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A Systematic Review of Studies about Conceptions on the Nature of Science in Science Education

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The nature of science (NOS) has been highlighted as an important component of science education, since scientific knowledge can contribute to decision-making by contemporary citizens. There are few quantitative review studies in the field of science education. Given the importance of the topic, and the need to organize and understand the knowledge produced by research on conceptions of NOS, we carried out a systematic review based on the principles of PRISMA, in order to quantify and initiate reflection on (i) the publication trends of articles on NOS conceptions (ii) the main characteristics of these articles, (iii) the NOS aspects frequently cited as important for teaching, and (iv) the main strategies used to access NOS conceptions. We analyzed 396 articles published up to February 2015 in Teaching and Education journals listed on WebQualis 2013. Our systematic review represented an initial effort to present an overview of the area, and enabled us to identify research trends and gaps. Investigational efforts are needed to investigate NOS conceptions in the Brazilian context that are associated with the teaching of specific disciplines. We found twenty-five NOS aspects reported to be important for teaching, addressed part of the debate on consensus and the lists of NOS aspects, and presented general characteristics of the main questionnaires used to investigate NOS conceptions.

Keywords: conceptions of science; consensus view; lists of NOS aspects; NOS lists; NOS views; research methods; research trends; systematic review; survey instruments.

Introduction

Students at different levels of education can demonstrate conceptions of science, and of the work of scientists, that are far removed from reality. The distance between students' conceptions and the reality may be due to the existence of a biased and decontextualized image associated with science and the work of scientists that is constantly being reinforced outside the classroom (Hodson, 1998). Identifying students' conceptions of science can help the teacher plan their classes better and identify the degree of distortion of the students' image of science. In an attempt to make sense of what they have learned, students think about scientific concepts based on their conceptions. There is, therefore, a potential discrepancy between the conceptions of the teacher, those of the students, and even those of the teaching material, which can make the proposal of critical learning challenging, as the students' epistemological beliefs may influence their learning process (Lidar, Lundqvist, & Ostman, 2006).

Despite the role that out-of-school experiences can play in an individual's views of science, the classroom can sometimes reinforce inadequate conceptions of science (Gil-Pérez, Fernández, Carrascosa, Cachapuz, & Praia, 2001). This is particularly true when the science teaching and learning process is based on the mere transmission of concepts, in which students are expected to simply repeat and memorize definitions, without being given any opportunity to observe, understand and reflect on the process of production of scientific knowledge. The literature indicates the existence of inadequate conceptions about science at various levels of education (e.g., Abd-El-Khalick & Lederman, 2000, Ajaja, 2012, Hacieminoglu, Yilmaz-Tuzun, & Ertepinar, 2012, Moss, Abrams & Robb, 2001, Waters-Adams & Nias, 2003), declaring the need to understand the factors that lead to such conceptions, to reflect on the knowledge that has been built in the area, and to rethink strategies that are effective in overcoming misinformed conceptions about science.

The existence of inadequate conceptions about science at different levels of education is worrying, given that scientific topics are increasingly present in everyday life, requiring citizens to make different decisions, such as critically evaluating whether to undergo a particular health treatment or adopt a certain diet, or which electronic equipment to buy. These decisions need to be meaningful, and students therefore need to know, for example, that scientists also make mistakes and that there are several sources of bias in scientific work. In many everyday situations, students need to know how to assess the quality of data and arguments in order to make their decisions (Fourez, 1997; Hodson, 2001), because in science, the way scientists generate data and validate knowledge is much more important than the statements that are produced (Lemke, 2001). Thus, the process of teaching and learning science must consider the dimensions of "*learning science*" (conceptual and theoretical knowledge), "*doing science*" (engagement in problem solving), "*learning about science*" (characteristics of the knowledge building process and relationships between science, technology, society and the environment) and learning to deal with socio-scientific issues (facing different aspects when making decisions about socioscientific topics) (Hodson, 2014, p. 2537). Conceptual learning has been strongly prioritized in science classes, where the current model of teaching and learning is still focused on a teaching pattern based on rote learning (Carvalho 2006; Figueirêdo & Justi, 2011; Freitas, 2008). On the other hand, Hodson (2014) argues that all dimensions involved in the objectives of science education are equally important.

In this scenario, science education researchers have investigated students' conceptions in an attempt to understand them and to construct a theoretical-practical corpus capable of contributing to a style of learning that involves a contextual (Allchin, 2011; Azevedo & Scarpa, 2017) explicit and reflective approach to the nature of science (Duschl & Grandy, 2013, Khishfe, 2014, Lederman, 2007, Matthews, 1992). We therefore believe that learning sciences must enable an understanding of how scientific knowledge is produced, validated and communicated, explicitly considering the epistemological particularities of science.

The term nature of science (NOS) is used by some authors to refer to the nature of scientific knowledge or the epistemology of science (e.g., Abd-El-Khalick & Lederman, 2000; Lederman, 1992). Others differentiate the nature of scientific knowledge from the nature of scientific research (e.g., Schwartz et al., 2008), restricting the processes through which knowledge is produced and justified in the latter category. Despite the different names given to it, there is a relative consensus that the fundamental aspects of NOS include: the characteristics of scientific research (its stages of research and methods), the role of knowledge generated, the paradigms that guide the work of scientists, how scientists work as a social group, and how science can be affected by the social context in which it operates (Clough & Olson, 2008; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Wong & Hodson, 2009).

The literature provides numerous justifications for including reflection on the process of producing scientific knowledge in the classroom (e.g., Bell & Lederman, 2003, Clough & Olson, 2008, Hodson 2001, Osborne et al., 2003; Taber, 2010) and NOS has been considered an important component in the global science education curricula (Abd-El-Khalick et al., 2004, Khishfe & Abd-El-Khalick, 2002, Ogunniyi, 2005). For these reasons, investigating NOS conceptions has become a relevant area associated with research on the teaching of science (Lederman, 1992) at various levels of education. Some traditional reviews (e.g., Abd-El-Khalick & Lederman 2000; Lederman, 2007) have already proposed summarizing some aspects of this area of research, yet taking into account the limited number of articles published in the English language.

Therefore, given the importance of the topic, considering that there are few review articles in the field of science education (Tsai & Wen, 2005), and in view of the need to organize and understand the knowledge produced by researches on conceptions of NOS, our objective here is to produce a systematic review that includes not only English-language journals, but also Latin American ones, in particular, as well as presenting a more quantitative view of what has been produced in the area of NOS, in order to reflect on the information provided by these articles.

This systematic review was part of the first stage of a more extensive research, which aimed to construct a contextualized instrument for investigating NOS concepts among Brazilian biology undergraduates (Azevedo & Scarpa, 2017). A preliminary survey indicated the need to take a structured and careful look at the large amount of studies focused on investigating NOS conceptions. This need led us to look for a methodology capable of mapping articles published in the area in a strategic and systematized way, in order to find possible answers that could guide the elaboration of a relevant and significant survey instrument for research on NOS in science education that would be effective in investigating NOS conceptions. Thus, the present systematic review aims to quantify and present exploratory analyses on the current context of research on NOS conceptions, in order to shed light on the contexts in which research efforts may still be necessary. Therefore, the review is guided by the following questions:

(i) What are the publication trends of articles on NOS conceptions?

We intend to investigate whether this type of research is growing and whether there is a profile of journals that publish these articles more frequently.

(ii) What are the characteristics of these articles?

We are interested in mapping (a) the most common research focuses, (b) whether there are disciplines or areas of knowledge that are more interested in understanding the conceptions of an audience, (c) what is the study focus in research on NOS conceptions (d) in which countries are NOS conceptions investigated most often.

(iii) What aspects of NOS are usually listed as important for teaching in these articles?

Knowing that there is an array of aspects frequently reported by various authors as relevant to teaching, we intend to identify which aspects are these.

(iv) What are the main strategies used to access NOS conceptions?

We are interested in investigating whether questionnaires, interviews or other means of accessing NOS conceptions are used. In the case of more recurrent instruments, we intend to identify their main characteristics, in terms of form and content.

Methodology

To plan the review, we adopted the principles formulated by PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyzes*), due to the clarity of its instructions and its recognized validity in different areas of research. The principles established by PRISMA are the result of the collective construction of a group of researchers interested in organizing knowledge and synthesizing relevant information. The systematic review adopted by PRISMA examines a relevant issue for a particular area, using "*systematic and explicit methods to identify, select and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review*" (Moher et al., 2009, p. 1).

Although the principles formulated by PRISMA focus on systematic reviews of areas of research such as Health, the transparency and replicability of its stages seem appropriate for accurate reviews in the area of Humanities as well. Reviews of the area of Education generally follow a model in which the authors start with sampling that is not systematized, and criteria that are not explicit. This type of review can be defined as a traditional or narrative review, and consists of describing and appraising previous studies, but without describing the specific methods used to identify, select and evaluate the reviewed studies (Knopf, 2006). Thus, although such a review model gives an overview and relevant critical discussions on previous articles, the selection of articles for a review of this nature remains unknown to readers, and may carry a number of biases that dictate whether or not certain works of literature should be included.

Well-established protocols such as PRISMA are relevant because the quality of the reports present in traditional reviews can vary, limiting the readers' interpretation of the real gaps in a given area. The principles of PRISMA allow us to build a comprehensive overview through explicit processes and methodological assumptions that are replicable by other researchers. These principles make it possible to describe a broad panorama of studies on NOS in science education.

Within this setting, we sought to follow every PRISMA's recommendations, incorporating the following steps in our review: (i) identification, screening and selection of relevant publications, (ii) critical evaluation of the selected articles, and (iii) clear presentation of results (Moher et al., 2009). Besides summarizing the studies of interest in a given subject area, the systematic review is intended to be clear and precise in its review protocol (or method). These steps are explored in detail in the following sections, the content of which was taken from the recommendations laid down by PRISMA.

Search strategy and selection of appropriate sources of information

An initial exploratory search was conducted in the *Web of Science* and *Scopus* databases. In this phase, we sought to identify the search terms that would be more inclusive for the purposes of our study, and to assess whether the journals indexed in these databases are representative of the areas of Teaching and Education, considering the context of Brazilian research. The choice of these databases would facilitate the organization of our database of articles and the quantification of some information, especially due to the possibility of exporting the search term and citation reports. However, Brazilian journals, like those of other developing countries, have difficulty integrating their scientific production into international scientific information bases (Packer, 2011). Spanning all areas of knowledge, *Web of Science* has a total of 11,500 indexed journals, while *Scopus* has 29,385. Of these, only 114 and 309 journals, respectively, are Brazilian (Rodrigues, Quartiero, & Neubert, 2015). In our opinion there is also a large number of relevant articles in the areas of Teaching and Education that are not published in English (the dominant language in these databases). Accordingly, due to the number of publications in Portuguese and Spanish in our area of interest, we would not have been able to identify relevant articles published in non-indexed Latin American journals, had the search been done another way.

In this scenario, we chose to systematize the searches using a comprehensive list of journals, which would allow us to establish a broad search and a certain degree of reliability in the generalization of the data. The list of the Qualis Journal Program of the Coordination for the Improvement of Higher Level Personnel (CAPES), known as WebQualis, appeared to be a good option. WebQualis is derived from the *Web of Science* indicator (Packer, 2011) and is the result of a set of procedures adopted by CAPES to categorize the quality of the intellectual production of graduate programs. This procedure involves analyzing the quality of the scientific journals in which the evaluated programs have been published (CAPES, 2015). The journals are stratified into seven categories that indicate their quality, with A1 being the highest, followed by strata A2, B1, B2, B3, B4, B5 and C. The evaluation is performed by different areas, which can independently delimit their assessment criteria and cut-off points for inclusion of a journal in a given stratum. The same journal may be evaluated by different areas, and can therefore be classified in different strata in each area. The criteria adopted in each area for this stratification are established by a group of experts from these areas. The list of journals is updated every three years, and published, along with the inclusion criteria of the journals, by stratum, according to area (CAPES, 2015).

The factors that formed the basis of our decision to use the WebQualis list included the following: (i) using a list as a starting point could facilitate a search outside the indexers, as it would facilitate the organization of a specific database for our review; (ii) the inclusion and quality criteria of the journals have already undergone a broad peer assessment and are published with easy access; (iii) the list includes a larger number of journals than the indexed databases, which may allow for more inclusive searches, and (iv) as the list includes a larger number of Latin American journals, we were able to conduct a broader and more contextualized assessment of the articles.

Selection and exclusion criteria

For the selection of journals, we considered those from strata A1 to B3, in the areas of Teaching and Education, listed in WebQualis 2013. However, from this list, we excluded all the journals whose focus on Teaching or on Education was not explicit on their respective websites. This decision was based on the fact that many journals have special sections or issues devoted to Teaching and Education, which leads to them being included by those areas in the WebQualis list. However, these journals do not often publish articles with this focus, they do not have editorial staff in these areas, and they are not very significant for researchers interested in articles about NOS. Science education journals in general, which may or may not involve themes of technology, mathematics and society, along with all the Education journals, including those focused on higher education, remained on the list. Journals on teaching in very specific areas such as Statistics, Geology, Astronomy and disciplines associated with Health, for example, were excluded. The full list of journals that we consulted is shown in *Appendix*.

For the selection of articles, we identified the main expressions used in the titles and keywords and organized a search list (Figure 1). For the selection of articles about NOS, we accessed the website of each of the selected journals and searched for articles on each website by following the list of terms. We considered all articles published up to February 2015. Thus, we did not establish an initial year of publication for inclusion of the article in our database, as we intended to include as many articles as possible. We did not count publications characterized as letters, editorials, reviews and comments.

Thus, our systematic review involved four major steps (Figure 2): (i) identification (selection of the journals and a preliminary review of the articles), (ii) screening (where a more detailed reading of the articles led to the exclusion of those in which NOS conceptions were not the main focus), (iii) eligibility (detailed analysis of the articles) and (iv) inclusion (closing the database). Note that after the initial article selection stage, we excluded articles covering other conceptions (for example: conceptions about the theory of evolution or about the concept of force), duplicate articles published in more than one journal (in different languages or with variations of writing and structure) and those for which the full text was not available.

Language	Search terms
Portuguese	natureza da ciência, concepção/concepções de ciência, imagem/imagens da ciência, visão de ciência
English	nature of science (NOS), views of nature of science (VNOS), images of science, beliefs about nature of science, scientist work
Spanish	naturaleza de la ciencia, concepciones epistemologicas, percepción de la ciencia

Figure 1. Lists of search terms used for the article searches directly on the website of the selected journals

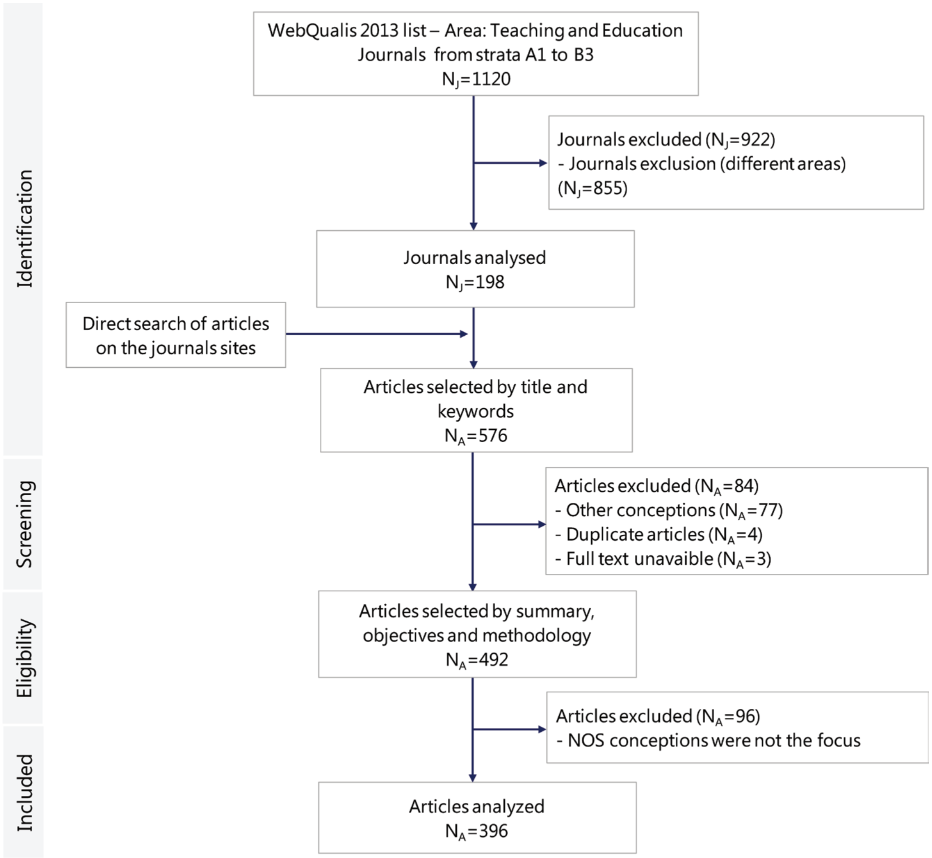

Figure 2. Diagram, according to PRISMA criteria, representing the sampling of articles at each stage of our systematic review. Caption: N_J corresponds to the number of journals and N_A, to the number of articles.

Extracting information from the articles, and analyses

We created *a priori* categories to classify the articles according to the objectives adopted for this review (Figure 3). However, the categories were constantly refined throughout sampling and readings. Since the systematic review is an iterative process (Moher et al., 2009), in which the classification of the articles occurs dynamically, it is not possible to delimit all the stages of the *a priori* methodology. Where necessary, articles already categorized were reevaluated according to the new classification categories. All the review stages were tabulated along with the classifications we adopted. In order to allow the retrieval of information and minimize the chance of errors, no article was deleted from our database.

Review question	Category description	Category divisions
(i) What are the publication trends of articles on NOS conceptions?	Qualis of the journal. Year of publication of the article.	
(ii) What are the characteristics of these articles?	Disciplines or area of knowledge associated with NOS conceptions.	We separated the articles according to the discipline associated with the journal or the topic of the article. The categories are: biology, physics, chemistry and general sciences.
	Type of article, according to the focus defined by the authors.	We separated the articles according to the objectives reported by the authors: articles that investigate NOS conceptions of a group, theoretical position of the authors, traditional literature review, creation of a new instrument to evaluate NOS conceptions and other types of review.
	Study focusing on articles that investigate NOS conceptions.	We created 13 subcategories according to the focus on one or more research subjects: teachers, secondary school students, teachers in training, primary school students, textbooks, teachers and students, undergraduates, materials produced by the teacher, scientists, newspapers and mass media, videos (cartoons, films and documentaries), curricular guidelines, the general public.
	Geographical origin of the research subject.	Nationality of what is being investigated in the study (e.g., audience, textbook/didactic material).

Figure 3. Article classification categories according to the review objectives (continue)

Review question	Category description	Category divisions
(iii) Which NOS aspects are usually listed as important for teaching in these articles?	List of aspects reported in the articles, regardless of the number of times the aspect NOS appears.	
(iv) What are the main strategies used to access NOS conceptions?	Type of strategy, with or without the use of a survey instrument.	If a survey instrument is used, what is the name of the instrument used in the article.

Figure 3. Article classification categories according to the review objectives

Results and Discussion

What are the publication trends of articles on NOS conceptions?

The identification of journals of the Teaching and Education areas of the WebQualis 2013 list resulted in a new list of 198 journals (Figure 2, Identification stage). The journals are listed in the *Appendix* at the end of the article). We found articles on NOS conceptions in 61 journals, of which 19 are Brazilian. After selection and screening (Figure 1), we obtained 396 articles. Stratum A1 had the highest occurrences of articles, representing 70.7% of the sample (Number of articles=N_A=280). In the A2 and B1 journals we recorded 12.6% (N_A=50) and 14.7% (N_A=58), respectively, while there were only 2% (N_A=8) in the B2 journals, and none in the B3 journals.

The article *Science Teaching and the Nature of Science* (Robinson, 1965) was the oldest to emerge from our sampling. We recorded growth of studies on NOS conceptions (Figure 4) based on the publications of WebQualis 2013 journals and on the *Web of Science* publications. However, the WebQualis list appears to be more inclusive (for the search terms that we used), and may provide a better quantitative notion of the production of the area for the period studied. In answering our review questions, in the following sections, we sought to determine how this review provides evidence of the broadening of the scope of traditional reviews published previously.

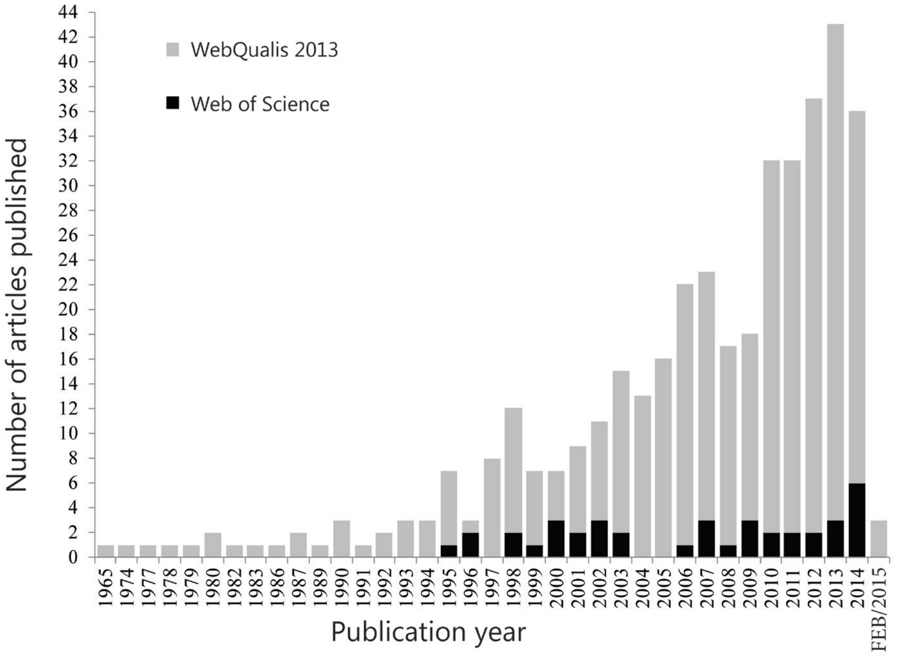

Figure 4. Comparison of the number of articles on NOS conceptions published annually (from the first incidence until February 2015) in the strata A1 to B3 journals, in the areas of Teaching and Education, listed in WebQualis 2013 (in gray) and in journals indexed in the Web of Science database (in black).

What are the characteristics of articles on NOS conceptions?

Interest in the investigation of NOS conceptions varies according to the area of knowledge (Table 1). Articles associated with science education journals (without detailing one of the natural sciences) were the most prevalent, representing 64.7% of studies on NOS conceptions. This fact is understandable, since the scope of these journals involves a broader set of topics and targets different levels of education. The journals associated with Biology education had the lowest number of articles, representing less than 10% of the sampled articles on NOS conceptions. Physics education journals published twice as many articles on the subject as those on Biology education in the same period.

Table 1. Area of knowledge involved in the surveys of NOS conceptions, according to the articles published up to February 2015 in strata A1 to B3 journals listed in WebQualis 2013 in the areas of Teaching and Education.

Area associated with the study	Number of articles	Proportion (%)
General Science	256	64.7
Physics	58	14.6
Chemistry	53	13.4
Biology	29	7.3

In the Brazilian context, the area of Physics education is older than Biology education, a fact that may be related to a greater tradition in surveys in the area of Physics education. This effort may also be related to attempts made by Physics education researchers to deal with the common reserve among students when it comes to studying disciplines of exact science.

The limited number of NOS articles associated with the Biology area merits attention, especially when we consider that Biology covers a range of sciences (Botany, Zoology, Physiology, Genetics, Ecology, Evolution, etc.) with particular methods and practices. Identifying the interest of researchers of the various sciences seems appropriate, since each area has some degree of idiosyncrasy, and may consider certain aspects of NOS as being of greater or lesser importance. For example, there is the differentiation of laws and theories, which may make sense for areas such as Physics, but is debatable for the area of Biology (e.g., Mayr, 2004; Rosenberg, 2008). In the same vein, we can think about the prominent role of experimentation in some areas of Biology and Chemistry. However, such practices are not the only ones contemplated as science methods. There are other ways of producing scientific knowledge, such as case studies (Shrader-Frechette & MacCoy, 1994), present in the natural and social sciences (Bayir, Cakici, & Ertas, 2014) and comparative studies (Shrader-Frechette & MacCoy, 1994). Nevertheless, certain classroom practices and many Biology teaching materials, for example, have historically emphasized a distorted view of the area, favoring the image that science is only done with experimentation (Marandino, Selles, & Ferreira, 2009). We emphasize that greater investments in the area of Biology education are required by researchers, in order to investigate NOS conceptions and aspects, and thereby contribute to the reflection on the different dimensions of the goals of science education in the field of biology as well.

Regarding the types of articles, 57.8% are studies on NOS conceptions of a particular group (Table 2). There are articles (35%) in which the authors present their positions (i) in favor of approaches that improve the NOS conceptions of an audience, (ii) advocating for the inclusion of certain aspects of NOS in the curriculum (discussion presented in more detail in the section on *Which aspects of NOS are usually listed as important for science education?*), (iii) criticizing the methods used to access NOS conceptions, or (iv) primarily sharing information with other works. In other articles (4%), the authors set out to conduct a traditional review of the area, including, according to them, key references on the subject and exploring them critically. A small number of articles (2.3%) were focused on presenting a new instrument for accessing NOS conceptions.

Although the creation of new instruments is not a trivial task, as it demands rigor in both their elaboration and validation, we expected this number to be higher, since there is a growing concern in the literature about the limitations of existing instruments, which leads us to question whether the development of more sensitive instruments is needed. In this regard, we sought to present a more contextualized overview in the section *What are the main instruments used to access NOS conceptions?* presented below. Less than 1% of the articles were aimed at quantifying publications with some specific focus (they chose a given scientific event/meeting or journal for sampling and analysis). In fact, the highest number of articles on NOS conceptions is focused on the investigation of conceptions (as reported in the traditional review of Lederman, 2007). However, a significant portion is also concerned with specifically discussing works produced in the area, focusing on elements such as: comments on the results of a selection of articles, discussion on NOS elements that should be part of the curriculum, or strategies to improve the NOS conceptions of a group.

Table 2.Types of articles on NOS conceptions published up to February of 2015 in strata A1 to B3 articles listed on WebQualis 2013 in the areas of Teaching and Education.

Type of article	Number of articles	Proportion (%)
Study of NOS conceptions of a group	229	57.8
Theoretical positioning	139	35.1
Traditional literature review	16	4.0
Creation of instrument	9	2.3
Other types of literature review	3	0.8

In terms of the total number of articles identified and categorized, this review shows quantitative indications of having broadened the scope of previous reviews, especially with regard to the understanding of which contexts may require additional research efforts. An initial point to note is that we did not find any systematic reviews related to the area of NOS (Table 2). The reviews that we found analyzed a limited number of articles, published in English, or articles available in the annals of scientific events. In addition, traditional review articles from the literature represented a low percentage of the total number of articles, especially if we consider that the publication of the oldest article in our survey dates back more than 60 years. Although traditional reviews are of the utmost importance, as they promote critical discussions that are relevant to the area, the fact that the authors do not explain their selection criteria for the articles discussed may lead to substantial bias, particularly when considering works produced by a specific group of researchers. In our survey we highlight the traditional reviews of Lederman (1992), Koulaidis and Ogborn (1995) and Harres (1999), whose comments are presented in some points of our discussion.

Lederman (1992) provides an overview of some empirical surveys of conceptions of NOS among students and teachers produced in the 40 years prior to the publication of the article (as we verified in the list of references of the article). The author reviewed the results of about twenty works related to students' conceptions, besides promoting discussion on the possible implications of teachers' conceptions of NOS for science education. Among the main conclusions of Lederman's review, he emphasized that (i) science teachers do not have adequate conceptions of NOS; (ii) the teachers' academic background is not related to their conceptions of NOS; and (iii) the improvement of teacher conceptions was associated with strategies that involved history of science and attention to NOS.

In regard to the study focus of articles investigating NOS conceptions (Table 3), about 30% of the studies focused on the conceptions of basic education teachers. Of these, 22.5% investigated the NOS conceptions of teachers, while 7.1% involved comparisons between the NOS conceptions of teachers and those of their students. Approximately 32% of the articles focused on the NOS conceptions of students (primary and secondary education), and a smaller number of articles dealt with didactic and instructional material (such as lesson planning, exercise lists, assignments, survey activities and laboratory scripts) produced by the teacher.

Table 3. Focus of study on articles that investigate NoS conceptions published up to February 2015 in strata A1 to B3 journals of the WebQualis 2013 list in the areas of Teaching and Education.

Study focus	Number of articles	Proportion (%)
Teachers	89	22.5
Secondary school students	67	16.9
Teachers in training	63	15.9
Primary school students	62	15.7
Textbooks	39	9.8
Teachers and students	28	7.1
Undergraduates	17	4.3
Material produced by the teacher	10	2.5
Scientists (all areas of knowledge)	7	1.7
Newspapers and mass media	5	1.3
Videos (cartoons, films and documentaries)	4	1.0
Curricular guidelines	3	0.8
General public	2	0.5

The focus of NOS conception survey articles is notably on basic education. In addition to articles that are focused on teachers and students, there is also a portion that investigate NOS conceptions of teachers in training (15.9%). A few surveys focus on mapping what is disseminated outside the classroom, surveying the NOS conceptions present in the media (2.4%) or among the general public (0.5%). Articles that seek to verify the possible consensuses between diverse areas of knowledge and evaluate the NOS conceptions of scientists and of curricular guidelines also represent a limited portion (2.5%).

In regard to the focal point of articles, the traditional review by Lederman (1992) cited works published between 1950 and 1991 in about ten English-language journals. The author proposed a classification of studies on NOS conceptions into four categories: (i) works on NOS conceptions among students; (ii) works on NOS conceptions among teachers; (iii) works on NOS conceptions in the school curriculum; and (iv) works that related the implications of teacher praxis to the NOS conceptions of their students. The focal point of this review differs from that of Lederman, who adopted the principles of a traditional review and focused, specifically, on the results of a group of works he had selected. In the final considerations, Lederman stated that teachers are expected to be able to bring about changes in the students' conceptions of NOS, even if they themselves have inadequate conceptions that conflict with the desirable conceptions of science advocated by the science curriculum up to that time. From the time of Lederman's review (1992) until January 2015, there has been a significant increase in the number of works, as shown in Figure 4.

In our survey, the limited number of articles that investigate N0S conceptions among undergraduate students and scientists was another factor that attracted our attention. While interest in conceptions of NOS related to elementary education is essential, given the objectives of science education, the understanding of science at other levels of education cannot be overlooked. The act of surveying the NOS conceptions among undergraduate students and scientists is relevant because it enables us to detect how this group views the construction of knowledge, and how certain myths can also be rooted in the academic setting (Feldman, Divoll, & Rogan-Klyve, 2013, Harding & Hare, 2000).

Table 4. Countries in which NOS conceptions (among different audiences or teaching materials) were the focus of 229 articles that investigate conceptions of NOS published up to February 2015 in A1 to B3 strata journals listed in WebQualis 2013 in the areas of Teaching and Education.

	Countries	Number of articles	Proportion (%)
1	United States	48	21.0
2	Taiwan	24	10.5
3	China	17	7.4
4*	Brazil, England	16*	7.0*
5	Turkey	13	5.7
6	Canada	11	4.8
7	Argentina	10	4.4
8	Spain	9	3.9
9	South Africa	8	3.5
10*	Colombia, Mexico	7*	3.1*
11	Germany	6	2.6
12*	South Korea, Israel	5*	2.2*
13*	Australia, Nigeria	3*	1.3*
14*	Cyprus, Egypt, Netherlands, India, Japan, Portugal	2*	0.9*
15*	Saudi Arabia, Bolivia, Singapore, United Arab Emirates, Philippines, Iran, Norway, New Zealand, Thailand	1*	0.4*

[*] The lines with more than one country indicate the number of articles and the proportion for each one.

The countries in which conceptions of NOS are more commonly studied (among different audiences, textbooks/teaching material) are the United States and Taiwan (Table 4). Brazil occupies fourth place, along with England (with 7% of the works each). Although we attempted to investigate Latin American journals with the choice of the WebQualis 2013 list, this effort was not reflected in a high total number of articles that focus on Latin American audiences or materials. On the other hand, this decision resulted in the fact that the list of journals includes a wider variation of nationalities in the sample, ensuring representativity (albeit small) of other countries (Table 4).

Which NOS aspects are usually listed as important for science education?

To identify the NOS aspects considered relevant, we concentrated on the 229 articles that focus on survey of conceptions. In about 48% of these articles (N_A=109), the authors discuss the aspects of NOS that are investigated throughout the study (Figure 5). In 36% of the articles (N_A=83), the authors use lists of NOS aspects to analyze NOS conceptions in a particular audience, but the implications of these aspects are not discussed based on the audience surveyed. In the remaining 16% of NOS conception survey articles (N_A=37), the authors did not describe the NOS aspects that were surveyed.

Table 5. Approaches used by the authors to discuss aspects of NOS, in the 229 articles that investigate NOS conceptions published up to February 2015 in the strata A1 to B3 journals listed in WebQualis 2013 in the areas of Teaching and Education.

Approach used by the authors	Number of articles	Proportion (%)
Use of lists of NOS aspects, with discussion of the NOS aspects investigated	109	47.6
Use of lists of NOS aspects, no discussion of the NOS aspects investigated	83	36.2
The authors do not describe the NOS aspects investigated	37	16.2

Based on the 192 articles that considered lists of NOS aspects to survey conceptions, we organized the aspects that are usually investigated and that are considered relevant for teaching. For this group of articles, the authors used as references to justify the inclusion of a particular NOS aspect were also identified and included in our summary (Figure 5). Regardless of the number of times a particular aspect appeared in this set of works, it was included in the list presented here, as our objective was to evidence the diversity of aspects highlighted in the literature, and which authors are frequently used to justify NOS aspects.

NoS Aspect	References in which the inclusion of the aspect was justified
The production of scientific knowledge involves curiosity, creativity and imagination.	Aikenhead & Ryan (1992), Alters (1997), McComas & Olson (1998), Smith & Scharmann (1999), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Scientific knowledge is transient and provisional.	Aikenhead & Ryan (1992), Alters (1997), McComas & Olson (1998), Smith & Scharmann (1999), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Science does not answer all questions, as its methods are limited.	Aikenhead & Ryan (1992), Alters (1997), McComas & Olson (1998), Smith & Scharmann (1999), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Scientific knowledge depends on the historical, political, social and cultural context.	Aikenhead & Ryan (1992), McComas & Olson (1998), Smith & Scharmann (1999), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Science is based on observations and uses inferences, each with specific characteristics.	Aikenhead & Ryan (1992), Alters (1997), McComas & Olson (1998), Smith & Scharmann (1999), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Science seeks data according to theories.	Aikenhead & Ryan (1992), Alters (1997), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), Lederman (2007), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Science can be based on empiricism.	Aikenhead & Ryan (1992), McComas & Olson (1998), Smith & Scharmann (1999), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Allchin (2011), Irzik & Nola (2011), Abd-El-Khalick (2012).
Scientific knowledge is constructed based on laws and theories, each with specific characteristics and limitations.	Aikenhead & Ryan (1992), Smith & Scharmann (1999), Lederman et al. (2002), Osborne et al. (2003), McComas (2006), Lederman (2007), Irzik & Nola (2011), Abd-El-Khalick (2012).
Scientific knowledge is constructed using multiple methods.	Aikenhead & Ryan (1992), Alters (1997), Gil-Pérez et al. (2001), Lederman et al. (2002), Osborne et al. (2003), Allchin (2011), Irzik & Nola (2011).
Science seeks the replicability and reliability of data.	McComas & Olson (1998), Smith & Scharmann (1999), Osborne et al. (2003), Allchin (2011), Irzik & Nola (2011).

Figure 5. List of NOS aspects present in the 192 articles that investigate NOS conceptions and references in which they were justified, according to a review of articles on NOS conceptions published up to February 2015 in strata A1 to B3 journals listed in WebQualis 2013 in the areas of Teaching and Education (continue)

NoS Aspect	References in which the inclusion of the aspect was justified
Science seeks systematization, compliance with rules and general coherence.	Aikenhead & Ryan (1992), Alters (1997), Smith & Scharmann (1999), Gil-Pérez et al. (2001), Allchin (2011).
Science is subjective.	Aikenhead & Ryan (1992), Lederman et al. (2002), McComas (2006), Lederman (2007), Allchin (2011).
Science develops through cooperation and collaboration.	Gil-Pérez et al. (2001), Osborne et al. (2003), Allchin (2011), Abd-El-Khalick (2012).
Science is not the work of isolated geniuses.	Gil-Pérez et al. (2001), Osborne et al. (2003), Allchin (2011), Abd-El-Khalick (2012).
Science is based on arguments.	Alters (1997), Smith & Scharmann (1999), Lederman (2007), Allchin (2011).
Science seeks synthesis and not just analyses, i.e. it seeks to simplify knowledge.	Alters (1997), Gil-Pérez et al. (2001), Osborne et al. (2003).
Science differs from technology.	Aikenhead & Ryan (1992), McComas & Olson (1998), McComas (2006).
Science is based on cumulative, non-linear knowledge.	Aikenhead & Ryan (1992), Gil-Pérez et al. (2001).
Science is based on hypotheses.	Gil-Pérez et al. (2001), Osborne et al. (2003).
Science seeks order in the physical world.	Alters (1997), McComas & Olson (1998)
Science seeks to explain phenomena.	Alters (1997), McComas & Olson (1998)
Science must have clear, open disclosure.	McComas & Olson (1998), Allchin (2011).
Science assumes there is a world independent of observation.	Alters (1997)
Science stems from the absence of a creator.	Alters (1997)
Science has global implications.	McComas & Olson (1998)

Figure 5. List of NOS aspects present in the 192 articles that investigate NOS conceptions and references in which they were justified, according to a review of articles on NOS conceptions published up to February 2015 in strata A1 to B3 journals listed in WebQualis 2013 in the areas of Teaching and Education

Although the purpose of the summary presented in Figure 5 is to detail the aspects of NOS that have been highlighted in articles of the field, we emphasize that the scope of this work is not to propose a list of aspects that can be used in research or teaching. What we aim to emphasize here is that there is a debate in the literature on various aspects of NOS and their inclusion as compulsory elements for elementary education. Within this setting, we recorded 25 aspects of NOS reported as important for teaching.

For some authors, there is a consensus on the aspects that should be included and investigated in basic education (e.g. Abd-El-Khalick, 2012; Lederman, 1992; Lederman, 2007 ; McComas, 2008; McComas & Almaznoa; 1998, Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Stanley & Brinckhouse, 2001). To justify their view as consensual, these authors argue that although the definition of science is still open to discussion from the philosophical perspective, there is a current pedagogical view concerning the underlying theme that permeates works on NOS. The view regarded as consensual addresses aspects present in Figure 5, and the articles that we have sampled explore these aspects to a greater or lesser extent (depending on the article and objectives). We emphasize that the 25 aspects found in our survey go beyond the aspects adopted as consensual by authors frequently cited in the literature (e.g., Lederman et al., 2002). The aspects regarded as consensual state that scientific knowledge is (i) tentative, (ii) the product of empiricism, (iii) theory-driven, (iv) partially dependent on inferences, creativity and imagination, (v) organized into laws and theories, (vi) produced within a social and cultural context and (vii) based on a variety of methods. Many of the articles that we used in our sample contain claims about scientific knowledge and mix them with different characteristics of science, such as epistemological, sociological and psychological elements, a fact already underscored by other authors (e.g., Matthews, 2012) who criticize the aspects considered in works that investigate NOS conceptions.

According to Clough (2006), aspects of NOS listed in the form of statements can be easily misunderstood, and can be considered with extreme relativism by students, who may consider, for instance, that the fact that scientific knowledge is provisional means that it is unreliable. There is also debate on the nature of the statements present in this so-called consensual view, which may cause interpretation difficulties or incur a limited view of science. To say, for example, that science is subjective, does not make it clear that we are referring to the fact that ideas and observations emerge from a theoretical context that may not be unique at a given time in history, and that it is therefore dependent on the choices of scientists. The construction of a hypothesis, for example, is dependent on a preexisting theoretical benchmark (Gil-Pérez et al., 2001), and the decision on whether to adopt a given paradigm to support a hypothesis may depend on a series of factors associated with the scientist's individual choices. Likewise, in saying that science has a creative component, we are not being clear about the role and the scope of creativity for the production of knowledge.

Authors who condemn the use of lists of NOS aspects generally do so because they consider these lists to be inadequate vis-a-vis the objectives of critical scientific education (Allchin, 2011; Irzik & Nola, 2011). There is a risk that lists of conceptions will be understood as just one more of the many lists of concepts that must be taught (or merely memorized) in the classroom when followed to the letter. In addition, the use of lists (based on a consensual view or not) poses an intrinsic problem, since it involves the notion of finitude, as relevant aspects, such as the role of feminism in science or the dynamics of knowledge production among different sciences, do not appear on these lists. The lists may violate the intent to provide students with alternatives capable of engaging them in critical debate and helping them formulate their own points of view. Some critics of the lists (e.g., Allchin, 2011; Clough, 2007; Irzik & Nola; 2011, Matthews, 2012) argue that the principles of NOS fail to provide an in-depth understanding of the processes of science, and that scant attention is paid to the specificities of the various sciences.

Faced with such considerations, there are some proposals to address NOS without the enunciation of affirmations in lists. Clough (2007) announces the idea of working with issues associated with NOS, rather than principles. Irzik and Nola (2011), in stating that there is more disagreement than consensus on the aspects of NOS that are relevant to teaching, explore the idea that a number of sciences share common characteristics and can be grouped into families, some of which overlap. On the other hand, Allchin (2011) advocates the use of NOS through contextualization, based on case studies that address the reliability of scientific practice, as well as other internal aspects of knowledge production that are usually left out of lists of conceptions, such as credibility and peer review. Along the same lines, Matthews (2012) advocates a reorganization of the aspects associated with the production of scientific knowledge in *characteristics of science* rather than *aspects of NOS*, in order to avoid mixing epistemological, sociological and similar characteristics in a list, and the association of NOS learning with the students' ability to identify declarative statements about NOS.

In addition to the debate about the existence of a consensual view and whether or not lists should be used, some authors invite reflection on the real need to include NOS contents in the curriculum without explicitly describing their contributions to the development of the individual and to society (e.g., Davson-Galle, 2008). In this respect, Hodson (1994) points out that NOS aspects need to be related to other educational objectives. Thus, the topic of NOS can be explored along with the aspects that motivate students to adopt a positive attitude to science, or along with aspects that help solve complex problems such as socioscientific issues. In this sense, Matthews (1998) states that the objectives of introducing history and philosophy of science to work on NOS aspects need to be modest. The author believes that although such an approach can humanize science and make teaching more meaningful, we cannot expect students to solve major epistemological debates. Rather, we should aim to give them an understanding of the contexts and implications of scientific concepts and themes.

Thus, we understand that while some authors consider NOS aspects to be a list of contents to be learned (e.g., Lederman et al., 2002; Schwartz, Lederman, & Lederman, 2008), there are those who justify the inclusion of NOS aspects in the curriculum due to their potential to contribute to the development of skills by students (e.g., Allchin, 2011). Teaching and learning environments that integrate historical didactic, investigative, and contemporary case study approaches (Allchin et al., 2014) can provide opportunities for students to build, use, and reflect on aspects of NOS, potentially developing a more informed view of the processes related to the production of scientific knowledge. From this perspective – and it is also the view that we take - lists of NOS aspects do not help the dimensions of *learning science, doing science, learning about science* and learning to deal with *socio-scientific issues* to be fully addressed in the classroom.

What are the main strategies used to access NOS conceptions?

A wide range of instruments have been developed to access NOS conceptions, not only in terms of form (interviews, questionnaires, discussion groups, classroom observations or drawing analysis), but also in terms of the study focus. We found instruments that are widely used, and a large number of articles that have created ways of collecting specific data for their own surveys (Table 6). In the 61 articles in which the researchers formulated their own methods, the authors did not declare their intention to create an instrument that could be applied to other contexts. The strategies ranged between interviews, open questions, analysis of materials produced by students and teachers, and combinations of these protocols.

Table 6. Survey instruments used to access NOS conceptions, considering the articles published up to February 2015 in strata A1 to B3 journals listed in WebQualis 2013 in the areas of Teaching and Education.

Survey instruments	Number of articles	Proportion (%)
VNOS (A to E)	64	27.9
TOUS	28	12.2
VOSTS	22	9.6
NOSS	11	4.8
DAST	11	4.8
SEVs	9	3.9
SUSSI	5	2.2
BASSQ, CI, ENOS, ISAIA, KASSPPI, LOS, MaNS, NOSI, NOST, SAQ, STAQ, TCNSQ, TIMSS, TUS, VaPS, VASM, VOS, VOSE.	1 occurrence for each questionnaire (18)	below 0.5
Articles in which the authors elaborate specific strategies for their own studies.	61	26.6

One of our objectives in the present review was to identify the main strategies used to survey NOS conceptions in order to develop an instrument (reported in Azevedo & Scarpa, 2017) that would be consistent with the most recent views in the literature and consider that contextualization, contrary to decontextualized questions in the form of statements, can enable access to more reliable NOS concepts that are closer to the real conceptions of the respondents (e.g. Allchin, 2011). However, beyond the initial goals of our research lies the possibility that both the form and the contents present in survey instruments say a lot about what researchers consider important with regard to NOS. Instruments can indicate both what is of interest to research and to teaching, and what can still be problematic. If we also consider that the questionnaires can be used in the school setting in evaluative circumstances, we cannot ignore the fact that assessment instruments play an important role in classroom discourse (Cazden, 2001). Thus, a systematic explanation of both the form and the content of such survey instruments is vital.

The most widely employed instrument for surveying NOS conceptions was the *Views of Nature of Science Questionnaire* (VNOS) (Lederman & O'malley, 1990), used in 64 articles. The first version of VNOS (VNOS-A) was developed for secondary school students and comprises seven open-ended questions (e.g. *Is there a difference between a theory and a scientific law? Give an example to illustrate your answer*) accompanied by interviews. Variations on the VNOS originated in the same research group, resulting in other instruments: VNOS-B (Abd-El-Khalick et al., 1998), VNOS-C (Abd-El-Khalick & Lederman, 2000), VNOS-D (Lederman & Khishfe, 2002) and VNOS-E (Lederman & Ko, 2004). Each one included adaptations tailored to a specific audience (e.g. VNOS-C was intended for elementary school teachers and the VNOS-E for children who cannot read), and the context of application (more or less time available), but they are all composed of open-ended questions followed by interviews. There are structural variations among these instruments in terms of size (VNOS-B has seven items while VNOS-C has ten) and in the aspects investigated (more, or less broad). The decision to group this "family" of questionnaires into a single set is due precisely to the considerable theoretical and structural similarity between them. Aspects investigated in the VNOS *family* include the following: science is tentative (the only aspect surveyed in VNOS-A), the role of creativity in science, nature and relationships between laws and scientific theories, the empirical and inferential characteristic of science, the absence of a single method (included in VNOS-C), and the role of society and of culture in science (included in VNOS-C). Together, these aspects make up the consensual view of science, as they were called by the group that created them.

Although created earlier, the *Test on Understanding Science* (TOUS) (Cooley & Klopfer, 1961) had fewer occurrences among the articles sampled, with 28 in all (12.2% of the sample). It is a questionnaire that gives four alternative responses, with a total of sixty multiple choice items. The NOS aspects surveyed include: the view of scientists, the methods and objectives of science, and the understanding of scientific enterprise.

The instrument *Views on Science-Technology-Society* (VOSTS) (Aikenhead & Ryan, 1992) was used in 22 articles. The questionnaire was developed for students aged 11 to 12 years and covers topics such as the influence of society on science and technology, the influence of school science on society, the social construction of scientific knowledge, the characteristics of a scientist, and the nature of scientific knowledge. The questionnaire comprises 114 multiple choice items and does not provide a numerical score at the end. The work involved in developing the instrument took about six years, because to overcome the problem of ambiguity associated with the answers to closed-ended questions and to avoid the forced choice of a particular item, the response options were developed based on written answers and interviews provided by more than two thousand students. This resulted in items with up to 10 different perspectives, and included the options "*I did not understand*" and "*I do not know enough about this subject to make a choice.*"

The *Nature of Science Scale* (NOSS) (Kimball, 1967) was used in 4.8% of the articles surveying NOS conceptions. Its objective is to verify the NOS conceptions of elementary school teachers. It contains 29 items, in which the respondent declares, through an interview, whether he or she agrees, disagrees with, or has a neutral opinion on each statement. The instrument was validated by nine educators prior to its application.

Used in 4.8% of the studies, the *Draw-a-Scientist Test* (DAST) (Chambers, 1983) is an instrument designed to access children's conceptions. It is completely different from the other instruments, inasmuch as its analysis consists of identifying patterns in children's drawings. In general, there is a tendency in these drawings (confirmed in articles of our review) to represent scientists as a male figure who wears glasses, is surrounded by laboratory instruments, books and technological gadgets and (sometimes) utters phrases like "Eureka" (Chambers, 1983). Criticism of this instrument consists of the inability to measure just how seriously children take the activity or understand the set task. There is a possibility that students will understand that they are supposed to draw the ideal image of a scientist rather than how they see scientists (Boylan, Hill, Wallace, & Wheeler, 1992). For this reason, in the more recent articles that have used DAST, the researchers also incorporated an interview stage in which children can express their ideas and tell about what inspired their drawings (e.g., Miller, 1993; Tucker-Raymond Varelas, Pappas, Korzh, & Wentland, 2007).

The *Scientific Epistemological Views* (SEVs) (Tsai & Liu, 2005), used in nine articles, is a questionnaire with 19 items, in which the answers are based on the five-point Likert scale (*Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree*). Among the aspects surveyed throughout the instruments are: the role of creativity, the cultural impact of science, dependence on scientific theories, social negotiation and the provisional nature of science.

Another instrument that uses the five-point Likert scale is the *Student Understanding of Science and Scientific Inquiry* (SUSSI) (Liang et al., 2006), employed in 2.2% of the articles. It is composed of six items followed by spaces in which the respondent should justify his or her answers. The aspects surveyed include: the role of imagination and creativity across scientific research, the difference between laws and theories, the role of observation and of inference, the possibility of change in scientific theories and sociocultural influence in science.

Many of the instruments used in the articles are often criticized, mainly because of the limitations on accessing the real conceptions of the study focus. In this regard, Koulaidis and Ogborn (1995) have focused primarily on the epistemology of science for the works they have reviewed. The authors were concerned with raising and discussing the theoretical assumptions that guide the elaboration of instruments used to survey NOS conceptions. The authors analyzed 26 empirical articles that used questionnaires to survey NOS conceptions. They classified the works into 5 categories (inductivism, hypothetico-deductivism, contextualism, relativism and lack of clear positioning of the authors of the works) and stated that "*the majority of studies tend to reflect an inductivist image of science*"(p. 278) although there is evidence, according to their survey, that teachers "*hold eclectic or mixed views, adhering to a diversity of elements taken from different philosophical positions*" (p. 280). Despite having been published more than 20 years ago, the discussions presented by the authors remain current, especially when we consider that much of the work they analyzed did not have a stance on the views of science that were considered when elaborating the instruments. Thus, the review of Koulaidis and Ogborn (1995) points to relevant issues such as the fact that (i) many questionnaires considered only one position as adequate in their studies; (ii) the questionnaires might not capture the real conceptions of an audience; and (iii) the results obtained from questionnaires may contradict the results of conceptions investigated by other means.

Other reasons for such limitations that are often contemplated in the literature (e.g., Koulaidis & Ogborn, 1995; Lederman et al., 2002; Lederman, 2007; Ryan & Aikenhead, 1992) are: (i) the same response provided by different individuals may have different meanings; (ii) likewise, the same meaning for different individuals may result in different responses; (iii) many instruments are built based on the point of view of researchers with a particular philosophical position, which may be inaccessible to the respondents; and (iv) the fact that the respondents' views do not correspond to the view of science considered in the instrument may mean that their conceptions of NOS are considered incorrect or inadequate.

Among the criticisms cited, the most incisive among the authors is that the respondents may have difficulty understanding the meaning of the questions. Instruments in which questions have multiple alternatives can be problematic, as besides the frequent similarity between alternatives, the respondent needs to choose one, which is not necessarily the alternative with which he or she agrees (Ryan & Aikenhead, 1992). This could jeopardize the legitimacy of the conclusions of the article. Using instruments with open-ended questions or interviews may resolve implications related to the ambiguity of responses, but does not solve the issue of the researchers' philosophical position. To overcome this problem, we have found a number of works that have sought to combine different instruments, or alternatively, to access NOS conceptions through investigational practices (e.g., Sandoval, 2005).

One problem associated with the variety of instruments is the difficulty in comparing studies, not only because of the variety of formats, but also due to the variety of philosophical positions of the researchers. On the other hand, the use of an instrument outside the context in which it was created must be done with caution, as instruments are generally developed for a specific audience and are dependent on a particular context. There are works in which the authors choose to make adaptations to conventional instruments, so that they can be applied to an audience from a specific age group, yet still make comparisons with other studies. In regard to this practice, the criticism directed at certain instruments in particular can be extrapolated in an attempt to look more carefully at the instruments they generate. For example, Abd-El-Khalick and BouJaoude (1997) and Botton and Brown (1998) criticized the VOSTS questionnaire, arguing that it is dependent on a sociocultural context (since its items were empirically derived from a particular audience) and that this could be a limiting factor in other contexts. We believe that this characteristic may be present in other questionnaires. Thus, care must be taken when selecting an appropriate instrument, not only in terms of study objectives, but also considering the age of the audience and the sociocultural context of the respondents.

Another point for reflection concerns the theoretical dimensions of instruments. Some include declarative questions such as "*What is a theory*?" or "*What is an experiment*?", which may be too broad or vague for students at different levels of education. Thus, not only the context, but also the language may be relevant in accessing students' conceptions of NOS (Leach, 2000). According to Allchin (2011), the validity of some instruments needs to be considered with caution because they may be inefficient in revealing critical skills, or the content of a questionnaire may be understood as a set of *new concepts* to be simply memorized in the post-test stage and not effectively understood by the students. On the same topic, Allchin (2011) argues that many instruments are incapable of evidencing students' critical and analytical thinking skills, which is essential for addressing the different dimensions of science education goals. This is a problem that is also associated with the decontextualized or literal use of lists of NOS conceptions, as presented above.

Although studies on NOS conceptions date back more than 60 years, critiques of lists of conceptions are still very recent, only gaining momentum in the last twenty years. Thus, it is possible that many of the critiques have not yet been strongly incorporated into the studies and reflections of the area. An example of this would be the principles that guided the elaboration of the family of VNOS questionnaires, widely used and disseminated by a group of researchers. The structuring NOS principles of the VNOS have only recently been weighed and explicitly advocated by their main research group, in Schwartz et al. (2012), as part of a heated discussion following the critiques present in the work written by Allchin (2011). The critiques and explicit positions in both publications have generated a series of articles that have given greater relevance to these discussions (e.g., Duschl & Grandy, 2013; Hodson & Wong, 2014).

Whilst the debate on the methods used to access NOS conceptions is of paramount importance, we should remember that any method will carry a risk that the conception of science attributed to the individual will be influenced by the method used. We sought to map the instruments used most often, and to outline the characteristics of this group. We therefore described the seven most common instruments, which corresponded to 65.4% of those used in the articles focusing on NOS conceptions that we investigated. However, the variety of these instruments is not limited to this number, as shown in Table 6 . Characteristics of some of the less frequently used instruments can be found in the traditional reviews of Hacieminoglu et. al., (2012) and Lederman (2007).

We also reiterate that it is not our intention here to do a meta-analysis of the results achieved in articles on NOS conceptions with different study focuses, such as diverse audiences or documents. There are traditional reviews designed to synthesize the knowledge produced, considering these different focuses, based on a group of articles (e.g., Abd-El-Khalick & Lederman 2000; Harres, 1999; Lederman, 1992, 2007). However, we emphasize that a careful analysis of the results generated by this diversity of methods, and that takes into account the possible bias in surveys of NOS conceptions (caused by the philosophical positions of the authors, by the format of the instruments, or the processing of data obtained from them) may be necessary for a true understanding of what we know so far about the NOS conceptions in a specific group of subjects.

Final considerations

Our survey indicated that although there has been a significant growth in publications on NOS in the last 60 years, there are few literature review articles, mainly non-traditional reviews. The use of replicable and explicit principles, such as those of PRISMA, can help elucidate contexts in which research efforts are still needed, and to understand what has been produced, in a critical and less subjective manner, in surveys in the area of science education. This systematic review represents an initial effort to present an overview of the area and allowed the authors to identify some trends and gaps in surveys involving NOS conceptions. Previous reviews have been crucial as they summarized the knowledge produced up to the date of their publications, and focused on different aspects: Lederman (1992) focused on the results of some surveys on the investigation of NOS conceptions of students and teachers; Koulaidis and Ogborn (1995) focused on the epistemological assumptions related to science that guided the survey of NOS conceptions; and Harres (1999) provided an overview of some surveys on NOS conceptions, focusing mainly on the results.

Our systematic review allowed us to identify some gaps where research efforts may still be needed. Considering the areas of knowledge associated with science education, we noted that Biology education researchers have dedicated little endeavor to the survey of NOS conceptions, compared to the areas of Physics and Chemistry education, even though Biology education also disseminates underinformed views of NOS. The focus of studies on NOS conceptions is mainly in basic education, and there is a lack of studies on NOS conceptions in higher education worldwide. In Brazil, there is still a need to advance in studies of this kind, in order to understand the role of the sociocultural context in the NOS conceptions of students and teachers at all education levels.

This article gives a general overview, with different views of research involving NOS conceptions. It covers the characteristics of survey instruments, and seeks to promote reflection on the extent to which they represent more than neutral possibilities of accessing data. In reflecting on the format of the instruments used to survey conceptions, we also reflected on the recent debate in the literature about the validity or invalidity of a consensus view of the aspects of NOS that must be present in education. Despite the debate (which has appeared more frequently in the literature only in recent years) on the existence of a possible consensual view, and the diversity of NOS aspects frequently investigated, we identified 25 aspects present in the literature. This number is far higher than the seven aspects frequently asserted as consensual in studies on NOS conceptions.

Future studies may explore other internal aspects of NOS productions. We envisage, as fruitful paths of research, the organization of new systematic reviews concentrating efforts on a single survey question, or the production of articles with meta-analyses, such as *which are the NOS conceptions of a particular group, based on the results of conception surveys*? We understand that such studies, although still uncommon in the field of Education, can contribute significantly to the organization of knowledge that has been produced in the area, and can enhance the chances of our finding responses present in many studies, such as which didactic strategies can improve NOS conceptions among teachers and students.

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References

Abd-El-Khalick, F. (2012). Examining the sources for ours understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, 34(3), 353–374.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82(4), 417–437.

Abd-El-Khalick, F., & Boujaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching*, 34(7), 673–699.

Abd-El-Khalick, F., Boujaoude, S., Duschl, R. A., Hofstein, A., Lederman, N. G., Mamlok, R., Niaz, M., Treagust, D., & Tuan, H. (2004). Inquiry in science education: International perspectives. *Science Education*, 88, 397–419.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, 22(7), 665–701.

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, 37(10), 1057–1095.

Aikenhead, G., & Ryan, A. (1992). The development of a new instrument: 'Views on Science-Technology-Society' (VOSTS). *Science Education*, 76, 477–492.

Ajaja, P. O. (2012). Senior Secondary School Science Teachers in Delta and Edo States Conceptualization about the Nature of Science. *International Education Studies*, 5(3), 67–85.

Allchin, D. (2011). Evaluating Knowledge of the Nature of (Whole) Science. *Science Education*, 95(3), 918–942.

Allchin, D., Andersen, H., & Nielsen, K. (2014). Complementary approaches to teaching nature of science: Integrating inquiry, historical cases and contemporary cases in classroom practice. *Science Education*, 98(3), 461–486.

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching*, 34(1), 39–55.

Azevedo, N. H., & Scarpa, D. L. (2017). Decisões envolvidas na elaboração e validação de um questionário contextualizado sobre concepções de natureza da ciência. *Investigações em Ensino de Ciências.* 22(2), 57–82.

Bayir, E., Cakici, Y., & Ertas, O. (2014). Exploring Natural and Social Scientists' Views of Nature of Science. *International Journal of Science Education*, 36(8), 1286–1312.

Bell, R. L., & Lederman, N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education*, 87(3), 352–377.

Botton, C., & Brown, C. (1998). The reliability of some VOSTS items when used with pre service secondary science teachers in England. *Journal of Research in Science Teaching,* 35(1), 53–71.

Boylan, C. R., Hill, D. M., Wallace, A. R., & Wheeler, A. E. (1992). Beyond stereotypes. *Science Education*, 76(5), 465–476.

CAPES. (2015). *Qualis Periódicos*. Retrieved from http://www.capes.gov.br/avaliacao/qualis.

Carvalho, A. M. P. (2006). Critérios estruturantes para o ensino das ciências. In A. M. P. Carvalho (Org.). *Ensino de Ciências: unindo a pesquisa e a prática*. (pp. 1–17). São Paulo: Pioneira Thomson Learning.

Cazden, C. B. (2001). *Classroom Discourse: The Language of Teaching and Learning*. (2nd ed.). New Hampshire: Heinemann.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education*, 67(2), 255–265.

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: considerations for effective nature of science instruction. *Science & Education*, 15(5), 463–494.

Clough, M. P., & Olson, J. K. (2008). Teaching and assessing the nature of science: An introduction. *Science & Education*, 17(2–3), 143–145.

Cooley, W. W., & Klopfer, L. E. (1961). *TOUS: Test on understanding science*. Princeton, NJ: Education Testing Service.

Davson-Galle, P. (2008). Why compulsory science education should not include philosophy of science. *Science & Education*, 17(7), 677–716.

Duschl, R., & Grandy, R. (2013). Two views about explicitly teaching nature of science. *Science and Education*, 22, 2109–2139. doi: 10.1007/s11191-012-9539-4

Feldman, A., Divoll, K. A., & Rogan-Klyve, A. (2013). Becoming researchers: The participation of undergraduate and graduate students in scientific research groups. *Science Education*, 97(2), 218–243.

Figueirêdo, K. L., Justi, R. (2011). Uma proposta de formação continuada de professores de ciências buscando inovação, autonomia e colaboração a partir de referenciais integrados. *Revista Brasileira de Pesquisa em Educação em Ciências*, 11(1), 169–190.

Fourez, G. (1997). Scientific and Technological Literacy as a Social Practice. *Social Studies of Science*, 27(6), 903–936.

Freitas, D. (2008). A perspectiva curricular Ciência Tecnologia e Sociedade – CTS – no ensino de ciência. In: A. C. Pavão, D. Freitas (Org.). *Quanta Ciência há no Ensino de Ciências*. (pp. 229–237). São Carlos: EdUFScar.

Gil-Pérez, D., Fernández, I., Carrascosa, J., Cachapuz, A., & Praia, J. (2001). Para uma imagem não deformada do trabalho científico. *Ciência & Educação*, 7(2), 125–153.

Hacieminoglu, E., YilmazTuzun, O., & Ertepinar, H. (2012). Development and validation of nature of science instrument for elementary school students. *Education 3-13: International Journal of Primary, Elementary and Early Years Education*, 42(3), 258–283.

Harding, P., & Hare, W. (2000). Portraying science accurately in classrooms: Emphasizing open-mindedness rather than relativism. *Journal of Research in Science Teaching*, 37(3), 225–235.

Harres, J. B. S. (1999). Uma revisão de pesquisas nas concepções de professores sobre a natureza da ciência e suas implicações para o ensino. *Investigações em Ensino de Ciências*, 4(3), 197–211.

Hodson, D. (1998). Science fiction: the continuing misrepresentation of science in the school curriculum**.** *Curriculum Studies*, 6(2), 191–216.

Hodson, D. (1994). Seeking directions for change: The personalization and politicization of science education. *Curriculum Studies*, 2(1), 71–98.

Hodson, D. (2001). Inclusion without assimilation: Science education from an anthropological and meta-cognitive perspective. *Canadian Journal of Science, Mathematics and Technological Education,* 1(2), 161–182.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, 36(15), 2534–2553.

Hodson, D., & Wong, S.L. (2014). From the horse's mouth: Why scientists' views are crucial to nature of science understanding. *International Journal of Science Education*, 36(16), 2639–2665.

Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education*, 20(7), 591–607.

Khishfe, R., & AbdElKhalick, F. (2002). Influence of explicit reflective versus implicit inquiryoriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, 39(7), 551–578.

Khishfe, R. (2014). Explicit Nature of Science and Argumentation Instruction in the Context of Socio-scientific Issues: An effect on student learning and transfer. *International Journal of Science Education*, 36(6), 974–1016.

Kimball, M. E. (1967). Understanding the nature of science: A comparison of scientists and science teachers. *Journal of Research in Science Teaching*, 5(2), 110–120.

Knopf, J. W. (2006). Doing a literature review. *PS: Political Science & Politics*, 39(1), 127–132.

Koulaidis, V., & Ogborn, J. (1995). Science teachers philosophical assumptions: How well do we understand them? *International Journal of Science Education*, 17(3), 273–283.

Leach, J., Millar, R., Ryder, J., & Sére, M. G. (2000). Epistemological understanding in science learning: The consistency of representations across contexts. *Learning and Instruction*, 10(6), 497–527.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(4), 331–359.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831879). Mahwah, N.J: Lawrence Erlbaum Associates

Lederman, N. G., AbdElKhalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497–521.

Lederman, J. S., & Khishfe, R. (2002). Views of nature of science, Form D. Unpublished paper. Illinois Institute of Technology, Chicago.

Lederman, J. S., & Ko, E. K. (2002). Views of nature of science, Form E. Unpublished paper. Illinois Institute of Technology, Chicago.

Lederman, N. G., & O'malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education*, 74(2), 225–239.

Lemke, J. L. (2001). Articulating Communities: Sociocultural Perspectives on Science Education. *Journal of Research in Science Teaching*, 38(3), 296–316.

Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M., & Ebenezer, J. (2006). Student understanding of science and scientific inquiry (SUSSI): Revision and further validation of an assessment instrument. Paper presented at the *The annual meeting of the National Association for Research in Science Teaching*, San Francisco, CA.

Lidar, M., Lundqvist, E., & Ostman, L. (2006). Teaching and learning in the science classroom: The interplay between teachers' epistemological moves and students' practical epistemology. *Science Education*, 90(1), 148–163.

Mayr, E. (2004). *What makes biology unique? Considerations on the autonomy of a scientific discipline*. Cambridge: Cambridge University Press.

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

Matthews, M. R. (1992). History, philosophy and science teaching: the present reapprochement. *Science & Education*, 1(1), 11–48.

Matthews, M. R. (1998). In defense of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching*, 35(2), 161–174.

Matthews, M. R. (2012). Changing the focus: from nature of science to features of science. In Khine, M. S. (Ed.). *Advances in nature of science research* (pp. 3–26). Dordrecht: Springer.

McComas, W. F. (2006). Science Teaching beyond the Classroom. *Science Teacher*, 73(1), 26–30.

McComas, W. F. (2008). Seeking historical examples to illustrate key aspects of the nature of science. *Science & Education*, 17(2–3), 249–263

McComas, W. F., Almazroa, H., Clough, M. (1998). The Nature of Science in Science Edu- cation: an introduction. *Science & Education*, 7(6), 11–532.

McComas, W. F., & Olson, J. K. (1998). The Nature of Science in International Science Education Standards Documents. In McComas, W. F. (Ed.). *The Nature of Science in Science Education: Rationales and Strategies* (pp. 41–52). Drodrecht: Kluwer.

Miller, J. D. (1993). Theory and measurement in the public understanding of science: a rejoinder to Bauer and Schoon. *Public Understanding of Science*, 2(3), 235–243.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). The PRISMA Group. *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. *PLoS Med*, 6(6). doi:10.1371/journal.pmed1000097.

Moss, D. M., Abrams, E. D., & Robb, J. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education*, 23(8), 771–790.

Ogunniyi, M. (2005). Relative effects of a history, philosophy and sociology of science course on teachers' understanding of the nature of science and instructional practice. *South African Journal of Higher Education*, 19, 1464-1472.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideasabout science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40(7), 692–720.

Packer, A. L. (2011). Os periódicos brasileiros e a comunicação da pesquisa nacional. *Revista USP*, 89, 26–61.

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education*, 76(6), 559–580.

Robinson, J. T. (1965). Science Teaching and the Nature of Science. *Journal of Research in Science Teaching*, 3(1), 37–50.

Rodrigues, R. S., Quartiero, E., & Neubert, P. (2015). Periódicos Científicos Brasileiros indexados na Web Of Science e Scopus: estrutura editorial e elementos básicos. *Informação & Sociedade: Estudos*, 25(2), 117–138.

Rosenberg, A. (2008). Biology. In: S. Psillos, & M. Curd. (Eds.). *The Routledge companion to philosophy of science* (pp. 511–519). London: Routledge.

Sandoval, W. A. (2005). Understanding student's practical epistemologies and their influence on learning through inquiry. *Science Education*, 89(4), 634–656.

Schwartz, R. S., Lederman, N. G., & Lederman, J. S. (2008). An Instrument to Assess Views of Scientific Inquiry: The VOSI Questionnaire. Paper presented at *The annual meeting of the National Association for Research in Science Teaching*, Baltimore, MD.

Schwartz, R. S., Lederman, N. G., & Abd-El-Khalick, F. (2012). A series of misrepresentations: A response to Allchin's whole approach to assessing nature of science understandings. *Science Education*, 96(4), 685–692.

Shader-Frechette, K., & McCoy, E. D. (1994). Applied ecology and the logic of case studies. *Philosophy of Science*, 61(2), 228–249.

Shader-Frechette, K., & McCoy, E. D. (1993). *Method in ecology: strategies for conservation*. Cambridge: Cambridge University Press.

Smith, M. U., & Scharmann, L. C. (1999). Defining versus describing the nature of science: A pragmatic analysis for classroom teachers and science educators. *Science Education,* 83(4), 493–509.

Stanley, W. B., Brickhouse, N. W. (2001). Teaching science: The multicultural question revisited. *Science Education*, 85(1), 35–49.

Taber, K. (2010). A comprehensive vision of 'the nature of science" in science education. *Studies in Science Education*, 46(2), 245–254.

Tsai, C. C., & Liu, S. Y. (2005). Developing a multidimensional instrument for assessing students' epistemological views toward science. *International Journal of Science Education*, 27(13), 1621–1638.

Tsai, C., & Wen, L. (2005). Research and trends in science education from 1998 to 2002: a content analysis of publication in selected journals. *Internacional Journal of Science in Education*, 27(1), 3–14.

Tucker-Raymond, E., Varelas, M., Pappas, C. C., Korzh, A., & Wentland, A. (2007). "They probably aren't named Rachel": Young children's scientist identities as emergent multimodal narratives. *Cultural Studies of Science Education*, 1(3), 559–592.

Waters-Adams, S., & Nias, J. (2003). Using action research as a methodological tool: Understanding teachers' understanding of science. *Educational Action Research*, 11(2), 283–300.

Wong, S. L., & Hodson, D. (2009). From the horse's mouth: What scientists say about scientific investigation and scientific knowledge. *Science Education*, 93(1), 109–130.

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Appendix

List of journals consulted during the systematic review. This listing originated from the WebQualis 2013 list and the journals belong to the strata of the range A1 to B3, in at least one of the areas of Education and Teaching.

ISSN	Journal title	Qualis	
		Education	Teaching
1983-6430	A Física na Escola (Online)	B4	B2
1517-4492	Acta Scientiae (ULBRA)	B2	B1
2178-5198	Acta Scientiarum. Education (Print)	A2	-
1409-4703	Actualidades Investigativas en Educación	B3	-
0342-7633	Adult Education and Development	B1	-
2165-9486	Advances in education	-	B2
1516-1498	Ágora (PPGTP/UFRJ)	A2	-
1133-9837	Alambique - Didactica de las Ciencias Experimentales (Barcelona)	B3	B1
1982-5153	Alexandria (UFSC)	B3	B1
2317-5125	Amazônia - Revista de Educação em Ciências e Matemáticas (Online)	-	B2
0002-9505	American Journal of Physics	-	A1
1678-2690	Anais da Academia Brasileira de Ciências (Online)	-	A2
2238-3905	Aprendizagem Significativa em Revista	C	B2
1809-0354	Atos de Pesquisa em Educação (FURB)	B2	B1
0214-3402	Aula (Salamanca)	-	B1
1414-4077	Avaliação (UNICAMP)	A1	A2
1470-8175	Biochemistry and Molecular Biology Education	-	A1
2027-1034	Bio-grafía: escritos sobre la biología y su enseñanza	C	B1
0392-8942	C n S. La Chimica nella Scuola	-	B3
2175-7941	Caderno Brasileiro de Ensino de Física (Online)	B1	B1
1809-1466	Caderno de Física da UEFS	-	B3
1518-109X	Caderno de Pedagogia (Ribeirão Preto)	B3	-
0101-3262	Cadernos CEDES (Impresso)	A2	A2
0104-1371	Cadernos de Educação (UFPel)	A2	B1
0100-1574	Cadernos de Pesquisa (Fundação Carlos Chagas. Impresso)	A1	B1
1519-4507	Cadernos de Pesquisa em Educação PPGE-UFES	B4	B2
1536-7509	Cell Biology Education (Life Sciences Education)	-	A1
1344-7963	Chemical Education Journal	-	A1
1414-5111	Ciência & Ensino (UNICAMP. Impresso)	B2	B1

0009-6725	Ciência e Cultura	B1	B2
1516-7313	Ciência e Educação (UNESP. Impresso)	A1	A1
ISSN	Journal title	Qualis	
		Education	Teaching
1806-5821	Ciências & Cognição (UFRJ)	B2	B2
0102-8758	Contexto & Educação	B3	B1
1668-0030	CTS. Ciencia, Tecnología y Sociedad	B2	-
1871-1502	Cultural Studies of Science Education (Print)	A2	A1
1645-1384	Currículo sem Fronteiras	A2	B1
0362-6784	Curriculum Inquiry	A1	-
2179-6955	Debates em Educação Científica e Tecnológica	C	B2
1982-2197	Diálogos & Ciência (FTC Feira de Santana. Impresso)	B4	B3
0101-465X	Educação (PUCRS. Impresso)	A2	B3
1981-8106	Educação (Rio Claro. Online)	B2	B3
0101-9031	Educação (UFSM)	B1	B2
1807-2194	Educação e Cultura Contemporânea	B1	B2
1982-6273	Educação e Fronteiras (UFGD)	B3	-
1517-9702	Educação e Pesquisa (USP. Impresso)	A1	B1
0100-3143	Educação e Realidade	A1	B1
1519-3322	Educação em Foco (Belo Horizonte. 1996)	B1	B2
0104-3293	Educação em Foco (Juiz de Fora)	B1	B2
2178-8359	Educacao em Perspectiva (Online)	B2	-
0102-4698	Educação em Revista (UFMG. Impresso)	A1	A2
1646-933X	Educacao, Formacao & Tecnologias	B3	-
0872-7643	Educação, Sociedade & Culturas	B1	-
1019-9403	Educación (Lima. 1992)	B3	-
0187-893X	Educación Química	B1	B1
1139-613X	Educación XX1	B1	-
0123-1294	Educacion y Educadores	B2	-
1576-5199	Educacion y Futuro: revista de investigacion aplicada y experiencias educativas	C	B1
0104-4060	Educar em Revista (Impresso)	A1	A2
0300-4279	Education 3-13: international Journal of primary, elementary and early years education	B1	-
1462-7272	Education Review (London)	A2	-
0965-0792	Educational Action Research	A1	-
1983-7771	Educativa (Goiânia. Online)	B2	B3
1316-4910	Educere – Revista Venezolana de Educación (Mérida)	B1	A2
0104-1037	Em Aberto	B1	B3
0104-4036	Ensaio (Fundação Cesgranrio. Impresso)	A1	B4

ISSN	Journal title	Qualis	
		Education	Teaching
1983-2117	Ensaio: Pesquisa em Educação em Ciências (Online)	A2	A2
0212-4521	Enseñanza de las Ciencias	A1	A1
2237-4450	Ensino de Ciências e Tecnologia em Revista	-	B2
0104-3757	Ensino em Re-vista (UFU. Impresso)	B3	B4
1350-4622	Environmental Education Research	-	A1
0103-6831	Estudos em Avaliação Educacional (Impresso)	A2	B3
1350-293X	European Early Childhood Education Research Journal	B1	-
1474-9041	European Educational Research Journal	A1	-
2000-7426	European Journal for Research on the Education and Learning of Adults	B1	-
2279-7505	European Journal of Research on Education and Teaching	B2	-
1982-2413	Experiências em Ensino de Ciências (UFRGS)	B2	B1
2178-6224	Filosofia e História da Biologia (Online)	B2	B3
2176-4360	Formação Docente	B3	-
1130-8656	Innovación Educativa	A1	-
1984-5499	Instrumento - Revista em estudo e pesquisa em educação	B4	B3
0378-1844	Interciencia (Caracas)	-	A1
1552-2237	Interdisciplinary Journal of Knowledge and Learning Objects	A2	-
1807-5762	Interface (Botucatu. Online)	A2	A2
2177-7691	Interfaces da Educação	B4	B1
1913-9020	International Education Studies	B1	-
0883-0355	International Journal of Educational Research	A1	-
1571-0068	International Journal of Science and Mathematical Education	A1	-
0950-0693	International Journal of Science Education	A1	A1
1309-6249	International Journal on New Trends in Education and Their Implications	B2	-
0020-8566	International Review of Education	A1	-
1728-5852	Investigación Educativa	B3	-
1518-9384	Investigações em Ensino de Ciências (UFRGS. Impresso)	A2	A2
1057-896X	JCT (Rochester. New York)	A2	-
1029-5968	Journal of the International Society for Teacher Education	B1	-
1740-2743	Journal for Critical Education Policy Studies	A2	A1
1648-3898	Journal of Baltic Science Education	A2	B1
0021-9266	Journal of Biological Education	A2	A1
0021-9584	Journal of Chemical Education	-	A1
0022-0272	Journal of Curriculum Studies (Print)	A1	-
0268-0939	Journal of Education Policy	A1	-

ISSN	Journal title	Qualis	
		Education	Teaching
0022-4308	Journal of Research in Science Teaching (Print)	A1	-
1059-0145	Journal of Science Education and Technology	A1	-
1870-9095	Latin - American Journal of Physics Education	-	B1
2014-2862	Multidisciplinary Journal of Educational Research	B1	-
1648-939X	Natural Science Education	A1	B2
0035-9149	Notes and Records of the Royal Society of London	-	A2
1413-9855	Nuances (UNESP Presidente Prudente)	B4	B1
0103-863X	Paidéia (USP. Ribeirao Preto. Impresso)	B1	B2
1806-0374	Periódico Tchê Química (Impresso)	-	B3
0102-5473	Perspectiva (UFSC)	A2	B1
0210-2331	Perspectiva Escolar	-	B3
2177-1626	Pesquiseduca	B2	B2
0031-9120	Physics Education (Bristol. Print)	A1	A1
2179-2534	POIÉSIS - Revista do Programa de Pós-Graduação em Educação (Unisul)	B3	B3
2178-4442	Poiesis Pedagogica	B3	B2
1478-2103	Policy Futures in Education (Online)	A1	-
0717-473X	Praxis	B5	B3
1809-4309	Práxis Educativa (UEPG. Online)	A2	B1
1822-7864	Problems of Education in the Twenty First Century	B2	B1
1980-6248	Pró-Posições (UNICAMP. Online)	A1	B1
0327-4829	Propuesta Educativa (Buenos Aires)	B1	-
0963-6625	Public Understanding of Science (Print)	-	A1
2177-5796	Quaestio: Revista de Estudos de Educação	B2	-
1077-8004	Qualitative Inquiry	A1	-
1353-8322	Quality in Higher Education	A1	-
1806-8405	RBPG. Revista Brasileira de Pós-Graduação	B3	B1
1677-3098	RECE: Revista Eletrônica de Ciências da Educação	B5	B3
1760-7760	Recherches & Éducations	A2	-
1954-3077	Recherches en Éducation	B1	-
1579-1513	REEC. Revista Electrónica de Enseñanza de las Ciencias	A2	A2
0103-8842	Reflexão e Ação (UNISC. Impr.)	B2	B1
1679-1916	RENOTE. Revista Novas Tecnologias na Educação	B4	B1
1941-3432	Research in Higher Education Journal	B2	-
0263-5143	Research in Science & Technological Education	-	A1
0157-244X	Research in Science Education	A1	A1
1982-131X	Retratos da Escola	B2	-
1514-2566	Revista Aula Universitaria	-	B3

ISSN	Journal title	Qualis	
		Education	Teaching
1809-449X	Revista Brasileira de Educação	A1	-
1677-2318	Revista Brasileira de Ensino de Bioquímica e Biologia Molecular	-	B1
1982-873X	Revista Brasileira de Ensino de Ciência e Tecnologia	B3	B1
1806-9126	Revista Brasileira de Ensino de Física (Online)	B2	A1
1809-6158	Revista Brasileira de Ensino de Química	B3	B1
1944-1951	revista brasileira de estudos pedagógicos	B2	-
2176-6681	Revista Brasileira de Estudos Pedagógicos RBEP-INEP	B1	-
1806-5104	Revista Brasileira de Pesquisa em Educação em Ciências	A2	A2
0717-9618	Revista Chilena de Educación Científica	B2	B1
1981-9269	Revista Cocar (UEPA)	B2	B5
2179-1309	Revista Contexto & Educação	B5	B2
1516-2907	Revista da FACED (Impresso)	B2	B4
1518-7039	Revista de Ciências da Educação	B3	B1
1678-5622	Revista de Educação Popular (Impresso)	B4	B2
0104-5962	Revista de Educação Publica (UFMT)	A2	B1
1519-3993	Revista de Educação (PUC-Campinas)	B2	B2
2238-2380	Revista de Educação, Ciências e Matemática	C	B2
0124-5481	Revista de Educacion de las Ciencias	A2	A1
0329-5192	Revista de Educación en Biología	A2	B1
0326-7091	Revista de Enseñanza de la Física	B1	B1
1982-1867	Revista de Ensino de Biologia da Associação Brasileira de Ensino de Biologia (SBEnBio)	B3	B2
2179-426X	Revista de Ensino de Ciências e Matemática (REnCiMa)	C	B2
0102-6437	Revista de Estudos Universitárias (Sorocaba)	B2	B5
1981-416X	Revista Diálogo Educacional (PUCPR)	A2	B1
1518-1839	Revista do Professor (Rio Pardo)	-	B3
1980-6469	Revista Educação (Guarulhos)	C	B1
1981-2582	Revista Educação (PUCRS. Online)	A2	B3
0102-7735	Revista Educação em Questão (UFRN. Impresso)	A2	B1
2316-8919	Revista Educação em Rede: formação e prática docente	-	B2
2237-1648	Revista Educação, Cultura e Sociedade	C	B3
0121-7593	Revista Educacion y Pedagogía	B4	B2
1607-4041	Revista Electrónica de Investigación Educativa	A2	A1
1850-6666	Revista Electrónica de Investigación en Educación en Ciencias	B2	A2
2215-8227	Revista eletrônica da associação colombiana para a pesquisa na educação em ciencias e tecnologias	-	B3

1982-7199	Revista Eletrônica de Educação (São Carlos)	B2	B1

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		Education	Teaching
2236-2150	Revista Eletrônica Debates em Educação Científica e Tecnológica	C	B2
1697-011X	Revista Eureka sobre Enseñanza y Divulgación de las Ciencias	B4	B1
2236-2983	Revista Exitus	C	B3
1681-5653	Revista Iberoamericana de Educación (Online)	B1	B1
1982-5587	Revista Ibero-Americana de Estudos em Educação	B1	-
1695-288X	Revista Latinoamericana de Tecnología Educativa	A2	A2
1645-7250	Revista Lusófona de Educação	A1	-
1405-6666	Revista Mexicana de Investigación Educativa	A2	A2
1665-7527	Revista Mexicana de Orientación Educativa	B2	-
1983-3946	Revista Pesquisa em Foco em Educação e Filosofia	B4	B2
0926-7220	Science & Education (Dordrecht)	A1	A1
0036-8326	Science Education (Salem, Mass. Print)	A1	-
2077-2327	Science Education International (Online)	A1	B1
0269-8897	Science in Context	-	A2
1818-0361	Science in School	-	B1
0786-3012	Science Studies (Tampere)	A1	-
0971-7218	Science, Technology and Society	B2	A2
1678-3166	Scientiae Studia (USP)	B1	B1
0039-3746	Studies in Philosophy and Education	A2	-
0305-7267	Studies in Science Education	A1	-
2035-844X	Studium Educationis	B2	-
0742-051X	Teaching and Teacher Education	A1	-
0102-5503	Tecnologia Educacional	B2	B1
1415-837X	Teoria e Prática da Educação	B2	B4
1809-1636	Vivências (URI. Erechim)	B5	B2
2215-8421	Voces y Silencios: Revista Latinoamericana de Educación	C	B1