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ARTICLE

Learning About the Nature of Science Using Newspaper Articles with Scientific Content

A Study in Initial Primary Teacher Education

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Abstract This article presents a study aiming at assessing the efficacy of reading newspaper articles with scientific content in order to incorporate nature of science (NOS) aspects in initial primary teacher education. To this aim, a short teaching intervention based on newspaper articles was planned and performed under regular class conditions. First, prospective teachers read two newspaper articles related to a recent and controversial scientific research report in the field of physics. Next, they responded reflectively in small groups to various questions related to NOS aspects insinuated in the articles in order for researchers to diagnose their prior ideas about these. Each group then presented their responses in class, and a discussion among groups was encouraged in order to provide feedback. Based on this, the groups revised their initial responses. The evolution of the written responses of the groups was analyzed through an interpretive approach using the methods of inter-rater and intra-rater analysis and low-inference descriptors. The findings showed that these prospective teachers in general improved their NOS views. In the absence of further research, these first findings make evident the pedagogical potential of reading certain newspaper articles for learning about NOS under usual classroom conditions. Finally, some educational implications and perspectives derived from the study are discussed.

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1 Introduction

Today there is a broad consensus on recognizing the curricular relevance of the nature of science (NOS) to improve students' scientific literacy (Acevedo 2008; Coll 2012; Lederman 2007). Nevertheless, the impact of NOS in the science classrooms is still scarce or ineffective, at least in Spain and other countries of Ibero-America according to the literature (Bennàssar et al. 2010; Vázquez et al. 2013, 2014). Consequently, it is essential to design programs oriented to helping teachers in understanding NOS and integrating it into science education (Bell et al. 2011; García-Carmona et al. 2011). Also, one demand is that the incorporation of NOS into the school science curriculum should begin in primary education, since research at this level has reported positive learning outcomes (e.g., Akerson and Donnelly 2010). Therefore, it is also necessary to pay attention to teaching NOS in prospective primary teacher education.

Over the last few years, research has been conducted to both diagnose prospective teachers' beliefs about NOS and compare them with the recommendations of documents on the reform of science teaching (e.g., García-Carmona and Acevedo 2016; Guisasola and Morentin 2007) in order to promote a better understanding about NOS. No doubt it is a necessary condition for NOS to be appropriately incorporated into science teaching, but by itself it is insufficient since many general and specific factors influence the incorporation of NOS and its pedagogical effectiveness (Acevedo 2008, 2009).

In Spain, little progress has been made toward fulfilling this aim. Some studies have shown that better science teacher education related to understanding and teaching NOS is necessary (Vázquez et al. 2013), more particularly in prospective primary teacher education (García-Carmona and Acevedo 2016; Guisasola and Morentin 2007). Consequently, innovatory, specific, and useful didactic proposals must be designed in order to motivate and guide primary education teachers toward introducing elementary notions of NOS in their classrooms. In the design of these proposals, the reality of each educational context, the usefulness of the resources and their availability, among other aspects, should be taken into account (Abd-El-Khalick 2012a). In this sense, the critical and reflective reading of some newspaper articles with scientific content has a great potential for addressing NOS in science classrooms (Cakmakci and Yalaki 2011; García-Carmona 2014; Huang et al. 2014; Shibley 2003), but its educational efficacy has not been assessed sufficiently yet.

Because of the need to promote an adequate understanding of NOS in prospective primary teacher education courses, a study was planned to respond to the following research question: *What is the efficacy of reading some newspaper articles with scientific content for learning NOS under usual prospective primary teacher education classroom conditions?*

The aim of this article is to present the findings and conclusions derived from the research conducted to answer this question.

2 Theoretical Framework and Background

2.1 What to Teach About NOS?

NOS is meta-knowledge about science that arises from the interdisciplinary reflections made by experts in the philosophy, history, and sociology of science, science educators, and by some scientists, but since the enterprise of science is multifaceted and dynamic, it is hard to define the concept of NOS precisely. Indeed, no consensus currently exists among these experts on any specific definition for NOS (Lederman, Antink, and Bartos, 2014). Perhaps one of the reasons may be that there is an attempt to establish a set of features that are common to all science disciplines, i.e., to provide a holistic view of NOS (Erduran and Dagher 2014). However, it seems clear that each science has its own specific features as well as others that it shares with the other sciences. This has led some authors (e.g., Samarapungavan et al. 2006) to consider whether one should speak of the nature of the sciences (NOSs) instead of NOS, while others (e.g., Irzik and Nola 2014) suggest taking as a basis the notion of *family resemblance* in the teaching of NOS. Erduran and Dagher (2014) argue that this approach "provided us with a unifying yet flexible framework for promoting a relatively broad and inclusive account of nature of science for science education, one that acknowledges common features while at the same time accommodating disciplinary particularities" (p. xiv).

In any case, when prospective teachers start their education in teaching NOS, they need some specific benchmark to decide what NOS issues might be addressed in the school science curriculum. However, the establishment of such a benchmark is not without controversy in view of the continuous debates about it within the science education community (Allchin 2011; Erduran and Dagher 2014; Matthews 2012; Schwartz et al. 2012). Nevertheless, this controversy or discussion is understandable because of the multifaceted nature and complexity of science, which, over the last few decades, have given rise to diverse proposals on what NOS is and what to teach about it (Acevedo and García-Carmona 2016a; Duschl and Grandy 2013; Kampourakis 2016).

Beyond these debates, a detailed description of which would exceed the scope of this article, for some years a certain degree of consensus has been achieved as to which aspects of NOS could be included in the school science curriculum (e.g., Lederman et al. 2002; Osborne et al. 2003). Bell (2009) has synthesized this consensus as presented in Table 1. In agreement with Abd-El-Khalick (2012b), the statements compiled in this table should not be considered as a fixed or exhaustive list of NOS aspects, but rather as a good benchmark for undertaking the teaching of NOS in science classrooms.

2.2 How Can NOS Be Included in the School Science Curriculum?

NOS issues can be included in science classrooms by embedding them in science content through contextualized activities (e.g., Khishfe 2014; Sadler et al. 2004), performing activities without intentionally relating them to science content, i.e., as a stand-alone topic (Lederman and Abd-El-Khalick 1998), or combining both approaches (e.g., Akerson and Donnelly 2010). Research shows improvements in students' understanding of NOS regardless of the approach employed. In addition, conclusive evidence in favor of one approach over the other has not been found (Bell et al. 2011), although the contextualized approach likely allows teachers to save some time in the development of science lessons. But above all, this latter approach may be more interesting when the purpose is to encourage teachers to incorporate NOS into their own instruction (Bell et al. 2012). In any case, the decisive factor for teaching NOS more effectively is that it is developed through an explicit and reflective approach (Abd-El-Khalick 2012a; Acevedo 2009).

The usual contexts in the teaching of NOS are the following (Acevedo 2009; García-Carmona et al. 2012):

Table 1 A set of consensus ideas to describe NOS (Bell 2009, pp. 2–3)

1. *Tentativeness.* All scientific knowledge is subject to change in light of new evidence and new ways of thinking—even scientific laws change. New ideas in science are often received with a degree of skepticism, especially if they are contrary to well-established scientific concepts. On the other hand, scientific knowledge, once generally accepted, can be robust and durable. Many ideas in science have survived repeated challenges and have remained largely unchanged for hundreds of years. Thus, it is reasonable to have confidence in scientific knowledge, even while realizing that such knowledge may change in the future
2. *Empirical evidence.* Scientific knowledge relies heavily upon empirical evidence. Empirical refers to both quantitative and qualitative data. While some scientific concepts are highly theoretical in that they are derived primarily from logic and reasoning, ultimately, all scientific ideas must conform to observational or experimental data to be considered valid
3. *Observation and inference.* Science involves more than the accumulation of countless observations—rather, it is derived from a combination of observation and inference. Observation refers to using the five senses to gather information, often augmented with technology. Inference involves developing explanations from observations and often involves entities that are not directly observable
4. *Scientific laws and theories.* In science, a law is a succinct description of relationships or patterns in nature consistently observed in nature. Laws are often expressed in mathematical terms. A scientific theory is a well-supported explanation of natural phenomena. Thus, theories and laws constitute two distinct types of knowledge. One can never change into the other. On the other hand, they are similar in that they both have substantial supporting evidence and are widely accepted by scientists. Either can change in light of new evidence
5. *Scientific methods.* There is no single universal scientific method. Scientists employ a wide variety of approaches to generate scientific knowledge, including observation, inference, experimentation, and even chance discovery. *Sometimes accidental or unexpected findings occur (serendipity) that represent important advances for science. Also, errors are frequent in scientific research and play an essential role in the development of science because their identification and analysis allow scientists to refine their experiments, reinterpret the data,* etc.*
6. *Creativity.* Creativity is a source of innovation and inspiration in science. Scientists use creativity and imagination throughout their investigations
7. *Objectivity and subjectivity.* Scientists tend to be skeptical and apply self-checking mechanisms such as peer review in order to improve objectivity. On the other hand, intuition, personal beliefs, and societal values all play significant roles in the development of scientific knowledge. Thus, subjectivity can never be (nor should it be) completely eliminated from the scientific enterprise

* The part of the text in italics of the description in Point 5 (Scientific methods) has been added by the authors. It has already been described in another work (García-Carmona 2015)

- *NOS teaching in the context of scientific inquiries.* This includes meta-reflective activities regarding aspects such as adaptation of the procedures in an investigation to the question(s) asked; influence of the chosen procedure on the subsequent results; distinction between observation and inference; effects of the measuring instruments employed on the data collection; role of established scientific knowledge in the interpretation of results; coherence between data and conclusions; importance of consensus on how to make observations and measurements, on how to overcome the difficulties encountered, on which criteria to agree on in order to draw conclusions, etc. (García-Carmona 2012a; Lederman, Lederman et al., 2014).
- *NOS teaching through the analysis of contemporary scientific and socio-scientific issues.* This context favors developing arguments based on evidence and valid scientific knowledge (Khishfe 2014; Sadler et al. 2004); therefore, it helps students to make informed decisions on scientifically based personal and societal matters. Very interesting in this context is the analysis of opposite views or interpretations with regard to contemporary scientific issues and the social processes among scientist that

are derived from them or with regard to controversial socio-scientific issues such as climate change, cloning, nuclear power, etc., because in having to decide who and what to trust, students will have to base their arguments on "reliability indicators" drawn from the assessment of the authority of researchers or other sources of information.

- *NOS teaching using the history of science.* This helps to show the development of scientific theories, to know the relationships between science and society during the different periods in history, to illustrate the universal and multicultural character of science, etc. (Acevedo 2016a; McComas and Kampourakis 2015). However, care should be taken when history of science is employed in teaching NOS (or other school science content) because frequently the processes of science are oversimplified and this contributes to stereotypes and false ideas about how science works (Allchin 2004; Numbers and Kampourakis 2015). Also, the history of science is interesting to know the arguments and reasoning that helped historical scientists interpret natural phenomena (Acevedo and García-Carmona 2016b in press; Acevedo, et al. 2016b in press).

2.3 The Use of Newspaper Articles with Scientific Content in the Teaching of NOS

For many citizens, newspaper articles with scientific content constitute one of their main sources of information about the progress of science and the problems currently of interest to scientists as well as about current controversial socio-scientific issues, anniversaries of scientific discoveries and past scientists, etc. Therefore, the critical and reflective reading of these is a crucial element of scientific literacy. In fact, it is recognized as a basic resource in science education (Jarman and McClune 2007).

Reading newspaper articles with scientific content has been used to diagnose prospective primary teachers' views of NOS (Murcia and Schibeci 1999). Also, it has begun to be considered for teaching about NOS (Cakmakci and Yalaki 2011; García-Carmona 2014; Huang et al. 2014; Shibley 2003). However, these newspaper articles are not written for educational purposes. Therefore, it is necessary to evaluate their pedagogical usefulness before planning their reading in science classes.

García-Carmona (2014) analyzed the pedagogical potential of teaching NOS of an ample repertoire of physics-related articles, published between 2005 and 2013 in major Spanish newspapers. He concluded that: (1) it is relatively easy to select a set of articles with explicit allusions to different NOS aspects; (2) many articles refer to various NOS aspects in the same context, which makes it possible to address more than one aspect of NOS in class using one single article; (3) it is possible to select articles that deal with NOS aspects in different contexts ("advances and limits of science," "history of science," and "socio-scientific controversy"); (4) the repertoire analyzed can facilitate the inclusion of NOS in the curriculum by integrating it into the rest of the content of school science because NOS aspects are illustrated in different fields of physics research (astronomy, climate change, quantum physics, physics of the Earth, radioactivity, etc.).

There have been very few studies about the efficacy of reading newspaper articles with scientific content for learning about NOS. One of them is that of Shibley (2003) who used articles with scientific content published in *The New York Times* in a philosophy of science course. From their readings and the subsequent exchange of ideas, students reflected on science-related controversies and improved their understanding of NOS aspects.

More recently, Cakmakci and Yalaki (2011) used science news to introduce NOS into prospective teacher education through an explicit and reflective instructional approach. The results of the study revealed that these prospective teachers improved their ideas about NOS, and the authors concluded that this resource is adequate to teach NOS through brief, well-designed and contextualized teaching interventions. Likewise, Huang et al. (2014) reported on improvements in eighth- and ninth-grade students' understanding of NOS when they participated in synchronous and asynchronous discussions about scientific news posted on Facebook. In a science course for non-science majors, Leung, Wong, and Yung (2015) also employed science (health) news articles to analyze whether better NOS understandings led to critical evaluation of science in the media. They found a lack of evidence for this correlation, although they suggest performing more research on the topic because an adequate understanding of NOS helps citizens to critically evaluate science in the media.

In summary, it can therefore be said that the reading of certain newspaper articles with scientific content has a clear pedagogical potential for use in addressing NOS in science classrooms. Nevertheless, more research is still necessary regarding the efficacy of this resource in the teaching of NOS with a critical and reflective approach.

3 Methods

3.1 Context and Participants

In Spain, prospective primary teacher education programs in science teaching are usually oriented to provide students with basic preparation in the design, implementation, and assessment of well-founded educational proposals in primary education science teaching. However, programs including NOS content are few (García-Carmona and Acevedo 2016; Guisasola and Morentin 2007).

At the Spanish university where the present study was conducted, concerns about including NOS teaching in primary teacher training came from some of the faculty who are teaching not science but science education. The official program of the subject of science teaching does not explicitly consider an introduction to NOS or guidelines about how to teach it. Its inclusion is thus subject to the instructor's decisions as to when and how it can be presented, in accordance with the context of the course and the time available.

The subject of science teaching is taught during the 2nd year of the bachelor's degree in Primary Education at the particular university. Most prospective primary teachers enter the university from the social sciences or humanities baccalaureate, or from higher vocational training related to education. The prospective primary teachers who have followed the baccalaureate line of pre-university studies have taken a compulsory subject called *Science for the Contemporary World* that officially includes some content related to NOS. However, a recent study (Vázquez et al. 2014) reveals that this subject has not had the desired efficacy in improving the students' conceptions of NOS.

Once admitted into the bachelor's degree course in Primary Education, prospective teachers study two science subjects during the 1st year. However, their programs included no NOS-related content or objectives. Therefore, it can be said that the prospective primary teachers involved in this study had not received any explicit NOS instruction previously. Their views about NOS were thus likely to be the result of their intuitions and of implicit and little-thought-out beliefs that may have been forged in a context of traditional science teaching (Banet 2010; Cañal et al. 2013), which has been found to implicitly convey poorly informed ideas about science and scientists' work (García-Carmona et al. 2012).

Bearing in mind all these circumstances, the present study was carried out within the subject of science teaching taught by the first author. The class group was composed of 67 prospective primary teachers (49 women and 18 men) organized into 19 small groups. However, the teaching intervention was performed under usual class conditions, and not all groups completed all of the three phases planned (see the following section). Some groups did not submit their final reports (a minority of the groups), and others did not include the responses corresponding to the third phase in their reports (they only included their initial responses and some comments about the whole-class discussion). Hence, in order to analyze the efficacy of the teaching intervention in depth, it was decided to select only those groups who finished all the planned tasks. Accordingly, data from eight groups (G1…G8), comprising 30 prospective primary teachers, were finally analyzed in the study.

3.2 Teaching Intervention

Given the time available for the teaching intervention, the learning goals had to be relatively modest (Matthews 2012). Hence, as in some other educational experiences where NOS has been introduced in science classrooms in similar circumstances (e.g., Leach et al. 2003), a strategy based on short teaching interventions was chosen. To do so, the subject content selected was "*What to teach in primary science education.*"

Consistent with the set of general ideas about NOS presented in Table 1, and as it was not possible to address all of them, it was decided to discuss the following NOS aspects from an explicit-reflective approach:

- *Objectivity and subjectivity in science*, which is directly related to the content of Aspect 7 ("Objectivity and subjectivity") in Table 1.
- *Scientists' skepticism*, which is related to the content of Aspect 1 ("Tentativeness") and 7 ("Objectivity and subjectivity") in Table 1.
- *The empirical evidence for scientific knowledge*, which is related to the content of Aspects 2 ("Empirical evidence") and 3 ("Observation and inference") in Table 1.
- *Role of current scientific knowledge in new research*, which is mainly related to the content of Aspects 1 ("Tentativeness") and 2 ("Empirical evidence") in Table 1.
- *The role of errors in the construction of science,* which is related to the content of Aspects 2 ("Empirical evidence") and 5 ("Scientific methods") in Table 1.

The researchers selected these NOS aspects fundamentally for two reasons: (1) most of them have not been analyzed sufficiently in previous research related to the understanding of NOS, at least from the perspective or context employed in this study, and (2) their understanding can motivate prospective primary teachers to become more receptive to science teaching strategies that are consistent with authentic scientific practice, i.e., to promote the discussion of ideas with teamwork, collaborative learning, and consensus building in science classes, to favor among the students a conception of error as a starting point in science learning, and to promote the idea that most of the time it is not enough to make a single measurement to check a phenomenon, etc.

In order to address the aforementioned NOS issues in class, two newspaper articles were selected that deal with the controversial OPERA experiment[1]: "*Tension and disagreement among physicists of the neutrinos experiment*"[2] and "*Two prestigious physicists disprove*

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[1] OPERA (Oscillation Project with Emulsion-tRacking Apparatus) is an important scientific project that studies neutrinos' behavior that is being developed by scientists at CERN (European Organization for Nuclear Research) for some years. More information is available at http://operaweb.lngs.infn.it.

[2] Available at http://sociedad.elpais.com/sociedad/2011/10/12/actualidad/1318370416_850215.html.

the neutrinos experiment."[3] Both articles were published in *El País*, which is one of the most read newspapers in Spain, and their pedagogical potential for reflection on NOS issues had been shown in a previous study (García-Carmona 2013, 2014).

The two newspaper articles explain the controversy in the scientific community concerning the experiment because the interpretation of the first results called into question one of the basic pillars of modern physics: the Theory of Relativity of Einstein (1905). According to a first experimental report (presented in September 2011 at the headquarters of CERN), neutrinos were found traveling faster than the speed of light, while the Theory of Relativity establishes that nothing in nature can exceed that speed. Obviously, if this result is confirmed, it will be a revolution in the domain of physics, since it will bring into question the validity of an essential part of its foundations. This therefore led to rivers of ink in the media, reporting the uncertainties, skepticism, and caution shown by leading particle physicists at the time. More recent checks by the project's same team of scientists revealed some flaws in the experiment, which would show that the detection of these "superluminal" neutrinos was the result of faulty measurements. Thus, the Theory of Relativity would maintain its validity.

Consequently, the two newspaper articles selected provided an excellent opportunity to reflect on selected aspects of NOS, without needing any advanced knowledge of physics as the emphasis was on the tensions, arguments, positions, and evaluations made by scientists participating in the scientific controversy over the experiment (García-Carmona 2013). This was an important aspect to consider in conducting the study because the physics competences of prospective primary school teachers are not usually of a high level (García-Carmona and Cruz-Guzmán 2016). In addition, this type of experiment related to particle physics and others of similar complexity are common in the news (García-Carmona 2014) and are likely to have an important influence on the development of the scientific literacy of the public (Hodson 2008), even though this public does not have an extensive knowledge of physics. It is reasonable, therefore, that prospective teachers acquire training in the use of this kind of scientific news in the press to foster critical reflection about the progress of contemporary science among their own students.

The prospective teachers were assigned to heterogeneous work groups of three or four members. In general, they already had well-developed teamwork competences, and they performed all the tasks in small groups during the teaching intervention. According to Salmerón (2013), the interaction of several individuals may lead to more complete responses since they have to reach agreement on a common representation that combines the different ideas of the various group members. For this process to be carried out successfully, the instructor (first author) monitored the development of the groups' work on the different tasks, occasionally giving them hints and encouraging them to decide on the responses by way of an initial discussion followed by a subsequent consensus among all the members. However, following the recommendation of Berland and Lee (2012), it was also clarified that if divergent views emerged that made it impossible for the group to agree on a common response to a question, they should then express the different perspectives.

The teaching intervention had the following phases:

- *Phase I: Reading the two newspaper articles.* Without previous instruction, the prospective teachers read the articles and then responded in group to various questions (Table 2). The questions were carefully designed to encourage the prospective teachers' reflection and debate on the selected aspects of NOS, within the scientific

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[3] Available at http://sociedad.elpais.com/sociedad/2011/10/03/actualidad/1317592818_850215.html.

Table 2 *Questions asked to reflect about NOS issues after reading the newspaper articles*

It is usually said that science is "objective." Then why do you think there are disagreements among prestigious physicists (such as those who work in CERN) in interpreting data or in considering them more or less valid?
Why do you think physicists are usually distrustful when new experiments and the interpretation of their results appear? Is it beneficial or harmful to the development of physics and why?
In view of the results of the OPERA experiment, why do you think some physicists recommended repeating it several more times and in different situations?
In each period, valid scientific knowledge is always present in new research. How do you think this scientific knowledge influences scientists when they interpret the results of a new experiment?
Sometimes, errors are made in science experiments. Is it beneficial or harmful to the development of science and why?

context referred to in the newspaper articles. As Clough notes (2011), learning about aspects of NOS is most effective when approached as reflection on questions that invite the students to think deeply about them. In designing the questions, a fundamental aspect was the researchers' experience with activities aimed at the students' reflecting on aspects of NOS (García-Carmona 2012a, 2013, 2015) and in evaluating conceptions of NOS (e.g., Acevedo et al. 2002; Vázquez et al. 2014). The groups' responses had to be registered in a group report. This first phase covered 2 h, and it allowed the researchers to diagnose the prospective teachers' prior conceptions about the NOS aspects that were being dealt with.

- *Phase II: Whole-class discussion of the groups' responses to the NOS questions.* After responding to the NOS questions regarding the articles' content, the groups shared and discussed their responses in a whole-class session lasting 1.5 h. The instructor moderated the discussion among groups and introduced some explanations, additional questions, etc., in order to enrich it as much as possible. The aim was for the groups to try to reach common conclusions regarding the NOS aspects addressed, without forcing this process. In this sense, when misconceptions about NOS appeared, the instructor tried to generate a cognitive conflict that would create dissatisfaction among the students so that they might reconsider their arguments.
- *Phase III: Conclusions from the whole-class session.* Once the groups' responses to the NOS questions had been discussed in class, each group checked their initial responses, refining, modifying, or reaffirming their arguments and views about the NOS aspects dealt with. The final responses were also registered in the group report following the initial responses. The groups did this task in a class session lasting 1.5 h. The reports were presented a week after concluding the teaching intervention.

3.3 Data Analysis

Taking into account the circumstances in which the study was carried out, a qualitative method was used to analyze the prospective teachers' understanding of the NOS aspects dealt with. The analysis was confined to examining the evolution of the responses from Phase I (prior views) to Phase III (final views) as a result of the feedback process among the groups and the instructor (Phase II), in the context of a critical and reflective reading of the two newspaper articles.

To classify the groups' responses, we used the following three categories (Rubba and Harkness 1993):

- *Appropriate* (A)—the response expresses an appropriate view of the respective NOS issue (e.g., scientists' skepticism is beneficial because in science the results of an experiment have always to be questioned before they can be finally accepted).
- *Plausible* (P)—although not totally adequate, the response expresses some acceptable NOS aspects (e.g., scientists' skepticism is beneficial because the results have to be verified, and, at the same time, it is harmful because it can hinder the progress of science).
- *Naive* (N)—the statement expresses a view that is neither appropriate nor plausible (e.g., scientists' skepticism is harmful because it hinders the progress of science).

As open-ended questions were asked, the responses were classified only after they had been carefully examined. To this purpose, the researchers employed the NOS aspects in Table 1 as benchmarks and the extensive catalog of adequate, plausible, and naive ideas about NOS given in Manassero et al. (2001, 2003). The classification process was the result of applying a combination of the methods of inter-rater and intra-rater analysis (Padilla 2002). Thus, the two researchers made a first classification of the responses separately, reaching a high level of agreement (over 80 %). The differences were mainly due to the possibility of classifying some responses in different ways because they referred to more than one NOS aspect. Consensus was reached after discussion between the two researchers. After a sufficient period of time (approximately 3 months), both researchers checked all the responses again and then finalized their evaluations. This last analysis allowed the researchers to make some additional adjustments, regrouping responses so as to reduce the number of categories of the prospective primary teachers' views. In this way the final classification was obtained.

For confirmability of the analysis performed (i.e., the objectivity criterion in qualitative analyses), *low-inference descriptors* (Seale 1999) are shown in the results section, i.e., some textual citations from the groups' responses to the different questions. The purpose of their use is that the results and conclusions of the research can also be confirmed by outside observers (the readers, in this case).

4 Results

The findings obtained from the analysis of the reports of the eight groups are described below. They are accompanied by some examples of textual citations from the groups' responses to the NOS questions. Table 3 presents a synthesis of the groups' main views about the NOS aspects dealt with in the teaching intervention and their corresponding classifications into appropriate, plausible or naive views.

4.1 The Groups' Views After Reading the Newspaper Articles: Diagnosing Prospective Teachers' Prior Views About NOS

On the *first question* (objectivity/subjectivity concerning the OPERA experiment), six groups commented that the differences among eminent scientists' responses to the results reflect the contradiction of those results with solidly established scientific knowledge:

Table 3 Synthesis of the groups' prior and final views about the NOS issues addressed and a classification ([A]-appropriate, [P]-plausible and [N]-naive) of those views

Questions	NOS issue	Prior views (Phase I)	Final views (Phase III)
1. It is usually said that science is 'objective'. Then why do you think there are disagreements among prestigious physicists (such as those who work in CERN) in interpreting data or considering them more or less valid?	Objectivity and subjectivity in science	Differences among scientists in interpreting the results of an experiment are due to these being contradictory to established knowledge [P]: G1, G2, G3, G5, G6, G7 Scientists' beliefs influence the construction of science [P]: G1, G4 G6, G8 Science is intrinsically subjective [P]: G6	Scientists are not fully objective because they are influenced by their beliefs; therefore, science is not fully objective [A]: G2, G3, G5, G6, G7 Objectivity in science is a result of intersubjectivity [A]: G2, G5, G6 Some scientists have spurious interests in their investigations [P]: G4 The cost of experiments hinders their replicability [P]: G4 Prior view was not modified: G1, G8
2. Why do you think physicists are usually distrustful when new experiments and the interpretation of their results appear? Is it beneficial or harmful to the development of physics and why?	Scientists' scepticism	Scientists' skepticism is beneficial because it leads to checking the accepted theories continually, and it is also harmful because it hinders the progress of science [P]: G1, G2, G3, G4 It is beneficial because it requires verifying the results exhaustively [A]: G5, G7, G8 It is harmful because it hinders the progress of science [N]: G6	Scientists' skepticism is beneficial because in science the results of an experiment always have to be questioned before they can be finally accepted [A]: G1, G2, G3, G4, G6, G7 It is beneficial because the results have to be verified, and, at the same time, it is harmful because it can hinder the progress of science [P]: G8 Prior view was not modified: G5
3. In view of the results of the OPERA experiment, why do you think some physicists recommend repeating it several more times and in different situations?	Empirical evidence	Experiments have to be repeated to get reliable results [A]: G1, G4, G8 These have to be repeated to find possible errors [P]: G2, G5, G8 These are repeated if the results are not enough to refute an accepted theory [P]: G3, G7	Experiments have to be repeated because the results must be universal (i.e., in different moments and contexts) [A]: G1, G2, G4, G5, G8 They have to be repeated because the scientific community must approve the validity of the results [A]: G6 Prior view was not modified: G3, G7

Table 3 continued

Questions	NOS issue	Prior views (Phase I)	Final views (Phase III)
4. In each period, valid scientific knowledge is always present in new research. How do you think this scientific knowledge influences scientists when they interpret the results of a new experiment?	Role of current scientific knowledge in new research	Current scientific knowledge influences new research negatively because it is very difficult to change accepted knowledge [N]: G2, G8 Its influence is to question the new results and to promote more research (A): G3, G4, G6 It influences positively (encouragement of more research) and negatively (difficulty in accepting new ideas) [P]: G5 Irrelevant responses [N]: G1, G7	Current scientific knowledge is basic for interpreting the results of a new experiment (to confirm or refute these) [A]: G7, G8 Its influence is positive because it forces there to be verification of the experiment more times under different conditions [A]: G2, G4 Its influence is negative… [N]: G1 Prior view was not modified: G3, G5, G6
5. Sometimes, errors are made in science experiments. Is it beneficial or harmful to the development of science and why?	Role of errors in the construction of science	Errors in science are positive because scientists learn from them and science progresses [P]: G1, G2, G5, G6, G7, G8 Errors in science are positive (deepening the research) and negative (waste of time and loss of credibility) [P]: G3 Role of errors depends on their severity and how they influence society [N]: G4	Errors in science are inevitable and new scientific discoveries are sometimes made by chance (serendipity) as a result of an error [A]: G1, G2, G3, G6, G7 Errors in science are beneficial because they force the scientists to check and to reformulate hypotheses [A]: G4, G5 Prior view was not modified: G8

> Because it contradicts a universal law that has been solidly founded since [it was posited in] 1905 by Albert Einstein (the Theory of Relativity), and they performed several experiments [to confirm the results] before rejecting the existing theory. (G1)

> …there exist differences because an important theory, that of Einstein's relativity, is being contradicted. There are two points, that some do not want to deny it because they value the importance of the preceding theory in science; and others want to do more tests to the experiment [that was] pulling down the preceding theory, basing themselves on the view that science is constantly changing, and, although a particular theory may have had a great impact, this does not mean that it is the only theory that is valid. (G5)

Three groups considered it to be due to scientists' different beliefs:

> One scientist can draw different conclusions from others depending on which factors he or she takes into account. Also, every scientist starts out from ideas and trends that have influenced them throughout their training, and they give priority to some things over others. (G4)

One group indicated that the different beliefs are due to the inherent subjectivity of science:

> …Science is not as objective as we think. It depends on each person's subjective processes and what conception they have of science. (G6)

There were more arguments than groups because some groups gave more than one.

On the *second question* (advantages vs. disadvantages of scientists' skepticism about new results), four groups believed that on the one hand it is beneficial because it leads scientists to question well-consolidated theories, and on the other it is prejudicial because it hinders the progress of science:

> We believe that in one way it can be detrimental because science would not be able to advance in this way. In another way however, we understand that some scientists are wary of such experiments because they bring down not just one theory, but many more theories that are based on it, and, unsurprisingly, they want to make sure and check everything before taking the plunge. (G1)

> On the one hand, we think that it is prejudicial to show themselves to be wary because if the hypothesis is correct then physics will advance, but, due to these scientists' rejection of the results, this advance will not take place. On the other hand, however, we believe it is beneficial to be wary as this will lead to a more thorough study of the experiment. They also avoid any hypothesis that has possibilities of not being true causing an unnecessary upheaval. (G3)

Three groups believed that it is beneficial because the results have to be checked thoroughly:

> We believe it is beneficial because the scientific community must demonstrate something starting from a doubt and demonstrating step by step whether or not that doubt is true; this means that they will always employ all means to objectively substantiate a theory and not just allow themselves to be led by first impressions. (G5)

One group considered it to be prejudicial because it is an obstacle to the advance of science:

> It is prejudicial because this mistrust causes a stagnation of science by making physicists' innovative nature be replaced by a traditional and objective view of science. (G6)

The responses were therefore relatively balanced between views that see scientists' skepticism as beneficial because the experiments have to be repeated to ensure the reliability of the results and prejudicial because it delays the progress of science.

On the *third question* (the need to repeat the experiment more times and in different situations), three groups argued that it is to ensure the reliability of the new results:

> Because the more often an experiment is repeated, the more reliable is its result. And since we are talking about such a very important theory, one should also consider the impact that such a theory would have for the scientific community if it turned out to be false. (G1)

Three groups indicated that it is done in order to find possible faults in the new experiment:

> We believe it is because these scientists are the ones who are closed to new research. They believe that the theory that is valid at this moment contains no errors, and more, they almost guarantee that the OPERA experiment has an error and they do not know which. So they believe more repetitions of the experiments are needed and in more different situations to find that error. (G8)

Two groups believed that it is because the results are insufficient to refute the prevailing theory:

> We believe that they [the physicists] do not see that the results are sufficient to disprove a theory like Einstein's. (G7)

The reasons given are divided among seeking reliability, finding possible errors, and insufficiency of the experiment's results.

On the *fourth question* (presence of current scientific knowledge in the interpretation of new research), four groups indicated that its influence is to question and interpret the results of the experiment. But for two of these four groups this was positive, while for the other two it was negative:

> …we think that, without theoretical knowledge that has been established as valid, these scientists would not be able to reason their responses in interpreting or evaluating a new experiment… (G3)

> …it may have a negative influence or hold things back since they [scientists] reject or give as negative the new discovery given that they base themselves on current laws that are inconsistent with what has been discovered. (G2)

One group responded that the influence of current scientific knowledge is to call into question the new results and to lead to more replicates of the experiment being done:

> …When they discover a new theory that contradicts the theoretical knowledge that has been established as valid up to now, they have to make the proposed theory very sure. This means repeating the experiment more times, and also a debate will emerge to get this new theory known. (G6)

One group stated that there is a positive influence in encouraging further research and a negative influence because it represents an obstacle to new ideas:

> Positive from the fact that this theory can be taken as the basis to always continue researching into it, and negative because the scientist can stay with that idea, base themself on them [such ideas] and not accept new ones. (G5)

The responses of the other two groups were unclear or irrelevant.

Most groups noted that the existing theoretical knowledge is necessary as a framework of reference to question the results of the experiment. They gave various reasons for this view. Some think that this influence is positive and others that it is negative. That two groups gave unclear or irrelevant responses was particularly worthy of note since it revealed that they knew nothing about the issue.

Finally, on the *fifth question* (regarding the role of errors in the construction of science), six groups considered it to be beneficial because one learns from errors, new research lines open up, and science advances:

> It may be beneficial because it helps to get further research done that may lead to new discoveries. (One learns from errors.) (G1)

> We think that it is beneficial, because it makes you look for the solution to the error and keep advancing gaining more knowledge about the given topic. Also, uncovering an error in the process may change the way of approaching it. (G7)

One group responded that it may be beneficial by encouraging scientists to go deeper in their research, but also prejudicial because it could waste money and time and lead to a loss of credibility:

> …it may be beneficial because, with the errors in the experiments, one can draw new conclusions since, when something gives an error, the research is greater, thus giving rise to new experiments or managing to get to the good hypothesis. But we also think that it is prejudicial because that [area of] science can lose credibility, and waste money or time… (G3)

Another group stated that it depends on the seriousness of the error and on how it influences society:

> …it depends on the degree of error. If it causes minimal damage to society, we consider that it is good since hypotheses are discarded. However, if the damage involves serious consequences for society, we think that it is prejudicial. (G4)

By far most of the groups responded that errors in scientific experiments are beneficial to the advancement of science because research then goes into greater depth and new lines of research are opened up.

Finally, it should be noted that in this first phase two groups (G1 and G2) used in some of their responses the terms “theory” and “law” without distinction. However, the analysis of the content of their responses did not provide sufficient evidence to determine whether or not they were confusing the two concepts. It seemed rather, in view of the context of those responses, that they were using the two terms to refer to scientific knowledge in general. This was not addressed in the whole-class discussion session because it was not expressed by these groups in their oral presentations to the rest of the class. The researchers only realized this when they evaluated the reports after the educational intervention had been completed. Also, it was not observed in any of the reformulated responses in Phase III, as will be seen below.

4.2 Whole-Class Discussion of the Groups' Initial Views

During the whole-class session, the groups exchanged their views about NOS issues that they had been asked about in the form of a debate. In this phase, the groups, with the help of the instructor, contrasted their initial arguments (Phase I) with those of their classmates and then reconsidered them. First, each group presented their responses. Then, when there was disagreement, the instructor encouraged reasoned debate among the groups. If the discussion began to stagnate, the instructor introduced some auxiliary question or counterexample to facilitate progress. For example, some groups were disappointed by the idea that science is not completely objective. G1 said in this regards: "If science is not objective, how can we believe what it says?" The instructor then encouraged students to consider that science, despite its limitations, has contributed to the development of humanity. In the same context, it was also necessary to emphasize the role of agreement among scientists to achieve new knowledge. To this aim, an auxiliary question was asked as to why they believed that Pluto was no longer considered to be a planet. Such questions encouraged students to understand the need for consensus in constructing scientific knowledge. Also, with regard to the analysis of errors in science, reference was made to known passages in the history of science in which there was a clear role of serendipity (discovery of radioactivity, of penicillin, etc.). After this session, the groups had to recheck their initial responses in order to make the necessary amendments. The result of this process will be presented in the following subsection.

4.3 The Groups' Views After the Whole-Class Session

With respect to the *first question*, six groups referred to scientists as not being wholly objective, but instead as being influenced by their beliefs. Therefore, science itself is not completely objective:

> …science is not completely objective. It is impossible to be so. We each see things according to our own way of thinking, because we have an idea of what we will find. (G6)

> …scientists are not objective, since they are people who are governed by their beliefs and ideas as is everybody else. For this reason, not all scientists agree on the interpretation of the same data. (G7)

Of those six groups, three alluded to objectivity as a process deriving from intersubjectivity:

> …something is objective when everyone reaches agreement. This process is known as intersubjectivity. (G2)

One of the first five groups pointed to spurious interests and also indicated that the high cost of the experiments hinders their replication:

> …every scientist is influenced by thoughts and ideologies, and starts out from different points of view. The experiments are sometimes very expensive, and this discrepancy is not so easily resolved. Sometimes the opinions of these professionals are being bought by politicians or by interests. (G4)

Two groups maintained their first responses.

There was a shift in the responses to the first question after the whole-class session. The reason most commonly given in the first phase was finally abandoned and replaced mainly by the lack of objectivity of scientists, and therefore of science itself, although this reason was also present in some groups initially. In particular, they considered subjectivity as being intrinsic to scientific work. Of particular interest was that three groups mentioned the notion of objectivity as being a result of intersubjectivity in the scientific community.

With respect to the *second question*, six groups stated that scientists' skepticism is beneficial to new discoveries because results always have to be questioned for them to be accepted:

> …we still find it to be an advantage, since in this way only things that are proven and after going through many research studies and questions are accepted. (G7)

One group believed that skepticism is beneficial because the facts have to be confirmed, but at the same time prejudicial because it may delay the progress of science:

> It can be beneficial because you cannot have blind faith and must prove the facts, and it is prejudicial because this mistrust causes a stagnation of science. (G8)

One group maintained its first response.

After the whole-class session, there was an important change in the views of several groups. At the end, by far most of them considered that scientists' skepticism is positive because the experiment must be replicated under different conditions and its reproducibility tested before the results can be accepted and considered as universal.

With respect to the *third question*, five groups indicated that the experiments must be reproduced for the results to be universal:

> …information [the results] must be checked several times and in different situations to see if in all of them one gets the same results. If so, we would have a new, now completely veracious, discovery. (G2)
>
> …we must doubt everything until we can demonstrate it through experiments and taking into account all the variables involved and also check it in various contexts to demonstrate that the scientific fact is universal and valid in many situations. (G5)

One group considered that a reason for the need to repeat the experiment is for the scientific community to be able to qualify the results as valid:

> An experiment must be checked many times and in different conditions for the whole scientific community to agree and give validity to those experiments. (G6)

Two groups maintained their first responses.

After the whole-class session, the reasons given by most groups were finally focused on the need for the results of the experiment to be universal. It was notable that two groups showed little understanding of the topic.

With respect to the *fourth question*, four groups considered that the influence of current scientific knowledge on the interpretation of new experiments is positive and fundamental. Two of them gave the interpretation of the results as a reason, confirming or refuting the experiments:

> We consider it necessary to take what there was before as the basis because otherwise it would be a case of starting from scratch. However, the new research studies will have the opportunity to refute that previous knowledge by demonstrating that they are invalid. (G8)

Another group noted as a motive the repetition of the experiment in various conditions before establishing any conclusions:

> …beneficial because in this way they will have to check their experiment more often and in different situations which will mean that we shall reach conclusions that are more veracious. (G2)

The other group's argument was that science progresses in that way by establishing new conclusions:

> Getting new conclusions implies greater advance in the world of science, and scientists usually do not mind that the work gets altered, since they are used to making and re-making hypotheses until they arrive at a new theory. (G4)

One group responded that current scientific knowledge has a positive influence on the acceptance or refutation of new ideas, but a negative influence due to scientists' preconceptions or prejudices:

> Scientists must base themselves on their ideas or hypotheses to investigate, but they must not be swayed by prejudices or conceptions of a moral or religious type, etc., since this will prevent them advancing properly in research. As the basis for their research, they can take current scientific knowledge that is related to the area to investigate, to see the errors that are made, the results, etc. And in this way [they will] progress correctly, although they may be led down wrong paths, or [they may hold] invalid preconceptions. Therefore, the results of the experiments can be seen to be influenced positively by the acquisition of scientific ideas that guide them [scientists] toward improvements in their research, or negatively by the preconceptions and/or prejudices that the researcher has and lets him or herself be swayed by them. (G5)

Two groups maintained their first responses.

Most groups felt that the existing theoretical knowledge, as a referent theoretical framework, has a beneficial influence for various reasons: to interpret the new results, to replicate the experiment under other conditions, and because science progresses in this way. Although fewer groups suggested that there is a negative influence, the lack of a response in two cases and the irrelevance of another seemed to indicate that the whole-class session did not have the desired effect in a substantial number of cases.

Finally, with respect to the *fifth question* (regarding the role of errors in the construction of science), five groups said it is beneficial because new discoveries are sometimes made by chance as a result of an error. Without naming the term, they were referring to serendipity:

> …errors have benefited science because, by doing more tests, we might for example find something that we were not even looking for, such as for example what happened to Fleming with the discovery of penicillin… (G2)

> …some of these research studies may turn out to be in error, but we think that this is not prejudicial, but rather it makes it possible to continue moving forward and learn…or even come to a discovery other than what you intended, like what happened with penicillin. (G7)

Two groups responded that it is beneficial because some hypotheses are discarded and others are formulated, which are then tested with new experiments. In this way, science advances:

> The fact that errors exist always benefits the advance of science, since, in discovering new errors, we then discard hypotheses that we once thought were true, and that now, with new experiments, are not. It causes there to be new studies and experiments about the new hypotheses, which will eventually benefit society. Therefore, thanks to the errors, we are always advancing in the hard and long field that is science. (G4)

One group maintained its first response.

After the whole-class session, there was still acceptance of the possible positive effect of errors in scientific experiments. However, it was noteworthy that, at the end, most groups included as one of the reasons the possibility of serendipity or unexpected discoveries resulting from what was originally an error.

4.4 Summary of the Evolution of the Groups' Views About the NOS Issues Addressed

In order to evaluate the evolution of the groups' views, in addition to Table 3 and Fig. 1 shows a graph for each of the NOS issues dealt with. First, one notes that the majority of groups (five or six of the eight groups) attained appropriate views in each of the five NOS aspects addressed by the end of the educational process.

With respect to the objectivity/subjectivity of science, all groups displayed plausible views at the beginning, but at the end, six of them had enriched their views with references to scientists, as human beings, not being fully objective and to objectivity in science as a result of intersubjectivity. However, three groups (G1, G4, and G8) maintained plausible views because they continued to argue that some scientists have spurious interests in their investigations or that science is subjective intrinsically without any further explanation, among other things.

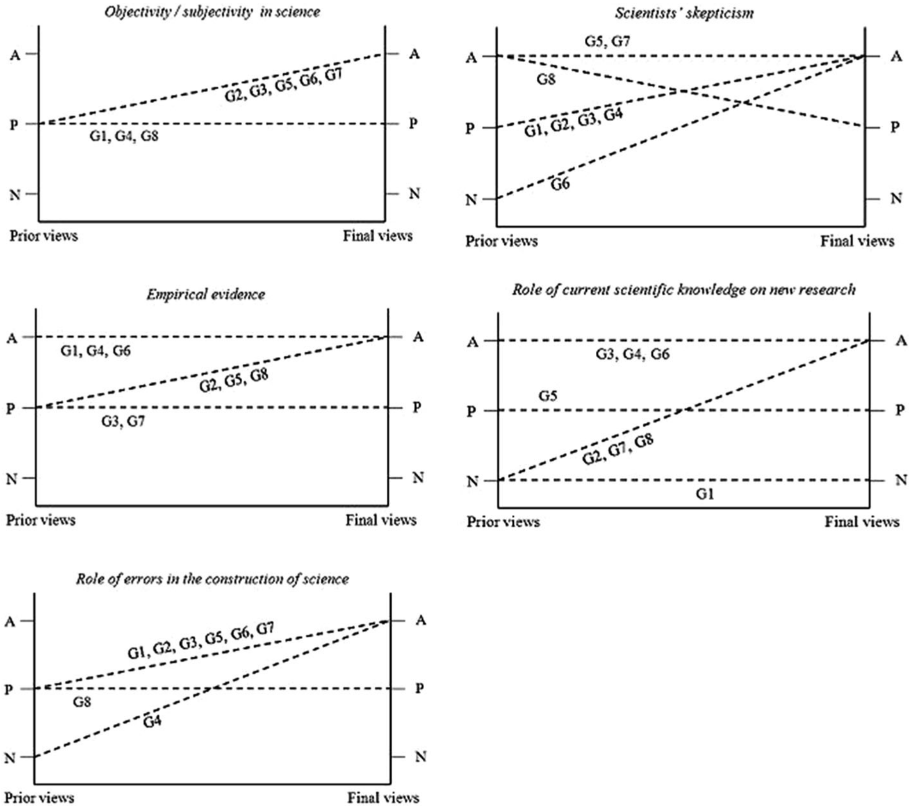

Fig. 1 Evolution of the groups' views regarding the different NOS issues addressed

Regarding the scientists' skepticism, three of the eight groups (G5, G7, and G8) had already displayed appropriate ideas at the beginning. Nevertheless, G8 changed to a plausible view, specifically because this added to its prior argument that scientists' skepticism is also an obstacle to new scientific research. Perhaps this group did not have great confidence in its initial view and was influenced by those teams (G1, G2, G3, G4, and G6) who expressed the above idea in the whole-class session, although we do not really know whether this was so. In any case, the decline undergone by G8 in this aspect should be considered as an outcome that may occur when carrying out educational research in normal class conditions as on this occasion. What can be highlighted is that the skepticism of scientists, rather than an obstacle, should be regarded as something that is necessary for further scientific research. Most groups finally adopted this idea.

In the context of empirical evidence, the necessity to repeat an experiment several times to improve its validity was already suggested by three groups appropriately in the first phase (G1, G4, and G6). The rest of the groups expressed plausible ideas in this respect. However, most of them improved their arguments in the revision of their responses. Only two groups (G3, G7) maintained a plausible view.

The role of accepted scientific knowledge in affecting new research generated different types of views among the groups at the start. While four groups had naive ideas (G1, G2, G7, and G8) and another a plausible idea (G5), three groups (G3, G4, and G6) appropriately argued that current scientific knowledge has an influence by questioning the new results and promoting more research. The main naive conception was that this hinders the development and interpretation of new experiments. After the whole-class discussion, the number of groups with appropriate responses was a majority, although one group (G1) maintained a naive view and another group (G5) its prior plausible idea.

Finally, with regard to the role of errors in science, no group expressed an appropriate prior view. However, they all improved their views in this respect after the teaching intervention except for one (G8), which maintained its prior conception taking errors to be an obstacle to the development of science. Otherwise, most groups finished by recognizing that errors in science are inevitable, that they are useful in obliging the scientists to check their investigations in greater depth, and new scientific discoveries are sometimes made by chance as a result of an error. This result is interesting because an appropriate view of errors in science is a key to understanding the tentative character of scientific knowledge (Allchin 2012).

5 Conclusions and Perspectives

Generally, it is difficult to attain significant educational results in such a short-term teaching intervention, especially if the aim is to teach about NOS, which is complex and has novel content for prospective teachers. All of this is also without detriment to other content that is more consolidated in the usual programs of prospective primary teacher education. However, in this study the instruction had to be adapted to the available conditions. Therefore, it was decided to conduct a short teaching intervention (Leach et al. 2003) with modest learning goals (Matthews 2012). In such circumstances, the critical and reflective reading of newspaper articles with scientific content was considered a good resource to address explicitly some NOS issues in class. Its educational potential for teaching NOS is beginning to be recognized (Cakmakci and Yalaki 2011; García-Carmona 2014; Huang et al. 2014; Leung et al. 2015; Shibley 2003), but its use is still limited in science classrooms.

We believe that this study contributes to the advancement of this research line for several reasons. First, we have chosen to investigate an educational context, that of Spain, which had not been studied so far. All previous studies had been conducted in other countries with educational cultures different from that of Spain where little attention is given to NOS in the basic science education programs. We believe it necessary to analyze how these resources work in contexts other than those already discussed because one must be cautious when trying to transfer the results of research among different educational contexts.

Second, we should note that the proposed activity was developed in the form of a brief teaching intervention because this favored its adaptation to the usual class conditions, given the short time available during the academic year for any introduction of educational innovations of this type (most of the previous studies were conducted in specific courses on NOS and lasted several weeks).

Third, the focus has been on analyzing specific aspects of NOS that have barely been addressed in previous research. They are also essential to orient initial teacher education toward teaching methods that are closer to authentic scientific activity. For example, if prospective teachers understand that scientists discuss with one another and may have different views on the interpretation of the results of an investigation, they may be more receptive to teaching approaches that promote school science activities based on the discussion of ideas, respect for the conclusions of others, the need for checks so that agreement can be reached on what conclusion is appropriate, etc.

Fourth, the fact that these prospective teachers could reflect and discuss in small groups to reach a consensus explanation of their views in response to open-ended questions allowed us to find some nuances and novel aspects about what has been shown so far in the literature regarding conceptions about NOS. In this sense, there is an educational effectiveness of the questions posed for the prospective teachers to reflect on the aspects of NOS that were put to them and to make the desired analysis. As is evident in the results, these questions allowed the information that was sought to be obtained without contradictions being observed in the groups' conceptions and patterns or trends of these conceptions to be established.

Focusing on the effectiveness of the use of selected newspaper articles to learn about NOS, the results reveal that these prospective primary teachers in general better understood NOS aspects such as the subjectivity of scientists, the objectivity of science as a result of intersubjectivity within the scientific community, the replication of experiments (empirical evidence), the role of accepted scientific knowledge in influencing new research, and the possibility of the serendipity of unexpected scientific discoveries (sometimes as a result of errors). Therefore, it can be said that the teaching intervention had a positive effect in encouraging these prospective teachers to reflect on some aspects of NOS and therefore to improve their understanding of them. These results are in line with findings of previous studies (Cakmakci and Yalaki 2011; Huang et al. 2014; Shibley 2003). Consequently, there would seem to be a clear educational potential for using newspaper articles to address some characteristics of NOS, mainly because it is an accessible resource that offers a suitable context to foster the students' critical reflection about those characteristics.

It should also be added that the selected newspaper articles and the questions posed in the context of a current problem of particle physics were effective in stimulating reflection on and the understanding of some aspects of NOS, regardless of whether or not the participating prospective teachers had a high level of knowledge in this field of physics. Nonetheless, it would be very interesting to analyze in the future whether this type of news in the press may be more effective for learning about NOS when the students have a better knowledge of physics in the scientific topic being reported.

Also, in order to improve the efficacy of reading scientific news in the press to learn about NOS, we consider it interesting in future interventions to add a question that invites the prospective primary teachers to make a metacognitive assessment of the process so that they can gain awareness of which aspects they have understood well and which they have doubts or are unsure about (García-Carmona 2012b). This may help avoid cases of going backwards in conceptions, as it occurred in the case of the G8 group in relation to the role of skeptical scientists in the development of science. Likewise, in future interventions, the instructor should review the groups' initial responses before the whole-class sharing session (Phase II). In this way, some of the naïve or plausible ideas can be identified and discussed during the whole-class session, even though they did not explicitly form part of the questions posed about NOS in the scientific context of the selected news. This would have allowed, for example, the differences between "law" and "theory" to have been treated in class, concepts that two groups used carelessly in their initial responses, but did not mention again in either of the other two phases of the intervention.

Even with the current limitations of science teaching, the purpose is to increase progressively the reading of newspaper articles with scientific content in order to promote prospective teachers' critical reflection on NOS issues. This will allow a more in-depth analysis of the efficacy of this educational resource. To this aim, newspaper articles will be selected that are well adapted to the content of the instruction program, following the typological classification proposed by García-Carmona (2014). For instance, in the teacher education context that refers to "Students' intuitive ideas about science and their importance for a constructivist learning," one might propose reading some newspaper article that makes a reference to how past scientists also had misconceptions and made errors in their experiments, although these errors played a key part in the construction of scientific knowledge. Likewise, in the context referring to the "Design of activities to teach science," one might include reading a newspaper article about some controversial socio-scientific issue that can permit role play with opposing views about it (Cakici and Bayir 2012), which is a useful didactic resource with which to encourage critical thinking about NOS.

The scientific controversy dealt with in the two newspaper articles (the OPERA experiment) was conducive for addressing the perspective of the internal sociology of science, which is an essential dimension of NOS. This NOS perspective is especially interesting for addressing such aspects as the importance of teamwork, the need for argument and discussion about ideas, and the joint decision-making in the construction of scientific knowledge, among other things, as part of the "Methods of science teaching-and-learning" content of the prospective primary teacher education program.

In conclusion, reading newspaper articles with scientific content can be an appropriate didactic resource to favor the prospective teachers' understanding of NOS and, at the same time, to provide them with a possible teaching strategy with which to address some aspects of NOS in their own science classrooms. However, more research is needed on analyzing the educational efficacy of this resource with a view to its further consideration in the teaching of NOS.

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