecke, and Silva [3] highlight as relevant: the teaching culture proper to school Physics (which differs from other teaching cultures); the skills, attitudes, and beliefs of Physics teachers about Physics teaching and epistemology; the institutional structure of Science teaching with a special focus on curriculum development; and the lack of adequate content on HPS in textbooks.

To implement HPS to learn scientific concepts, teachers are expected to hold positive beliefs about classroom organization, recognize students' epistemological ideas and beliefs, have the pedagogical content knowledge to moderate discussions and negotiations among students, support students' meaning and transform views expressed by students about NOS during teaching [3]. However, it appears that teachers do not assume the NOS as an explicit teaching objective, as recommended by the literature [3], and therefore do not explicitly reflect on it in classrooms. Moreover, teachers' beliefs about classroom organization, epistemological beliefs, and beliefs about teaching objectives are predominantly traditional [3].

Although they appreciate and recognize the context and process of building Science and its importance as learning content, many teachers feel insecure about teaching about HPS [3, 31]. Teachers attribute this insecurity to lacking skills and specific education [32, 33], considering that HPS does not belong to Science and Physics teaching tradition or culture. There is also a tendency for Physics teachers not to value meta-scientific knowledge as content to be taught [3].

Research on teachers' personal epistemological beliefs has shown that epistemological beliefs are extremely important due to their impact on the choices teachers make in their classroom practice [28, 34, 35, 36, 37, 38].

In an analysis of the dynamics between teachers' personal epistemological beliefs, teachers' understandings of NOS, and the appreciation attributed to NOS teaching, Hulling [34] emphasizes that **more sophisticated levels of understanding about NOS do not ensure high levels of personal epistemological beliefs**. On the other hand, **high indices of personal epistemological beliefs may serve as adequate predictors for a better understanding of the NOS** [34]. For the author, "(...) knowledge alone does not always translate into practice. Teachers must possess not only adequate knowledge and pedagogy to teach it but also, they must believe NOS to be important." [34, p. 218-219].

However, Hulling [34] argues that "that it is possible to include aspects of NOS within instruction without the threshold NOS knowledge being met if certain criteria are in place in terms of epistemological beliefs" [34, p. 220], even because the limits of what is an adequate understanding of the NOS do not seem evident.

For the author, "personal epistemological beliefs may buffer or catalyze the importance placed on NOS, as judged by their inclusion within instruction" [34, p. 221]. Hence, although teachers consider it important to understand the NOS for Science learning, it is the epistemological beliefs of these teachers that influence their teaching. This means that for effective teaching on the NOS, there is no doubt that

adequate knowledge of the topic is required. Nevertheless, *higher levels of personal epistemological beliefs indicate and direct the quality of the teaching type to more constructivist strategies. Teachers who demonstrate more constructivist teaching practices perceive fewer obstacles in their practice than their more traditional peers.*

The results of Huling's research [34] indicate "what came to be an interesting bit of evidence was that personal epistemological beliefs that led to constructivist practices were typically associated with good NOS practice" [34, p. 225]. A tendency to modify positivist approaches to more constructivist teaching practices emerged throughout the investigation, albeit without an explicit and reflective reflection on the NOS. Even those who had a more sophisticated view of the NOS, due to their scientific background, developed knowledge and teaching strategies about the NOS in a limited way.

Although Hötteck & Silva [3] and Hulling [34] have developed their research with Science/Physics teachers in teaching NOS in basic education, these studies provide very interesting elements to consider in higher education, particularly the Physics teachers' education. The research instruments developed by Hulling [34] provide methodological support for the research carried out with university professors of Physics teacher training courses at Public Higher Education Institutions (PHEI) in Brazil that we present below.

III. METHODOLOGY

In research on personal epistemological beliefs, declarative investigation instruments are suggested, in which participants describe their epistemological beliefs, because "(…) when we want to inquire about an individual's personal epistemology, we ask them questions regarding their views on knowledge" [25, p.10].

For data collection, we conducted semi-structured interviews based on instruments used in Hulling [34]. The questionnaire questions were carefully prepared and organized in blocks with well-defined objectives to ensure the interview data's reliability, credibility, and validity. The blocks are (i) general and specific professional education and professional performance of university professors; (ii) university professors' beliefs about their research practice, the undergraduates, the NOS, and the NOS teaching and their pedagogical practice; (iii) knowledge about legislation for the physicist education and the teachers' education; (iv) and the course's pedagogical project[1] where the professor teaches.

To avoid dubious interpretations of the questions, bring them closer to the language of the respondents, and offer credibility and confidence in the information collected through this instrument, we performed the semantic validation of the interview protocol's questions [39], which resulted in the instrument in its final version. This paper will address the issues surrounding university professors' epistemological beliefs.

The interviews were conducted with university professors who teach in the Physics teacher undergraduate courses at PHEI in Brazil, restricted to courses with two or more disciplines in their curricular structure with discussions about NOS, at least one of which is mandatory.[2] Professors from 32 courses of 25 PHEI were contacted. Of these, 20 professors from 14 Physics courses belonging to 13 PHEI agreed to participate in the interview[3].

Among the university professors interviewed, most attended undergraduate in Physics, master's, and doctoral degrees and Science Education, completed from the 1970s until recently, concentrated in state and federal PHEI at São Paulo, Rio de Janeiro, and Santa Catarina.

What draws attention regarding the academic education of these university professors is the fact that part of them developed their graduate studies, that is, their master's and doctoral research, in the same institution. Some university professors in the same graduate program and the same line of research, more frequently in Teacher Education, History of Science, History, and Philosophy of Science, and Teaching Methodologies. Another highlight but concerning the professional actuation of university professors is the fact that part of the professors remains working in PHEI at São Paulo and Rio Janeiro, primarily in Physics Education, concentrating their activities and research interests in the lines of History, Philosophy, Epistemology, Sociology of Science/Physics, Science, Technology, Society and Environment, Socio-Scientific Issues, and Teacher Education. These topics make it possible to approach discussions on aspects of the NOS.

The analysis of the interviews is presented below, and the excerpts of the speeches of the university professors are identified by the terminology D1, D2, D3, and so on.

IV. ANALYSIS OF INTERVIEWS

The interviews were analyzed based on the perspective of teachers' beliefs and personal epistemological beliefs supported by the discussion of the literature on the NOS. The professors' beliefs descriptors focused were beliefs about the NOS; beliefs about the learning of the NOS by undergraduates; and beliefs about the teaching of the NOS and the influence on the pedagogical practice of university professors.

[1] In Brazil, the course's pedagogical project consists of a course guiding document that gathers basic information about the course's design, general objectives of the course, expected profile for those who graduate from the course, curricular matrix, and ways for its effective implementation - workloads, course syllabi, the composition of mandatory and complementary activities.

[2] The professors declared their acceptance to participate in the research through the Free and Informed Consent Form. The interviews, conducted virtually or in person, lasted from 0.5 to 1.5 hours and were also audio recorded, transcribed, and analyzed by Author 1.

[3] This approach was necessary because at the time the survey was conducted, 186 Physics teacher undergraduate courses were identified in 111 Brazilian PHEI.

A. Beliefs about the Nature of Science

The university professors were asked to express what they understood about the NOS. Generally, they mentioned the existence of several theoretical perspectives on what the NOS is, which influence the expression of their epistemological beliefs, and that it is not possible to establish a universal and consensual way that is accepted by the entire community of researchers, educators, historians, and epistemologists of Science. From the analysis, it is possible to identify two distinct levels of discussion and, consequently, epistemological beliefs supported by the professors we present next.

- *Approximation of NOS tendencies and perspectives*

Part of the professors expressed their beliefs regarding identifying or approximating conceptions with some NOS tendency or perspective – whether consensual or renewed, externalist or internalist – or even approximating ideas of some epistemological perspective of Science in particular. For professors, understandings based on consensual points or renewed perspectives, based on the literature in Science Education and the defense of one perspective or another will depend largely on the ideological and epistemological position of each professor or researcher (D8, D14).

Some professors expressed approaches based on a socio-historical, relativistic, and sociological bias, justifying the influence of their education and master's and doctoral research. For example, D2 claims to support a belief about Science close to a Kuhnian position. He/she highlights that this position relates to its approximation with the approaches to Science, Technology, and Society, coming from the studies developed in the master's and doctorate. On the other hand, D4 claims to hold a belief about Science that approaches a relativistic position.

The professors relate these philosophical and epistemological positions to their understandings of the construction and production of Science as a socially constructed, non-linear, and non-neutral knowledge, as well as on the validation and legitimation of scientific status based on aspects of collectivity, heterogeneity, and criticism, whose development is often associated with and influenced by economic, political, social, and technological issues (D5, D7, D10, D12, D19, D20).

There is also a position of a professor (D3) that the conceptions of NOS expressed in Science Education and the Philosophy of Science may not reflect an adequate idea or image of the NOS, mentioning the difficulty of conceptually delimiting what NOS is. However, he/she acknowledges that usually presents the ideas of some references in the systematization of the NOS in the classes he/she teaches at the undergraduate and graduate level, such as the ideas of Douglas Allchin.

- *NOS as a field of study and research*

We identified that some professors added to the expression of their beliefs, the argumentation of the NOS as a field of study and research (D8, D9, D11, D14, D15, D20) referring to a perspective of the NOS as "a framework of knowledge on the construction of scientific knowledge" (D8), to discuss the production and legitimation of Science and scientific knowledge. These professors list as belonging to this framework of knowledge and skills of the NOS, knowledge of the History of Science, Philosophy of Science, Sociology of Science, and Epistemology of Science, among others (D8, D9, D11, D15, D14, D20).

Some professors also report that the debate about the NOS is a discussion that originated in the Epistemology of Science and that the educational area appropriated the term that "became very popular (...) also within the scope of curricular debates to defend the presence of explicit discussions about the Sciences" (D9). Also for this reason, it is important to distinguish between questions and problems in the NOS area and questions and problems in Science teaching (D14).

University professors who expressed their beliefs about the NOS as a field of study and research developed their academic training (master's and/or doctorate) in the line of research of History of Science. They also mentioned the area of History and Philosophy of Science and Physics as a field of interesting research during their recent professional activity. The permanence of these university professors in the areas of origin of their master's and/or doctoral research seems to have played an important role in establishing the belief about the NOS as a field of study and research.

B. Beliefs about the learning of the NOS by undergraduates

The university professors were asked to express their beliefs about learning the NOS regarding two main descriptors: the importance of NOS learning and the obstacles and difficulties undergraduates face in NOS learning. We present the analysis below.

- *The importance of NOS learning*

In general, professors consider it fundamental that undergraduates know about the NOS in the Physics teacher undergraduate courses. Professors hold beliefs about NOS learning that this type of discussion contributes largely to the education of both the teacher (D10, D14, D15, D20) and the scientist (D1, D6, D11, D12). Besides, they argue that learning the NOS contributes to a broader and more critical view of Science, favors the recognition of more organic dynamics, and develops more refined conceptions about the construction of Science and scientific knowledge (D5, D7, D8). One professor (D1) mentions that knowledge about NOS is important for establishing affective bonds by undergraduates with scientific knowledge because "I understand that teaching about the History and Philosophy of Science, of discussing NOS, demystifies Physics; I believe that it has the potential to make students create a greater affective bond with Physics."

The professors also justify that it is already a consensus of the community of researchers in Science Education that the NOS should be addressed in teacher education (D14), given the formative objectives of the undergraduate teaching courses and emphasize the need for articulation of the NOS

and the pedagogical practices of future professionals (D10). Another relevant justification for the influence of the NOS debate on the education of the bachelor scientist, their research practice, and their belonging to a community of their own, the professors argue that undergraduates "know this Science practice, that they can think how they place themselves within this scientific practice, what are the positions they want to have, so that they are critical when making choices in their performance, (...) that they can question why they are part of this community" (D6).

Furthermore, professors mention and believe that, in any situation, talking about Science content or the structure of Science, or even the teaching process itself, decisions, and choices of the teacher in the organization of their practice, always refer to a view, albeit not explicit, about Science. In the words of a professor, "regardless of whether they are explicitly addressing History and Philosophy of Science content in the classroom, everything they do as teachers carries an epistemology, (...) sometimes when we deal with Science, teaching a class, doing scientific dissemination or in a bar conversation, we are always transmitting a view of Science." (D9). Other professors state that "(...) the Physics or Science teacher needs to be aware of the view of Science he has because teaching means transmitting a view of Science." (D4) because "I think that how the teacher organizes his practice implicitly passes a view of the Nature of Science." (D2)

In summary, university professors support the belief that undergraduates' learning of the NOS contributes greatly to the education for teaching and in the development of conceptions about the construction and development of Science and more qualified scientific knowledge.

- *Obstacles and difficulties faced by undergraduates in NOS learning*

One of the obstacles mentioned by professors to learning about the NOS is associated with the strict and closed view that students generally have about Science, the dynamics of its construction, and its structure. Professors report that undergraduates often present a naive and distorted view that Science is true and absolute knowledge, the work of geniuses (D6, D8, D12, D13, D14, D20), also supported by the experiences they have in other Physics disciplines in the undergraduate course (D8, D20).

Some professors report realizing that undergraduates resist questioning these views and building others that present more contemporary elements of Philosophy, History, Epistemology, and Sociology (D6, D12, D19). They emphasize that this difficulty is revealed in disciplines throughout the undergraduate course, both by entrants and graduates (D6, D13), and that distorted views of undergraduates on the NOS can remain even after the formal discussion on the topic in teacher education.

According to professors, the origin of this difficulty may be associated with the fact that undergraduates are not accustomed, or are little stimulated, to classroom dynamics that allow questioning, reflection, criticism, and construction of opinions, strategies that require greater autonomy, participation, and reflection of ideas, or even have no familiarity with approaches that incorporate historical, philosophical, sociological, and epistemological issues to the discussion of Physics concepts (D6, D14, D20). Additionally, professors emphasize that the educational path of the undergraduates contributes greatly to the view they build on Science, and the discussions in Physics teaching throughout the education of future teachers positively influence the construction of this reflection (D6). Related to this, the professors add that an obstacle to the teaching of the NOS consists of the beliefs shared by colleagues who also teach in the undergraduate course and who often end up supporting, reinforcing, and sharing inadequate views associated with a mathematical, strict, and closed Science conception (D10, D14, D20).

Other difficulties for the learning and approach of the NOS mentioned by the professors are associated with the readings that are performed in the disciplines, of philosophical and historical bias, as well as the lack of knowledge of the undergraduates on the content of ***P***hilosophy and ***H***istory related to ***Science*** (D1, D2, D5, D8, D9, D11, D15, D20). The difficulty in understanding a more conceptual vocabulary and in developing more technical and not-so-didactic readings on the ***Philosophy of Science***, which are important for the conceptualization and qualification of philosophical positions regarding the view on ***Science*** and scientific knowledge (D9), as well as the low frequency of materials that make explicit associations between the historical and epistemological content of ***Science*** (D11) are common problems for a more qualified discussion on the topic.

For example, the difficulties in distinguishing characteristics that demarcate the different philosophical and epistemological positions are mentioned, as well as difficulties in maintaining a position consistent with one epistemology or another (D10). In the discussions that take place in the disciplines, a professor (D12) recognizes that there is a certain approximation of the undergraduates with the ideas of Thomas Kuhn. This university professor believes that this approximation is since, among the epistemologists of Science often studied, the Kuhnian ideas seem, for the undergraduates, to overcome the criticism of naive empiricism with a certain degree of sophistication and, consequently, to enable a seemingly better-structured view of Science.

Still, regarding the identification of the origin of the obstacles faced by the undergraduates, the professors mention the devaluation and little importance attributed to the discussion about NOS and the area of Physics teaching in Physics courses (D1), the heterogeneity of the education among students, as well as the little involvement in discussions of historical, philosophical, sociological, and epistemological bias (D3), and the lack of maturity and formative experiences that go beyond the mere technique application (D3, D20). However, some professors emphasize that they begin to perceive an advance in the views about the NOS of the undergraduates, assessing that "it is closer to a view of contemporary Epistemology than an empiricist-inductivist view that is very hard for us to break" (D14). Undergraduates' view of Science has changed over time and the tendency is that those who previously held more naive or

scientific positions start to explain less strict views and understandings about Science (D9). To definitively break the distorted views that undergraduates hold is not a simple task, and one of the professors (D14) mentions the notion of conceptual profile proposed by Mortimer [40] to assess the students' views on the NOS.

In short, university professors associate the obstacles and difficulties faced in learning about the NOS with the strict and closed view that undergraduates have about Science, the dynamics of its construction, and its structure, as well as the experiences they have in the disciplines throughout the undergraduate course and the need for more qualified and sophisticated philosophical debates.

C. Beliefs about the teaching of the NOS and its influence on the pedagogical practice of the professor

The university professors interviewed were asked to express their beliefs about the teaching of NOS regarding four main descriptors: the performance for teaching NOS, which they consider important in teaching NOS and influence on their pedagogical practice, the quality of the discussion on the NOS in classes, the articulation between NOS topics and teaching topics, as well as on the articulation between NOS topics and Physics content. We present it below.

- *Performance for teaching NOS*

Regarding the beliefs about performance in teaching the NOS, most professors consider that they perform well in teaching about it. In other words, they have a high self-efficacy belief for teaching the NOS. They also report the expressive contribution of the graduate studies to their performance in the education of Physics teachers and to teach NOS (D10, D12, D13, D19). Nevertheless, even considering that the training they received was adequate to address NOS topics, some professors reflect on changes in their pedagogical practice throughout their professional career, which highlights a relevant concern in the search for renewed perspectives on the NOS interpretation, as well as produce and systematize understandings that they consider less distorted about what Science is (D1).

Only two professors consider that their domain to teach on the NOS topic is somewhat restricted and that they have low self-efficacy beliefs. It means they do not consider themselves proficient in teaching on NOS. One of them (D5) states that his approach to the theme was due to the need to teach a specific discipline of the Physics course. At the same time, another professor (D7) adds that, although his/her education for the NOS is not compatible with his/her expectations, the general training received still in the undergraduate course made it possible to seek knowledge on the topic to teach it.

In summary, most university professors have a high self-efficacy belief in performance for NOS teaching, and graduate studies (master's and doctorate) positively contribute to this belief. While a smaller portion holds a low self-efficacy belief, presenting restrictions regarding the performance in the education of Physics teachers and for the NOS topic.

- *NOS teaching and influence on pedagogical practice*

Regarding the belief about NOS teaching and its influence on their pedagogical practice, most professors consider it essential to teach topics of History of Science and Philosophy of Science, in addition to other topics, justifying that they believe it can contribute to the understanding of the production of scientific knowledge. The professors' reports mention different strategies and approaches and, in short, they believe that themes of History and Philosophy of Science, concepts associated with the philosophies and epistemologies of modern Science proposed by the 'canonical' epistemologists of Science, as well as distorted images and views about the NOS are indispensable in teaching about the NOS.

For example, some professors (D2, D9, D14) defend the explicit teaching of the NOS, considering that "research shows that explicit approaches are more effective, from the point of view of teaching and learning Science for students" (D14) and for this "(...) an explicit way of teaching is either using the Philosophy of Science or the History of Science. And then, how you approach the History of Science also influences your philosophical view, your view of the Nature of Science." (D2). Concerning the possible approaches to the History of Science, some professors (D1, D11) expose their option for an internalist approach, defending the importance of knowing deeply the History of Physics, from which it is possible to make philosophical interpretations pertinent to historical periods and contexts.

Other professors (D4, D10) consider it essential to discuss with undergraduates the distorted images and views about the NOS, as they believe it enables "raising awareness of the view of Science" (D4) and "start a movement to think about Science itself, especially from the point of view of those who will teach this Science" (D4). This belief reinforces the conception that the teaching process itself, the decisions, and choices in the organization of its practice, refer to a view of the NOS, albeit not explicit. To this end, these professors (D4, D10) claim to use as a basis the article by Gil-Pérez et al. (2001) on the construction of an undeformed image about the NOS, as well as working concepts associated with the philosophies and epistemologies of modern Science proposed by epistemologists such as Thomas Kuhn, Paul Feyerabend, Karl Popper, and Imre Lakatos. Still regarding the NOS teaching, a professor (D14) mentions two perspectives that he deems important: an academic based on the thoughts of the philosophers of the 'New Philosophy of Science', such as Thomas Kuhn, Karl Popper, Imre Lakatos, and another sociological from a Science, Technology, Society, and Environment perspective or from the Sociology of Science.

Ultimately, some professors mention other topics and points that they deem important and that contribute to the understanding of the production of scientific knowledge, among which: are the 'intersubjective practice' in the production of knowledge in Science (D12); the role of theory and non-neutral observation in the construction of scientific

knowledge (D14); the genesis and origin of knowledge and issues around the non-neutrality of scientific practice and the production of scientific knowledge (D19, D20); approach to controversial topics in the context of the discussion of production in more current Science, such as gender and diversity issues (D7). Within the diversity of topics and approaches, it is noticeable in the professors' beliefs that there is no consensus on what to teach about NOS in the context of teacher education. An emerging challenge indicated in one of the professors' reports is the search for an interdisciplinary perspective for the teaching of the:

> "And I think a great challenge of Science Education is to try to seek in interdisciplinarity a possible path for discussing the nature of Science. (...) From the epistemological point of view, interdisciplinarity is born through a problem, (...) where it has to seek knowledge in other disciplines, mobilize other knowledge to try to answer this problem. Interdisciplinarity, as an epistemological and dynamic element, happens naturally. Seeking consensus points between the Chemical Sciences, Physics, Biology, Geology, even Human Sciences, depending on the objectivity of subjective questions, can foster this interdisciplinarity. One challenge is to try to find common ground among the Sciences. (...) And what they have in common leads us precisely to understand what kind of Philosophy of Science we have in common among the Sciences (...). I think this is an interesting challenge for our area that is not very well established." (D14)

- *Quality of discussion about NOS in classes*

About the quality of the discussion about NOS in classes, professors hold diverse beliefs and attribute to a diversity of factors, influenced mainly by the undergraduates' educational contexts and interests. Some of the professors positively judge the discussions about NOS developed by the undergraduates (D4, D9, D11, D12, D14), assessing that the quality of the work generates rich and fruitful discussions and problematizations in the disciplines they teach (D9, D11, D14), especially when the undergraduates' report having understood different views of Science and position themselves in relation to them (D4). Although positively assessing the quality of the discussion on the NOS, a professor (D9) reinforces that difficulties arise when these undergraduates need to advance to a more in-depth and qualified level of the discussion.

Another part of the professors reports that the quality of discussions about NOS depends on the classes and the difficulties and obstacles students face during discussions and problematizations (D1, D2, D5, D6, D7, D10, D13, D15, D20). Among the obstacles and difficulties, professors mention the resistance of undergraduates to carrying out mandatory readings of texts in the teaching area (D2) and resistance to studying themes and participating in discussions other than traditional Physics content (D1). A professor (D1) adds that he/she realizes that the devaluation and little importance attributed to the themes of the teaching area - related to the belief that these discussions are less relevant than those on the more traditional themes and that they are propagated in the area of Physics - hinder the work of the area of research in Science teaching and in Physics teaching, as well as of the NOS.

A third part of the professors assesses that the quality of the discussions about NOS in their classes is average (D8, D10), noting that many times the undergraduates tend to understand that the knowledge shared in class is absolute and true, even though it is being discussed about the process of constitution and appropriation of knowledge (D8).

A professor (D10) realizes that the quality of classes is more positive when undergraduates can relate discussions about NOS with Physics content. What seems to be an alternative to be reflected to overcome the obstacle mentioned above is that the NOS debate, among other more specific topics in Physics teaching, is not as valued by undergraduates as specific Physics content. Finally, some professors believe that it is possible to perceive a maturation of discussions in the classes throughout the periods of the undergraduate course and, over time, the discussions become more attractive, mature, and in-depth (D6, D7).

- *Articulation between NOS topics and Physics teaching topics and articulation between NOS topics and Physics content*

Professors are unanimous in stating that they consider important the articulation between NOS topics and teaching topics and the articulation between NOS topics and Physics content. The possibilities of articulations between NOS topics and teaching topics and between NOS topics and Physics contents are diverse. According to the beliefs held by university professors, the attempt to promote them in the classroom will depend on the interest and views of the teachers involved in this task.

Most professors claim to promote these articulations in the classroom (D3, D5, D6, D8, D9, D10, D11, D12, D13, D14, D15, D19, D20), although some recognize difficulties in developing them (D4, D7). Those who seek to promote these articulations in their classes believe that it is not possible to dissociate NOS topics and those from Physics teaching, as well as NOS topics and Physics contents, justifying those beliefs about NOS permeate, explicitly or implicitly, the discourse of teachers and researchers (D12).

Hence, among the concerns regarding these articulations, the justification that every discourse or narrative has an epistemological bias is highlighted, including in scientific production and the History of this Science (D11). Despite the unanimity about the importance of these articulations and that some of these professors seek to promote them in classrooms, some recognize the difficulty in developing them, especially regarding the articulations between NOS topics and Physics content. This difficulty is firmly attributed to the tradition of the curricula of Physics undergraduate courses in approaching the conceptual aspects of Physics in a restricted manner and the obstacles they face when trying to incorporate aspects of the NOS in classes (D7, D4).

These beliefs reveal the influence of the academic culture of origin of these professors in their performance concerning provoking changes in their pedagogical practices. This belief of origin prevents changes such as the integration and

articulation of discussions about NOS with emerging social knowledge from the tradition of selected Physics studies and present in university instruction, for example.

Professors recognize difficulties in changing their practices and incorporating discussions that break with the rigidity of the academic culture of Physics. Although professors can interact with different academic cultures and contexts, the culture of origin often conditions their epistemological, professional, and didactic conceptions, as well as their performance criteria, and may thus generate tensions in the performance of professors in the target context [41]. Although most of the university professors interviewed recognize their education to teach in disciplines that contemplate the NOS, which means that they had a formative experience in both contexts, there is a 'hard core' of beliefs of aspects proper to the culture of physicists who are university professors, to a large extent associated with professional identity, resistant to changes, and with a great influence on the modes of action in classes [41].

Professors believe that the articulations between NOS topics and teaching topics and NOS topics and Physics contents that they promote in the disciplines they teach contribute to the teaching practice of the future teacher (D1, D6, D10, D14, D20), to the identification and reflection on the implications of distorted views on Science (D14, D20), to the overcoming of Science learning obstacles (D10, D20), and also allow the future teacher to understand how the construction of Physics school knowledge by basic education students occurs (D6, D20). Professors also reveal that they believe that both articulations in the classes depend on the university professor's education, as well as the interest, view, and epistemological positioning of each one of them (D2, D3, D5, D9, D15). For professors, "I have no doubt that all this is the result of this educational route that each one had, which influences their way of seeing, addressing, and teaching" (D3), yet "it depends a lot on the disciplines, which depends a lot on the professor, on the interest he has, on the view he has" (D2).

In this same sense, one of the professors (D5) recognizes that undergraduate education did not promote these articulations, but that, despite this, he/she is concerned and develops this perspective in his/her classes, believing that he/she has been stimulated by graduate education he/she had. The 'educational route' (mentioned by D2), as well as the recognition of graduate education in teaching in stimulating the promotion of articulations between the NOS topic and teaching and between the NOS topic and Physics content (mentioned by D5), has a certain connection with the discussions on academic culture of origin and culture of destination. Hence, professors need to overcome obstacles, tensions, and dilemmas arising from the decision-making process and the insertion of discussions about the NOS in Science and Physics teaching [4].

In this context, some professors state that, although they consider it important, this articulation between NOS topics and Physics contents in basic Physics disciplines is very unlikely (D1, D2, D9). The belief in improbable articulation is supported and attributed to the education and interest of professors who teach in these disciplines, as already mentioned, and to the influence of traditional textbooks often used as a reference by professors in the organization of the curricular structure of Physics courses. In this regard, some professors mention the importance of disciplines addressing NOS content not only for students of Physics teacher education but also for students of scientific physicists, for example (D1, D11, D12).

All university professors interviewed presented suggestions and alternatives that they consider possible and that they practice in the disciplines they teach to promote articulations between NOS topics and Physics content. Among the suggestions, they mentioned issues related to addressing the historicity and temporality of concepts, laws, and theories (D8), discussing the role of scientific experiments and the controversies and problems in the construction of physical knowledge in an attempt to demystify an 'aseptic' version of Science (D12), as well as questions of a methodological nature, such as discussing the role of experimental activities in Science and school education (D13) and approaches to Science, Technology, and Society (D2).

Regarding the articulation of NOS topics and teaching topics, the professors suggest discussing views of education and views of Science implicit in the choices and methodological decisions related to the strategies used to teach Physics, whether they are experimentation, History, and Philosophy of Science, Science, Technology, and Society, Art and Science, among others (D4). On a methodological level, the professors suggest analyzing didactic materials – textbooks, experiments, documentaries/films – in search of the identification of distorted views about NOS. They also suggest the incorporation of these discussions into lesson plans and activities developed in the supervised teaching internships in Physics teacher education, promoting a philosophically and historically grounded view on Science (D14).

One of the professors (D9), when considering the History and Philosophy of Science as a NOS topic, reports three possibilities of articulations, discouraging the first two and defending the third one. The two views he/she discourages are a view of the History and Philosophy of Science as specific content to be taught and a view of the History and Philosophy of Science as a teaching strategy, often fulfilling a secondary role. The third possibility of articulation, defended by the professor (D9), consists of considering "History and Epistemology more as a posture, a way of understanding things" (D9) and "the historical view can be an approach to knowledge" (D9) and thus it is impossible to separate the History of Science from the Science content itself.

V. DISCUSSION

Our investigation revealed some important correspondences in the beliefs of university professors with the academic and professional culture of the groups to which they belong, the origin, and the destination contexts [41]. Some identify with some tendency or perspective of NOS, whether consensual or renewed, or approach some epistemological perspective of Science in particular, or even understand the NOS area as a

field of study and research.

All university professors support the belief that learning the NOS is important, recognizing its contribution to the Physics teacher's education and to the bachelor undergraduates, who often also will work in PHEI as professors. Furthermore, professors also recognize the role of the discussion on NOS in constructing more refined, more critical, and broad views and conceptions about the progress of Science and the development of scientific knowledge from a more organic understanding of this dynamic. These beliefs align with the indications and suggestions of the literature around the importance of the debate on NOS in Scientific Education [1, 2, 4, 5, 6, 7, 8, 9].

We also identified that most university professors believe that talking about Science, or even the teaching process itself, decisions and choices of the professor in the organization of their practice, although not explicitly, always refer to a view on Science [4]. These professors seem aware of their beliefs and intentions regarding informing, communicating, and teaching about Sciences, do not demonstrate an intention to share a neutral debate and claim to seek alternatives to incorporate important aspects of the theoretical debate and mention oppositions between different approaches in the disciplines they teach.

University professors believe that strict, closed, and distorted views on undergraduates' Sciences, supported based on their experiences of previous education or experiences in the other Physics disciplines of the undergraduate course, hinder and impair the learning of the NOS. This is because many of these views are resistant to questions and tend not to change throughout the course, even though attempts at qualified discussions on the topic are promoted. At this point, the professors consider that the educational routes of the undergraduates are strongly influenced by the beliefs shared by other university professors of the Physics courses who do not have education or concern with the debates about the NOS, which sometimes support little refined epistemological beliefs of mathematically, neutral, strict, closed, and epistemologically empty Science. In this sense, the indications that the debate on the NOS is promoted both in teacher education (teaching degree) and the scientist (bachelor's degree) are extremely relevant [18; 42; 43] and can contribute to overcoming the devaluation of these discussions in Physics courses.

The analyses also considered the beliefs of university professors about NOS teaching regarding the judgment on performance for NOS teaching, the importance of teaching the NOS and its influence on their pedagogical practice, the quality of the discussion on the NOS topic in classes, the articulation between NOS topics and teaching topics, as well as the articulation between NOS topics and Physics content. Most university professors believe they have a high self-efficacy belief in NOS teaching. In other words, they consider that they have a good performance in teaching about NOS, reporting the expressive contribution of graduate studies to their performance in teacher education and to the NOS. Generally, university professors make different assessments about the quality of discussion of the NOS topic in classes and the undergraduates' involvement. While some professors positively assess the work developed in the disciplines they teach around the discussions about NOS, another part assesses that the quality depends on the classes, the difficulties, and the obstacles the undergraduates face.

Among the beliefs expressed by university professors regarding obstacles and difficulties, mention should be made of the fact that undergraduates are used to being more passive and raise few questions in the classroom. At the same time, discussing History, Philosophy, Epistemology, and Sociology of Science and Physics, for example, presupposes less directive and more dialogical dynamics, with opportunities to question and develop some intellectual autonomy. As indicated by university professors, unfortunately, this is an obstacle associated with the teaching faced by undergraduates.

Another important issue expressed in the beliefs of university professors is related to the dilemma professors face when selecting study materials on the NOS for use in the disciplines they teach. The most didacticized texts, when greatly simplified, can lead to a poor-quality discussion, and damage the understanding of central ideas. When very complex, the deeper materials may require greater sophistication in the discussions, and perhaps, the undergraduates may not have enough maturity to follow them.

University professors believe and consider it important to teach about NOS topics that contribute to the understanding of the production of scientific knowledge, such as the History of Science and the Philosophy of Science. Concerning the History of Science, they suggest an internalist approach, from which it is possible to make philosophical interpretations pertinent to historical periods and contexts. Some professors mention these topics as constituents of what they understand as 'a framework of knowledge on the epistemological, philosophical, historical, and cultural bases of Science'.

In previous works, Ferreira and Custódio [12] conduct a documentary analysis from the syllabi of disciplines of the Physics teacher undergraduate courses in Brazilian PHEI to investigate how the debate on the NOS is approached. The authors [12] show that, at a propositional level, the syllabi often present a NOS approach based on the History of Science or the History of Physics. Therefore, besides this propositional level of curricula, it seems that the university professors interviewed also support the belief that a debate on the History of Science should be established in the classroom and that, in addition, the debate should be articulated with the epistemological, philosophical, and cultural considerations and analyses of Science.

The articulation proposed from different theoretical fields of Science is important, considering the main problems pointed out by the literature in the area regarding historical approaches, among which are anachronisms in the decontextualized, mistaken, biased, authoritarian, romanticized, and linear reconstruction interpretation of the History of Science [4, 19]. Although some professors have supported (apparently) more refined beliefs about the importance and adequacy of the use of the History of Science, we recognize the impossibility of all professors mastering and applying well-articulated conceptions about the History and contemporary Historiography of Science, which can assist in the construction of a more adequate, updated,

renewed, or informed conception of the NOS. As evidenced in other investigations, the History of Science is not articulated to the philosophical and epistemological debate in most undergraduate teaching degrees. The philosophical debate has no connection with historical aspects [42, 43, 44, 45].

Regarding the Philosophy of Science, the professors mention the importance of approaching an 'academic' perspective based on the thoughts of Thomas Kuhn, Paul Feyerabend, Karl Popper, and Imre Lakatos, or even on other more contemporary epistemologists and philosophers of Science. The same perspective was evidenced in the documentary analysis conducted by Ferreira and Custodio [12], which suggests the debate on the NOS in the discipline's syllabi, mentions more often that the discussion on the Philosophy of Science is based on these four philosophers and epistemologists of Science. Therefore, in addition to the propositional level of the curricula [12], it seems that university professors also support the belief that the ideas of the Philosophy of Science contribute to a description, explanation, and reflection on the process of knowledge construction in Science and scientific activity, and, consequently, to the understanding of how students, at different levels, understand Science. According to considerations on aspects of Philosophy and Epistemology of Science in the literature in Scientific Education, there is a considerable effort to understand the ideas of these philosophers, epistemologists, and sociologists of Science(s) in the teaching of Physics and their implications for the teaching of Science and Physics, whether in basic or higher education classes.

University professors also suggest exploring distorted images and views about NOS with undergraduates. In the analysis conducted by Ferreira and Custódio [12], mentions of views and conceptions about the NOS in teaching were identified in the syllabi of the disciplines. Thus, it is noted that, besides the propositional level of the curricula, university professors also support the belief about the importance of problematizing views, conceptions, and images about Sciences, which are often considered inadequate. In Science Education literature, there are a set of recommendations on how to map and assess the views of students and teachers [13, 14, 15, 16, 17, 18, 19], as well as which views on Science are appropriate to be built [10]. Some of these instruments and mappings were mentioned by university professors that claim to use them in class.

Moreover, university professors consider important the articulation between NOS topics and teaching topics and the articulation between NOS topics and Physics content. Among the justifications presented by the professors to support their beliefs about this, they mention that it is impossible to dissociate NOS topics and Physics teaching, as well as NOS topics and Physics contents, justifying those beliefs about NOS permeate, explicitly or implicitly, the discourse of teachers and researchers and that these discourses have an epistemological bias, including in the context of scientific production and the History of this Science. Professors also believe that these articulations contribute to identifying and reflecting the implications of distorted views on Science for teaching practice by enabling the future teacher to understand how the construction of school knowledge by students of basic education occurs, as well as to overcome obstacles of Science learning.

Despite the unanimity in considering such articulations important, only part of the university professors claim to promote them in the classroom, and another part recognizes difficulties in doing them, especially concerning the articulations between NOS topics and Physics content. These professors associate the difficulty with the educational routes, the tradition and restriction of the curricula for the Physics teachers' education, and other obstacles they face when trying to incorporate updated discussions about the NOS in Physics classes. In the documentary analysis of Ferreira and Custódio [12], the low frequency of the NOS (only 0.32%) of disciplines that address contents related to social knowledge emerging from the tradition of Physics studies at the university educational level.

In this context, university professors support the belief that the articulations between NOS topics and teaching topics, as well as the articulation between NOS topics and Physics content, in classes and disciplines of Physics undergraduate courses, depending on the education, interest, view, and epistemological positioning of each teacher, and therefore it is unlikely in the Physics teachers' education when carried out in a traditional perspective. In the case of this group of university professors, who consider compatible the education received with the activities they develop, including for the NOS teaching, there is a recognition of graduate education in this sense of breaking with inadequate views and conceptions. Thus, we noticed that university professors' express beliefs very similar to each other to support the justification for the importance of learning about NOS and for the importance of articulation between NOS topics to the methodological debate and between NOS topics and Physics content.

The 'educational route' and the recognition of the role of graduate education in the 'teaching' knowledge area in the sense of stimulating the promotion of the aforementioned articulations - NOS topics and teaching topics, or NOS topics and Physics contents - has a certain relation with the discussions on academic culture of origin and destination of university professors, that is, the context and culture from which they originate, and the route from initial to graduate education and the context and culture where they work [41]. Professors often need to overcome obstacles, tensions, and dilemmas arising from the decision-making process and the insertion of discussions about the NOS in the teaching of Science and Physics [4], which contributes to the recognition that these articulations, encouraged by the literature in Scientific Education, are very unlikely in the education of Physics teachers.

As possibilities for articulation between NOS topics and Physics content, university professors suggest addressing the historicity and temporality of concepts, laws, and theories, discussing the role of scientific experiments and controversies and problems in the construction of physical knowledge in an attempt to demystify an 'aseptic' version of Science, as well as the role of experimental activities in Science and school education, and also the relations between Science, Technology, and Society. As a possibility of

articulation between NOS topics and teaching topics, university professors suggest discussing views of education and Science implicit in the choices and methodological decisions related to the strategies used to teach Physics, whether they are experimentation, History and Philosophy of Science, Science, Technology and Society, Art and Science, analyzing didactic materials in search of the identification of distorted views about NOS, and incorporating these discussions into the lesson plans and activities developed in the supervised teaching internships of the Physics undergraduate courses, promoting a philosophically and historically grounded view on Science. All these suggestions have some approximation, to a greater or lesser extent, with the recommendations of the NOS approach in the literature in Scientific Education [1, 2, 3, 4, 5, 6, 7, 8,9].

VI. FINAL REMARKS

Among the contributions of the research developed, we would like to highlight three main points. The first is the lack of articulation between NOS topics and Physics teaching topics and between NOS topics and Physics content. This is evidenced in the interviews when university professors expressed beliefs about the lack of willingness of undergraduates to reflect on NOS. They even mention a certain unwillingness by other professors to reflect on this issue and incorporate them into the disciplines they teach in Physics teacher education courses. Even those who work with the NOS in exclusive disciplines, entitled Evolution of Physics Concepts or History and Philosophy of Science, face difficulties promoting these articulations when teaching General Physics disciplines, for example.

Furthermore, the weak presence of this type of discussion and the gap of a more qualified debate on the NOS, especially seeking articulations and intersections, leaves room for the epistemological beliefs of undergraduates and university teacher educators to be more valued than knowledge about the broad field of History, Philosophy, Epistemology, and Sociology of Science and Physics, strengthening a naive conception of the NOS, as has been widely criticized by researchers in Science education and Science teachers.

The second point refers to the lack of homogeneity and consensus on what to teach about the NOS. At the limit of the analysis, it is impossible to choose a consensual view among university professors. However, as mentioned by the professors in the interviews, some topics are predominant, such as observation, neutrality, truth, collectivity, and provisionality of the scientific knowledge produced. It seems that there is no clarity about what to teach about the NOS, and even among those who choose a consensual view of the NOS, it is possible to identify divergences so that while some professors choose as indispensable an approach to general themes of the NOS, other professors choose specific ideas presented by epistemologists of Science - Thomas Kuhn, Karl Popper, Imre Lakatos, Paul Feyerabend, and Gaston Bachelard - whose epistemologies have been thoroughly debated, some of them criticized, and some even overcome, or complemented by more recent literature.

The third point refers to the need for updating/renewal in the debate on the NOS in the education of Physics teachers. The analysis of professors' beliefs regarding the NOS and its teaching leaves a predominance of works associated with the consensual view of the Nature of Science, expressed in the works of Gil-Pérez *et al*. [10] and Lederman *et al*. [14], although there are very well articulated criticisms about these works [19, 20, 21, 23, 46, 47, 48, 49, 50, 51].

The fact that renewed perspectives on NOS, expressed in the ideas of Adúriz-Bravo [17], Clough [46, 47], Allchin [20], Irzik and Nola [21], Matthews [23], Martins [19] are little mentioned by university professors is also worrying. Although some professors claim to promote the incorporation of other perspectives and renewed tendencies about the NOS in their classes, most do not do so, either because they are unaware of new approaches, unaware of criticism of traditional views, or even because they believe that the consensual view is compatible and sufficient for an adequate reflection of the NOS. It seems that university professors who develop academic research in History, Philosophy, Epistemology, and Sociology of Science in Scientific and Technological Education are more dynamic and updated in developing strategies for teaching the NOS, also highlighting the importance of integrating research and teaching.

Finally, as a recommendation for scientific education, the Nature of Science, and the professors' beliefs, we point out the need to propose further investigations with university teacher educators. There are a variety of investigations on the topic in the context of basic education, especially with high school students and teachers, on their conceptions and views on the NOS, as well as recommendations on how to teach. However, there is still little research on university teaching, especially among university professors in teacher education. The debate on the consensual and renewed views of the NOS, as well as on teachers' beliefs, proposes a set of research and investigations for the context of basic education, and with rare exceptions, we find the same number and effort of investigations in the context of higher education [18] and teacher education [16, 43, 44, 52]. On the one hand, this gap makes it difficult to establish a more intense dialogue with the literature currently; on the other hand, the various open questions represent a fruitful field for further investigation.

REFERENCES

[1] Martins, R.A. *O que é a ciência do ponto de vista da epistemologia?*, Cad. de Metod. e Téc. de Pes. **9**, 5-20 (1999).
[2] Almeida, A.V. e Farias, C.R.O. *A Natureza da Ciência na Formação de Professores: Reflexões a partir de um curso de Licenciatura em Ciências Biológicas*, Inv. Ens. de Ciên. **16**, 473-488 (2011).
[3] Höttecke, D. e Silva, C.C. *Why Implementing History and Philosophy in School Science Education is a Challenge: An Analysis of Obstacles*, Sci. & Educ. **20**, 293-316 (2011).
[4] Forato, T.C.M., Pietrocola, M. e Martins, R.A. *Historiografia e natureza da ciência na sala de aula*, Cad. Bras. Ens. Fís. **28**, 27-59 (2011).
[5] Forato, T.C.M., Martins, R.A. e Pietrocola, M. *History and Nature of Science in high school: building up parameters to guide educational materials and strategies'*, Sci. Educ.,

21, 657-682 (2012).
[6] Rudge, D.W., Cassidy, D.P., Fulford, J.M. e Howe, E.M. *Changes observed in views of Nature of Science during a historically based unit*, Sci. & Educ. **23**, 1879-1909 (2014).
[7] García-Carmona, A. e Acevedo-Díaz, J.A. *Learning about the Nature of Science using newspaper articles with scientific content: A study in initial primary teacher education*, Sci. & Educ. **25**, 523-546 (2016).
[8] García-Carmona, A. e Acevedo-Díaz, J.A. *Understanding the Nature of Science through a critical and reflective analysis of the controversy between Pasteur and Liebig on fermentation*, Sci. & Educ. **26**, 65-91 (2017).
[9] García-Carmona, A. e Acevedo-Díaz, J.A. *The Nature of Scientific Practice and Science Education Rationale of a Set of Essential Pedagogical Principles*, Sci. Educ. **27**, 5-6, 435-455 (2018).
[10] Gil-Pérez, D. et al. *Para uma imagem não deformada do trabalho científico*, Ciên. & Educ. **7**, 125-153 (2001).
[11] Ferreira, G.K. "Reflexões sobre a Natureza da Ciência: configurações e intenções na formação de professores de Física". Tese de Doutorado, PPG em Educação Científica e Tecnológica, Universidade Federal de Santa Catarina, 2018. Disponível em: <https://tede.ufsc.br/teses/PECT0386-T.pdf>.
[12] Ferreira, G.K. e Custódio, J.F. *Cenários do Debate sobre a Natureza da Ciência nos Cursos de Licenciatura em Física no Brasil*, Cad. Bras. Ens. Fís. **38**, 1022-1066 (2021).
[13] Abd-el-Khalick, F. e Lederman, N.G. *The influence of history of science courses on students' views of Nature of Science*, J. Res. in Sci. Teach. **37**, 1057-1095 (2000b).
[14] Lederman, N.G., Schwartz, R., Abd-el-Khalick, F. e Bell, R.L. *Preservice teachers' understanding and teaching of Nature of Science: An intervention study*, Can. J. Sci., Math., and Techno. Educ. **1**, 135-160 (2001).
[15] Schwartz, R.S., Lederman, N.G. e Crawford, B. *Understanding the Nature of Science through scientific inquiry: An explicit approach to bridging the gap*, Nat. Assoc. Res. Sci. Teach. (Annual meeting), New Orleans, LA (2000).
[16] Gatti, S.R.T, Nardi, R. e Silva, D. *A história da ciência na formação do professor de Física: subsídios para um curso sobre o tema atração gravitacional visando às mudanças de postura na ação docente*, Ciên. & Educ. **10**, 491-500 (2004).
[17] Adúriz-Bravo, A. *A proposal to teach the Nature of Science (NOS) to science teachers: The 'structuring theoretical fields' of NOS*, Rev. Sci., Math. and ICT Educ., **1**, 2, 41-56 (2007).
[18] Ferreira, J.M.H. e Martins, A.F.P. *Avaliando a inserção da natureza da ciência na disciplina de história e filosofia da ciência para graduandos em Física da UFRN*, (Peduzzi, L.Q., Martins, A.F.P. e Ferreira, J.M.H. Temas de História e Filosofia da Ciência no Ensino, EDUFRN, Natal 2012).
[19] Martins, A.F.P. *Natureza da Ciência no ensino de ciências: uma proposta baseada em temas e questões*, Cad. Bras. Ens. Fís., **32**, 3, 703-737 (2015).
[20] Allchin, D. *Evaluating knowledge of the nature of (Whole) Science*. Sci. Educ. **95**, 518-542 (2011).
[21] Irzik, G. e Nola, R. *A Family Resemblance Approach to the Nature of Science for Science Education*. Sci. & Educ. **20**, 591-607 (2011).
[22] Abd-El-Khalick, F. *Teaching with and about Nature of Science, and science teacher knowledge domains*. Sci. & Educ. **22**, 2087-2107 (2013).
[23] Matthews, M.R. *Changing the focus: from Nature of Science to features of science*, (Khine, M.S., Advances in Nature of Science research. Dordrecht: Springer, 3-26, 2012).
[24] Lederman, N.G.; Bartos, S.A.; Lederman, J.S. *The development, use, and interpretation of Nature of Science assessments.* (Matthews, M.R., International Handbook of Research in History, Philosophy and Science Teaching. The Netherlands: Springer, 971-997, 2014).
[25] Tafreshi, D. e Rancine, T.P. *Conceptualizing personal epistemology as beliefs about knowledge and knowing*, Theory & Psycho., 1-18 (2015).
[26] Hofer, B.K. *Personal epistemology research: implications for learning and teaching*, Educ. Psycho. Rev. **13**, 353-383 (2001).
[27] Yerrick, R., Parke, H. e Nugent, J. *Struggling to promote deeply rooted change: The "filtering effect" of teachers' beliefs on understanding transformational views of teaching science*, Sci. Educ. **81**, 137-159 (1997).
[28] Tsai, C.C. *Nested epistemologies: Science teachers' beliefs of teaching, learning and science*, Inter. J. Sci. Educ. **24**, 771-783 (2002).
[29] Markic, S., Valanides, N. e Eilks, I. *Freshman science student teachers' beliefs on science teaching and learning–a mixed methods study*. (Eilks, I. e Ralle, B., Towards research-based science teacher education, Shaker-Verlag, Aachen, 2006).
[30] Jones, M.G. e Carter, G. *Science teacher attitudes and beliefs*. (Abell, S.K. e Lederman, N.G., Handbook of research in science education, Routledge, New York, London, 2007).
[31] Wang, H.A.; Marsh, D.D. *Science instruction with a humanistic twist teachers' perception and practice in using the history of science in their classrooms*, Sci. & Educ. **11**, 169-189 (2002).
[32] King, B.B. *Beginning teachers' knowledge of and attitude towards history and philosophy of science*, Sci. Educ. **75**, 135-141 (1991).
[33] Wang, H. e Cox-Peterson, A. *A comparison of elementary, secondary and student teachers' perceptions and practices related to history of science instruction*, Sci. & Educ. **11**, 69-81 (2002).
[34] Hulling, M.D. "The Effect of Teachers' Epistemological Beliefs on Practice", Graduate School Theses and Dissertations, University of South Florida, 2014. Disponível em <http://scholarcommons.usf.edu/etd/5044>.
[35] Feucht, F. "The nature of epistemic climates in elementary classrooms", Doctoral Dissertation, University of Las Vegas, 2008 (unpublished).
[36] Feucht, F. e Bendixen, L.D. *Personal epistemology in the classroom: A welcome and guide for the reader*, (Bendixen, L. e Feucht, F., Personal Epistemology in the Classroom. Cambridge University Press, New York, 2010).
[37] Patrick, H. e Pintrich, P. *Conceptual Change in teachers' intuitive conceptions and epistemological beliefs*, (Torf, B. e Sternberg, R.J., Understanding and teaching the intuitive minds. Lawrence Erlbaum Associates, Mahwah, NJ, 2001).
[38] Schraw, G. e Olafson, L. *Teacher's epistemological worldviews and educational practices*, Issues in Education **8**,

99-148 (2002).
[39] Ferreira, G.K e Custódio, J.F. *Crenças de Docentes Universitários sobre a Natureza da Ciência: validação de um protocolo de entrevista*, Simpósio Nacional de Ensino de Física, Salvador, BA (2019).
[40] Mortimer, E. F. Conceptual change or conceptual profile change? (1995) Sci. & Educ. **4**, 265-287 (1995).
[41] Milicic, B., Sanjosé, V., Utges, G. e Salinas, B. *La cultura académica como condicionante del pensamiento y la acción de los profesores universitarios de física*. Inv. Ens. de Ciên. **12**, 263-284 (2007).
[42] Rosa, K. e Martins, M.C. *A inserção de História e Filosofia da Ciência no Currículo de Licenciatura em Física da Universidade Federal da Bahia: Uma visão de professores universitários*, Inv. Ens. de Ciên. **12**, 321-337 (2007).
[43] Tenfen, D.N. "Mapas conceituais como ferramentas para a organização do conhecimento em uma disciplina sobre a história da física", Dissertação de Mestrado, PPG em Educação Científica e Tecnológica, Universidade Federal de Santa Catarina, 2011. Disponível em: <https://www.tede.ufsc.br/teses/PECT0143-D.pdf>.
[44] Pereira, G.J.S.A. e Martins, A.F.P. *A inserção de conteúdo histórico-filosófico no currículo dos cursos de Licenciatura em Física e em Química da UFRN: Uma análise comparativa*, Cad. Bras. Ens. Fís. **28**, 229-258 (2011).
[45] Londero, L. *A História e a Filosofia da Ciência na formação de professores de Física: controvérsias curriculares*, Hist. da Ciên. e Ens. **11** (2015).
[46] Clough, M.P. *Learners' responses to the demands of conceptual change: considerations for effective Nature of Science instruction*, Sci. & Educ. **15**, 463-494 (2006).
[47] Clough, M.P. *Teaching the Nature of Science to secondary and postsecondary students: Questions rather than tenets*, The Pantaneto Forum. **25** (2007).
[48] Van Dijk, E.M. *Portraying real science in science communication*, Sci. Educ. **95**, 1086-1100 (2011).
[49] Duschl, R.A. e Grandy, R. *Two views about explicitly teaching Nature of Science*. Sci. & Educ. **22**, 2109-2139 (2013).
[50] Forato, T. C. M., Bagdonas, A. e Testoni, A. *Episódios históricos e natureza da ciência na formação de professores*, Ens. de las Cien., nº extraordinário, 3511-3516 (2017).
[51] Rodríguez, R.Y.A. e Adúriz-Bravo, A. *Concepciones emergentes de naturaleza de la ciencia para la didáctica de las ciências*, Ens. de las Cien., nº extraordinário, 3499-3504 (2017).
[52] Adúriz-Bravo, A., Izquierdo, M. e Estany, A. *Una propuesta para estructurar la enseñanza de la filosofia de la ciencia para el profesorado de ciencias en formación*. Ens. de las Cien. **20**, 465-476 (2002).