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Article

Models and the Nature of Science: What Mediates Their Implementation in Portuguese Biology and Geology Classes?

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Abstract: Currently, it is considered fundamental to improve students' views of the nature of science (NOS) in science classes. In addition, models are also important in science education, not only as contributors for students to develop their views of the NOS, but also for them to develop conceptual knowledge, as well as inquiry skills. Teachers greatly influence students' learning experience. With the aim to improve prospective science teachers' views of the NOS and about models, and to better understand the factors that mediate the translation of their views into their classroom practices, a research project was conducted. An intervention programme was applied, and prospective science teachers' classes were observed. Data were collected, encompassing a diverse set of data sources: (i) questionnaires and interviews (given to prospective science teachers before and after the intervention programme); (ii) prospective science teachers' lesson plans and portfolios: (iii) videotapes and observations of the classroom instruction; (iv) and, lastly, final interviews were given to both prospective science teachers and their school supervisors. Although prospective science teachers have improved their views regarding the NOS and models, they taught about the NOS and used models in very different ways. Some factors that mediate the translation of teachers' views and some educational implications will be discussed.

Keywords: models; nature of science; prospective teachers; biology and geology classes; science education

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1. Introduction

Improving students' views of the nature of science (NOS) is currently considered one of the principal goals of science education [1–4], namely in biology and geology classes [5–9], which is the scope of the present study. Although results are rather inconclusive and there are still many questions to be answered [10,11], students having accurate views of the NOS is considered to be integral for students for the following reasons: to be literate about science (as the NOS is considered to be a fundamental component of scientific literacy) [1,3]; to make informed decisions; to develop critical thinking; to better learn scientific content; to better understand science, its potential and limitations; and to become more interested in science [10–13].

However, many studies indicate that students do not possess accurate views of the NOS, as they may have developed limited understandings or even misconceptions regarding NOS [10,11,14,15]. Given the importance that is attributed to teachers' influence on classroom learning, researchers naturally focused their attention on teachers' views and practices about the NOS [16,17]. Indeed, many studies indicated that even science teachers do not hold accurate views of the NOS [11,17,18] and do not really emphasize the NOS in their teaching [11,19]. For example, in a study conducted by Capps and Crawford [20] with twenty-six well-qualified and highly motivated teachers from the United States, it was revealed that teachers hold limited views concerning the NOS and that they do not commonly teach about the NOS in their classes.

Taking into account the relevance of scientific models in scientific enterprise [21], it seems obvious that the understanding of models also contributes to a better understanding of the NOS [22]. As such, models are crucial in science classes, as they may contribute to a more authentic learning of sciences [23,24]. Nevertheless, it was also revealed that there is a lack of teachers who use models in classes in a systematic way and that both teachers [25,26] and students [27] possessed an inadequate knowledge about models in science and for teaching.

In Portugal, it was also concluded that high school students, prospective science teachers, and in-service teachers also hold limited views concerning the NOS and models [28,29]. Moreover, it was verified that in-service teachers use models in a very limited way [28].

In light of everything mentioned above, we consider it important to improve science teachers views of the NOS and models, as well as to understand the factors that mediate the translation of teachers' views into their practices.

As such, we intended not only to improve prospective science teachers' views of the NOS and models, but also to better understand the factors that mediate the translation of teachers' views into their practice. Although teachers' accurate knowledge about the NOS (and models) is a necessary condition for teachers to teach about the NOS (and to use models), it is not a sufficient condition per se [30,31]. Therefore, it becomes fundamental to clarify and understand the mechanisms and factors that explain how teachers translate their views about the NOS and models into their classroom practice [31,32]. In the present study, we tried to understand the translation of prospective teachers' views into their classroom practice by relying on a diverse dataset, namely on the final interviews that were given to prospective science teachers and their school supervisors. These interviews were conducted after class observation and the analysis of checklists, lesson plans, and the portfolios of the prospective science teachers, in order to better understand the factors and circumstances that mediate the translation of prospective science teachers' views into their practice.

2. Research Questions

The purpose of this study was to examine how prospective science (biology and geology) teachers improved their views of the NOS and models after attending one intervention programme, and the factors that mediate the translation of teachers' views into their practices. Below, we present the main research questions that guided our study:

How do prospective science teachers change their views of specific aspects of the NOS and about models?

How do prospective science teachers emphasize the NOS and the use of models in their teaching after the intervention programme?

Which factor influence teaching about the NOS, and the use of models, in science classrooms?

3. Nature of Science

The nature of science generally "refers to characteristics of scientific knowledge that are inherently derived from the manner in which it is produced, that is scientific inquiry" [33] (p. 286). Although Acevedo-Díaz and García-Carmona [34] assume that it is difficult to define the NOS, they believe that the NOS is related to everything that characterizes science, as the construction of a special type of knowledge. Therefore, even though teaching about the NOS is currently considered fundamental in science education, there remains a lack of consensus regarding the definition of the NOS [19,33] and the aspects of the NOS that should be focused on classes [34]. On the other hand, some authors consider that there are some aspects of the NOS that are noncontentious and that are accessible and relevant for secondary students [4,30,35,36]. As a matter of fact, this consensus view concerning the NOS is widely accepted, educationally appropriate for learners [32], and considered to be effective as a starting point for students to start thinking about the NOS and to attain an understanding of various aspects of the NOS [10]. In our work, we have adopted this view by acknowledging that: (i) scientific knowledge is empirical; (ii) scientific knowledge is tentative; (iii) scientific knowledge is partially subjective; (iv) scientific knowledge is influenced by the creativity and imagination of scientists, and is both influenced by and acts as an influence on our society and culture; (v) theories and laws are distinct forms of knowledge; (vi) there is no single scientific method; and (vii) both inferences and observations are fundamental in scientific knowledge construction, with it being important to distinguish between them [4,30,36].

Studies also revealed that an explicit, embedded, and reflective instruction of the NOS is an effective approach both for science teachers [17,31,37] and for advanced science students [8].

4. Models

Models are fundamental in scientific activity, being not only products of science but also tools and processes of science [21]. Thus, models may be used to describe, explain, or predict [38,39], helping scientists to think, to generate new knowledge and to communicate scientific ideas to others [40,41]. In general terms, we may define a scientific model as a representation of a target, built according to a specific segment of that target and with particular purposes [29,42].

Scientific theories are consistent systems of explanations, that play a crucial role in the explanation of diverse observations and in guiding future research [4,36]. As scientific theories do not have a direct correspondence to natural entities, models provide the connection between theories and phenomena, as models may represent phenomena and may provide useful information for the development of theories [41,43,44].

As scientific models are fundamental in scientific activity and may be used with different purposes, models are also essential in science education for students to understand the main processes and products of science [45–47]. In this way, models are important for students to learn *of* science, i.e., to learn the major models that are the products of science; to learn how *to do* science, by creating and testing their own models; and to learn *about* science, by developing an accurate view of the NOS, as well as an accurate view of the nature of models and their role in science [29,48–51]. Thus, "understanding the nature of models and their use in science can be a fundamental component of the nature of science" [52]. For example, by understanding the tentativeness of scientific models, students may better understand the tentativeness of scientific knowledge [52]. Moreover, by understanding that multiple models may exist to study the same aspect of the world (given the fact that scientists may possess different ideas and resources to construct models) [41], and the undeniable role of creativity in models' production [53], students may better understand the theory-laden, yet creative and imaginative nature of scientific knowledge.

Furthermore, by developing modelling activities, i.e., by creating, evaluating, and using their models [48], students may develop their inquiry skills and may also understand how scientists work [40,54].

Moreover, the analysis of the historical evolution of models may also contribute to the development of informed views of the NOS [55], as students may better understand science construction and evolution, as well as the constraints and contexts that influence scientific knowledge development [28].

Models are also relevant in biology and geology classes because both sciences deal with models in their research process [27,41,56].

However, to use models in an efficient way, i.e., by taking advantage of their full potential for the understanding *of* science, of how *to do* science and *about* science, it is necessary for teachers to understand the relevance of models in science and for teaching [25]. Based on a literature review, Oh and Oh [41] identified five important topics that science teachers must know about models: (i) meanings of a model; (ii) purposes of modelling; (iii) multiplicity of scientific models; (iv) change in scientific models; and (v) uses of models in the sciences classrooms. Moreover, we also consider it important that teachers both understand the potential of models and their limitations in science education, as well as the potential and limitations of models in science, while understanding the difference between scientific models and teaching models [57,58].

5. Materials and Methods

To improve prospective science teachers' views of the NOS and models, we developed and applied an intervention programme. A total of nine prospective science teachers attended the classes of this intervention programme, and six of them were monitored during their internships in schools. We intend to present a rich thick description of their views and to understand the reasons behind their actions when teaching about the NOS and when using models. Therefore, we used diverse data sources, which included the following: questionnaires and interviews (applied to prospective science teachers before and after the intervention programme), to examine if prospective science teachers improved their views of the NOS and models; prospective science teachers' lesson plans and portfolios; videotapes and observations of classroom teaching (which were analysed according to a checklist); and final interviews applied to both prospective science teachers and their school supervisors, to better understand how they value teaching about the NOS and the use of models, and the factors that influence their teaching about the NOS and their use of models in their classes.

5.1. Context of the Study

In Portugal, documents pertaining to national science education standards (for middle and secondary students) recommend the development of the students' understanding of the nature of science, as well as the use of models in biology and geology classes [5,6,29,59–61]. However, as is better described in the theoretical framework, teachers and students display a lack of knowledge regarding the NOS and models, as models are usually used in a limited way; in other words, they are mostly used with the unique intention of developing conceptual knowledge [28,29]. Moreover, it was also found that little attention is given to models in preservice biology and geology teacher training [62].

Having the aforementioned aspects in mind, we considered it important to improve prospective science teachers' views of the NOS and models, in order to contribute to an efficient education in the NOS and to an efficient use of models in science classes, as well as to understand the factors that mediate prospective teachers' views into their pedagogical approach.

5.2. Participants

Our sample is composed of prospective science teachers that will teach biology and geology to middle and high school students. All of them are enrolled in a master's programme in biology and geology teaching at a public university in the north of Portugal, and all of them already hold a bachelor's degree, either in biology or geology, or even in both biology and geology. In Portugal, to teach biology and geology in middle and secondary schools, prospective teachers must complete this master's degree. In the first year, prospective teachers attend classes of educational subjects, as well as complementary classes of biology and geology subjects. In the second year of the master's programme, prospective teachers attend only a few classes at the university and their time is mainly dedicated to their internship in schools. In their internships, they observe the lessons given by their school supervisors, and prospective science teachers also give a certain number of lessons to the students of their school supervisor.

A total of nine prospective science teachers voluntarily participated in the first phase of this study (which is composed of the implementation and evaluation of the intervention programme), that took place during the first year of their master's studies (when students attend classes of both educational and scientific subjects). A total of six prospective science teachers continued and participated in the second phase of this study, which occurred during the second year of their master's program and which was mainly devoted to their internships in schools. Our results will mainly focus on the results related to these six prospective science teachers (five females and one male), with ages ranging from 21 to 38 (average = 25.3 and mode = 21). In this study, they have been designated fictional names: Maria, Sofia, Carolina, Inês, Rita and Francisco.

School supervisors of these prospective science teachers also voluntarily participated in this study and will also be designated fictional names. José was the school supervisor of Sofia and Francisco and has thirty-five years of experience as a teacher; Paula was the school supervisor of Maria and Inês and has twenty-four years of experience; and Joana was the school supervisor of Rita and Carolina and has thirty-two years of experience. Their participation was fundamental to understand how they may influence the translation of prospective science teachers' views into their practice.

5.3. Procedures and Instruments

With the aim of improving prospective science teachers' views of the NOS and models, an intervention programme was prepared and implemented. This intervention programme was evaluated by means of questionnaires and interviews, which were administered both before and after this intervention programme. Data were analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package, concerning specific NOS aspects and prospective teachers' views of models in science and for teaching science.

Regarding their views of the NOS, we administered a questionnaire that was adapted from the *Views of Nature of Science Questionnaire — Form C (VNOS-C)* [36] and validated for Portuguese prospective science teachers in a previous study, in view of the specificity of the sample and the inclusion of different questions [63]. Concerning their views of models, we administered a questionnaire that was constructed and validated in a previous study [64]. Two interviews (one concerning their views of the NOS and another concerning their views of models) were also conducted after filling out both questionnaires (before and after the intervention programme), for them to better explain and justify certain answers and also to clarify some unclear responses.

As better described in [54], prospective science teachers' views concerning the NOS were classified as "naïve", "transitional" and "informed", by comparing them with the contemporary conceptions of the NOS described in Section 5. Informed views are those that match current conceptions of NOS aspects and naïve views do not match the accepted conceptions. Their views were classified as transitional when they simultaneously present arguments that were aligned and other arguments that were not aligned with currently accepted conceptions.

Prospective science teachers' views about models were classified as "informed" or "naïve" concerning the evaluated aspects Prospective science teachers' conceptions of models were compared with the current conceptions of models that are described in Section 4. In this case, prospective science teachers do not present transitional views and their views were classified as "informed" and "naïve", as better described in [65].

Afterwards, classes of the six prospective science teachers who remained in the study (that took place in the year following the intervention programme) were observed by the first author of this paper and were analysed according to a grid (verification checklist) that was previously validated by three experts in science education. This checklist was organized into four categories of analysis: (i) nature of science; (ii) didactical resources; (iii) how nature of science is taught; and (iv) use of models. During the class, the researcher filled in the checklist by verifying the aspects that were observed in the classroom (identifying which aspect of the nature of science was focused on in the classroom, the different resources that were used to explore the nature of science, how the NOS was explored, and if models were used (and if so, what kind of models were used, with which purpose and strategy). Classes were also recorded, in order to subsequently verify and complete the analysis that was conducted during the observation of the classes with the checklist, making it possible to have access to more detailed examples by utilising the transcript of what prospective science teachers said. With these records, it was possible to have access to all of the information at a later date, in order to prevent the loss of information.

After analysing the checklists, lesson plans and portfolios of the prospective science teachers, we conducted semi-structured interviews (final interviews) to both prospective science teachers that participated in this study since its beginning (Appendix A) and to their school supervisors (Appendix B), in order to better understand the factors and circumstances that mediate the translation of prospective science teachers' views into their practices. The interviews' scripts which were conducted to prospective science teachers were constructed according to what was observed in the classes and after analysing prospective science teachers' lesson plans and portfolios, and were validated by three experts in science education. The final interview that was administered to school supervisors was firstly validated by three experts in science education. After some adjustments, we also tested those interviews with two science teachers, using the spoken reflection method, where they revealed their understanding of the question, and what they would answer for each question. In general terms, they understood all of the questions that they were asked, giving only a few suggestions in order to clarify the questions.

5.4. Intervention Programme

The intervention programme, which is fully described by the authors in [66], was developed by having in mind the topics mentioned above and the three major aims, proposed by Justi and Gilbert [48,49], of models and modelling in science education. Furthermore, it was also developed according to the consensus views of the NOS as described above, i.e., the NOS being taught in an explicit, embedded, and reflective way.

The intervention programme lasted 25 h (five classes of five hours each). The first class was devoted to the understanding of scientific models and their role in science. For that purpose, starting with a problematic scenario regarding Earth's interior model, prospective science teachers were asked to analyse papers, as well as to discuss and respond to some questions concerning the main theme of the class (scientific models and their role in science). Furthermore, the analysis of a PowerPoint presentation and an activity to apply the developed knowledge were also performed. In the second class, with the main aim of understanding the role of models for teaching (specifically, for the learning of science, of how to do science and about science) prospective teachers developed modelling activities, discussed theoretical aspects and answered some questions. In the third class, it was mainly intended that prospective science teachers recognised the relevance of resorting to historical models for the understanding of different aspects of the nature of science, for teachers to reflect on how to teach about the NOS, and on the relevance for students to develop accurate views of the NOS. In this regard, to deepen their knowledge regarding the NOS, prospective science teachers analysed three documents regarding the historical evolution of models of Earth's structure, after which they discussed and responded to some questions. A final discussion was also held regarding the relevance for students to develop informed views of the NOS and of teaching it in an explicit, embedded, and reflective way. In the fourth class, prospective science teachers critically analysed how Portuguese biology and geology textbooks and the science standard documents recommend and cover the nature of science, models and modelling activities. An activity was also analysed in order to promote discussion regarding the advantages of using models and analogies in science classes, the characteristics of good analogies and models, and the precautions to take when using them. In the final class, prospective science teachers were expected to present and discuss their final work, which consisted of a lesson plan and associated didactical materials. In this work, prospective science teachers should have applied the concepts that they developed during the intervention programme, as they had to plan a lesson in which they were expected to both teach on the NOS and use models [54,66].

6. Results

In this paper, we are going to present various data, which result from a larger research project, and the results will be presented mainly on a case-by-case basis. In other words, we intend to deeply describe the views of each prospective science teacher (that participated in all the study), how they teach on the NOS and use models in science classes, and the factors that mediate the translation of their views to instructional practice.

6.1. Prospective Science Teachers' Views of NOS and Models

As described by the authors in [54], prospective science teachers developed their views of the NOS after attending the intervention programme.

We analysed fourteen specific aspects of the NOS (see Table 1), and we verified that these six prospective science teachers hold informed views concerning almost all aspects that were evaluated in the end of the intervention programme (Table 2). Only three naïve views were revealed (two concerning theories change and one concerning the general structure of experiments) and eight transitional views, in other words, views that simultaneously reveal arguments aligned and others not aligned with currently accepted conceptions (three regarding the difference between theories and laws; three regarding the inferential nature of scientific knowledge; one regarding the general structure of experiments; and another regarding subjectivity in science).

Table 1. Illustrative Examples of Informed and Naïve Views of the Nature of Science (NOS) Aspects Evaluated.

Targeted NOS Aspects \ Views Categories	Examples of More Informed Views	Examples of More Naïve Views
Empirical Basis of Science	*Science is based on facts, principles, theories and laws in order to explain scientific knowledge (. . .)* ***Q (questionnaire)_Maria (Pre)*** *Science differs from other disciplines because, although it is based on interpretations, scientific disciplines try to explain phenomena and processes of nature.* ***Q_Francisco (Post)***	*Science is based on facts and concrete things, while other disciplines are influenced by individuals (. . .). Scientific knowledge requires experiments. We need to conduct experiments for the development of scientific knowledge.* ***Q_Francisco (Pre)***
Scientific Method	*No, there are many scientific methods.* *Scientists used direct and indirect methods to study the interior of the Earth. Scientists must also use creativity and imagination to create those models. (. . .)* ***I (interview)_Carolina (Post)***	*Yes, I think that, in order to construct scientific knowledge, we must employ the scientific method, in terms of a certain stepwise procedure.* ***I_Francisco (Pre)***
General Structure of Experiments	*[An experiment] is mainly based on the manipulation of variables with the aim of observing and collecting data and evidence which allow us to take conclusions and to respond to the objective/central question of the situation.* ***Q_Inês (Post)***	*Yes, an experiment is to prove. (. . .)* *[A scientific experiment may involve] the manipulation of variables or not. I may perform an experiment only by observing (. . .)* ***I_Maria (Post)***
Observationally Based Disciplines	*I think that an experiment is not the only requirement for the development of scientific knowledge. Observation and the use of models also contribute to scientific development, as well as imagination and creativity.* ***Q_Rita (Post)***	*Yes, I think that scientific knowledge requires scientific experiments, as ideas and hypotheses obtained after questioning, must be tested through experiments.* ***Q_Sofia (Pre)*** *Yes, I think that it is possible to conduct experiments [in scientific areas, like astronomy and anatomy].* ***I_Sofia (Pre)***

Table 1. *Cont.*

Targeted NOS Aspects / Views Categories	Examples of More Informed Views	Examples of More Naïve Views
Inferential Nature of Scientific Knowledge	*Scientists are as certain as the current knowledge allows (...). Based on what they have today, in what they thought, in what they inferred, in what they saw, in the technology they have, the current model is that one. However, it doesn't mean that this model lasts unchangeable forever. For example, modelling is very important, as by simulating phenomena, we may construct some knowledge. (...) Yes, they construct models through inferences. It is not possible to prove everything.* ***I_Rita (Post)***	*I think that scientists are certain about the atomic model. In fact, our society makes us believe that everything is correct; we do not question ourselves about things. (...) I think that scientists are certain concerning species definition. In fact, I never asked myself about that, I believe in that.* ***I_Sofia (Pre)***
Subjectivity in Science	*With the same data, same things, different conclusions are possible because we are talking about people and people are subjective. Also, by selecting certain hypotheses instead of others, by manipulating certain variables instead of others, they are influencing the research, as they are subjective and they use their imagination. As a result it is obvious that they can reach different conclusions.* ***I_Rita (Post)***	*I think that the method of an exact science is more objective and will produce more concrete answers. Philosophy, for example, is based on people's opinions, so there aren't correct answers in philosophy. (...) There are two hypotheses (...) that occurred at the same time and that were strong enough to lead to the extinction of species (...) Despite both being correct, it is not possible that one invalidates the other, as we are not certain of anything.* ***I_Carolina (Pre)***
Creativity and Imagination in Science	*Of course, imagination and creativity are fundamental for scientific knowledge construction. They are used especially in the analysis and understanding of data collected. (...) Scientific knowledge is a result of imagination and creativity (...) we have the need to understand our world (...) Imagination and creativity are used in all stages of the research. I have changed my view, as in the first questionnaire I have said that imagination and creativity are only used in the planning stage.* ***Q/I_Inês (Post)***	*Yes, I think that scientists only use creativity and imagination in the planning stage, as data collection follow a predetermined procedure. They use imagination and creativity (...) There is a need to formulate assumptions, even when they seem to be inappropriate.* ***Q_Inês (Pre)***
Social/Cultural Influences	*Science is influenced by cultural, social, political, religious and economic values, among others. We may verify that throughout history when religion hindered certain theories explanations, as they went against the ideas of God. Today we also verify that in the extreme development of particular areas, such as medicine and military engineering.* ***Q_Carolina (Post)***	*I think that science is universal, as water freezes at 0°C in Portugal and in Japan or in Antarctic. Science should be the same for all, as well as theories and experiments.* ***Q_Francisco (Pre)***
Tentativeness of Scientific Knowledge	*I believe that scientific theories change and may be reformulated. They are not eternal for many reasons (...). A law describes something that we observe repeatedly (...), while a theory is something more comprehensive. A theory was accepted by the scientific community (...)* ***I_Rita (Post)***	*A theory is something that may change, while a law is something concrete and immutable.* ***Q_Francisco (Pre)***

Table 1. *Cont.*

Targeted NOS Aspects / Views Categories	Examples of More Informed Views	Examples of More Naïve Views
Theories Change	*I believe that scientific theories change and may be reformulated. They are not eternal for many reasons . . . or due to new observations, or due to new results in experiments, or due to scientists' creativity and imagination. Someone may think in something different, as a consequence things may be reformulated.* ***I_Rita (Post)***	*Acquisition of new data that prove and that better justify those facts (. . .) [theories] may be reformulated with new scientific data that make more sense than the previous data.* ***I_Inês (Pre)***
Scientific Theories/Laws	*A scientific theory intends to explain phenomena or processes that occur in nature. A scientific law is based on observable/experimental patterns (. . .). Gravity law—all objects are submitted to gravity, which is responsible for their downward movement. Tectonic plates movement—it explains how the movement of tectonic plates occur and which factors influence this movement.* ***Q_Maria (Post)***	*A scientific theory may be something that is suggested as an explanation for certain phenomena, structures and actions. A scientific law consists of a theory that becomes a true and not mutable.* ***Q_Carolina (Pre)***
Scientific Theories Nature	*For example, the theory of plate tectonics, that tries to explain the movement of the tectonic plates.* ***Q_Francisco (Post)***	*A theory is something that may suffer changes. On the other hand, a law is something concrete and immutable.* ***Q_Francisco (Pre)***
Scientific Theories' Functions	*Because theories intend to explain phenomena/processes in order to complete or improve scientific knowledge.* ***Q_Maria (Post)***	*We bother to learn scientific theories because we are very curious and we wonder ourselves about the world.* ***Q_Sofia (Pre)***
History of Science and Historical Models	*History of science is fundamental in science teaching as it is important that students understand scientific knowledge development (. . .). Historical models in science education allow students to develop a higher contact with history of science evolution.* ***Q_Inês (Post)***	*History of science allows students to understand science evolution, the perspectives that appeared and that were advocated in a certain period of time. With historical models it is easier to explain students certain scientific concepts.* **Q/I_Inês (Pre)**

Table 2. Prospective Science Teachers' Views of the Fourteen Aspects of the NOS Evaluated Before (Pre) And After (Post) The Intervention Programme.

Views Categories / Teacher	Pre				Post		
	Without Information	**Informed Views**	**Transitional views**	**Naïve Views**	**Informed Views**	**Transitional Views**	**Naïve Views**
Maria	—	8	2	4	12	—	2
Sofia	1	7	2	4	12	2	—
Inês	—	3	2	9	12	2	—
Rita	1	6	1	6	13	1	—
Francisco	—	3	1	10	13	1	—
Carolina	—	6	2	6	11	2	1

In the same way, prospective science teachers also improved their views about models, an issue which is better described in [65]. After the intervention programme, all of the prospective teachers held informed views concerning the bulk of the aspects about models evaluated (Table 3). For example, Rita held informed views concerning all aspects which were evaluated about models (Table 4) and only Sofia possessed naïve views concerning three of the aspects which were evaluated (the others only possessed naïve views concerning one or two aspects evaluated). Five naïve views were revealed concerning the relationship between scientific models and theory; one regarding scientific model purposes; one regarding models' contribution to science teaching; and one regarding the favourable conditions for students to develop models.

Table 3. Illustrative Examples of Informed and Naïve Views of the Aspects About Models Evaluated.

Evaluated Aspects / Views Categories	Examples of More Informed Views	Examples of More Naïve Views
Scientific Model Concept	*A scientific model is a representation of an idea or phenomena. When we represent what we think about something, about science and phenomena, we are representing models. There are many ways of representing models. In science they are used to explain and predict. Models are applied in different ways and they vary according to the purposes of who used them.* ***Q_Rita (Post)***	*In my opinion, a scientific model is a set of ideas, theories and methods to follow towards a problem to solve.* ***Q_Sofia (Pre)***
Scientific Model Purposes	*Models are used to explain phenomena, processes, ideas, among others. They contribute to a better understanding (. . .)* *And also to predict, predict, explain (. . .) In geology they may be used to explain past events (. . .)* ***Q/I_Maria (Post)***	*To explain in a more detailed and practical way the currently accepted scientific theories. Models should be used in classes in order to facilitate understanding. (. . .) Even in an out of school context, models are used to put theories in practice (. . .), they are used to present scientific theories.* ***Q/I_Carolina (Pre)***
What Can Be Represented by a Scientific Model	*A model may represent an idea or a phenomenon included in a scientific area, isn't it?* ***I_Rita (Post)***	*A scientific theory, I think that it is a theory, I think so.* ***I_Sofia (Pre)***
Relationship Between Scientific Model and Theory	*(. . .) A theory may be explained through model construction. However, it may also be the opposite. (. . .) mainly for us to explain a theory or to verify if a theory really works, we may construct a model. By constructing a model we may also understand the errors of theories and reformulate it.* ***I_Rita (Pre)***	*A scientific model intends to support in a practical way a scientific theory.* ***Q_Sofia (Pre)***
Change in Scientific Models	*Yes, scientific models may change over the course of time, as well as scientific theories. This happens as scientific knowledge is in permanent change; in permanent reformulation.* ***Q_Sofia (Pre)***	—

Table 3. *Cont.*

Views / Categories / Evaluated Aspects	Examples of More Informed Views	Examples of More Naïve Views
Multiplicity of Scientific Models	*Yes, I think that different models may exist to represent different aspects of the same target. For example, we can observe the different layers of the Earth from different perspectives, according to their size, composition ... I think that there are different models to represent the same thing which are correct. And yes, different models may exist to study the same target.* **I_Carolina (Pre)** *Yes, since they explain and focus on what it is intended to be demonstrated (...)* **I_Maria_ (Post)**	*(...) I am trying to compare this situation with the heart function, but the heart is what it is (...). No, there are no multiple models to study the same target.* **I_Maria (Pre)**
Models' Contribution in Science Teaching	*Models may be use to explain phenomena that are complex for students. (...) Modelling may help students to interpret scientist role. Through modelling, students may observe, question, critically think and suggest solutions.* **Q_Rita (Post)**	*Models may be used to a better visualization and understanding of conceptual knowledge. It is important that students construct models, under the supervision of the teacher. Bibliographic research may be performed in an autonomous way, but it must be verified by the teacher.* **Q_Inês (Pre)**
Favourable Conditions for Students to Develop Models	*To construct models, students need to be imaginative, practical and objective. They also need to define strategies to bring the model closer to reality. (...) Also, to construct a model, there is a need of having good conceptual knowledge about that. (...) By constructing a model, students deepen the knowledge about a thematic and develop their creativity.* **Q_Francisco (Pre)**	*A good theoretical background and a well-done bibliographic research. Students need a good theoretical background to create models. I also think that teacher's help is crucial.* **Q/I_Carolina (Pre)**
Differences Between Models in Science Teaching and Models in Science	*Absolutely [they must be different]. The purpose of models in teaching is to teach and reflect scientist's work, and not to do research. Models in teaching must be adapted according to students (...).* **Q_Carolina (Post)**	*No [they should not be different], because the objectives, both of teaching and of science, is to prompt students' understanding. The procedure is the same.* **Q_Maria (Pre)**

Moreover, prospective science teachers recognised that they had changed their views of the NOS and about models, and that they had a better understanding of the relevance of education on the NOS and of using models in science classes.

Table 4. Prospective Science Teachers' Views of the Nine Aspects About Models Evaluated Before (Pre) And After (Post) The Intervention Programme.

Teacher \ Views Categories	Pre		Post	
	Informed Views	**Naïve Views**	**Informed Views**	**Naïve Views**
Maria	3	6	8	1
Sofia	3	6	6	3
Inês	4	5	8	1
Rita	6	3	9	—
Francisco	5	4	7	2
Carolina	4	5	8	1

6.2. Class Observation

Although all the prospective science teachers improved their views of the NOS and about models, they taught the aspects of the NOS and used models in very different ways. In Table 5, we briefly summarized the aspects that we observed in classes. It is possible to verify that while Rita and Carolina taught the aspects of the NOS and used models in a very positive way (Carolina only missed using models for the understanding of the NOS), Sofia did not teach the aspects of the NOS and did not use models in her classes, relying mostly on a traditional lecture-based learning approach.

Rita was the prospective science teacher that exploited more aspects of the NOS in classes, such as the tentativeness of scientific knowledge, the relevance of imagination and creativity in science, the meaning of a scientific model, its purposes, and its characteristics. While Rita and Carolina addressed many aspects of the NOS, Maria and Inês only focused on a few aspects of the NOS and Sofia and Francisco did not teach any aspect of the NOS. We felt that although Rita, Carolina, Maria and Inês showed that they can teach about the aspects of the NOS in an explicit and contextualized way, they should promote more debate, especially Carolina and Inês.

Table 5. Summarized Aspects Observed in Classes.

Observations \ Teachers	Maria	Sofia	Inês	Rita	Francisco	Carolina
Teach Certain NOS Aspects	Yes (in a limited way)	No	Yes (in a limited way)	Yes	No	Yes
Use Models in Science Classes	Yes	No	Yes	Yes	Yes	Yes
For the Understanding of Content Knowledge	Yes	No	Yes	Yes	Yes	Yes
For the Understanding of How to Perform Science	Yes	No	No	Yes	No	Yes
For the Understanding of Nature of Science	No	No	No	Yes	No	No

Carolina, Francisco and Maria used physical models (for example, models about mass movement and faults, among others) and digital models, and Rita and Inês used only physical models (for example, organism models and models about coastal erosion). In most of the models activities which were developed, students played an active role.

More specific details about how these prospective science teachers taught on the NOS and used models, and about the reasons that justify their options, will be analysed by combining the data obtained through class observations and interviews, and will be further discussed in the individual analysis section.

6.3. Final Interviews

6.3.1. Prospective Science Teachers

Although prospective science teachers gave more emphasis to models as contributors to the development of students' conceptual knowledge, they also recognised the value of models in promoting students' inquiry skills and in developing students' informed views of the NOS. Although all prospective science teachers believed that education on the NOS is important in science classes, one of them did not teach about the NOS during the classes of her internship (more detailed information is presented in the individual analysis section of this paper).

6.3.2. School Supervisors

The three school supervisors that participated in this study recognized that they frequently use models in their science classes. However, they gave more emphasis to the models' value in how they contribute to the development of content knowledge. In this regard, only Paula mentioned that models are important for students to develop inquiry skills and no supervisor mentioned models' contribution in the development of accurate views of the NOS, a fact which suggests a lack of knowledge regarding the full potential of models in science classes. Both Paula and Joana present models to students and ask them to produce their own models. On the other hand, José only uses models that are already constructed, explaining that "model-building takes too much time and, apart from being interesting, we must admit that the construction of models makes more sense in crafts class". Nevertheless, Joana claimed that the construction of models is more effective in a student's learning process. When asked about possible limitations of using models in school, both Paula and José indicated the lack of time or curriculum extension. Paula also mentioned financial limitations and Joana did not point to any limitation. All of them considered that a good model must be rigorous. It was also mentioned that a good model must be appealing (Joana) and of suitable dimensions (José), and its use must be pertinent (Paula). Considering the precautions to take when using models, both Joana and José indicated that it is important that students understand the differences between models and reality, which reveals some knowledge concerning the nature of models. Joana stated that models should be adapted to the age profile of students and Paula also indicated that the use of models should be safe and pertinent.

Concerning the NOS, all of the supervisors indicated that they teach about the NOS in their classes; however, they restrict aspects of the NOS to history of science (Joana, Paula and José) and to the tentativeness of scientific knowledge (Joana and Paula). Moreover, José revealed that he did not plan on teaching about the NOS and that it was taught as a result of "informal discussion". Joana mentioned that she limited her use of the NOS to historical episodes and images, debates and role-playing and Paula to texts, debates, videos and reflection activities.

When it comes to the limitations regarding teaching and understanding the NOS, we find different points of view. While Joana mentioned the fact that students are not accustomed to discussing the aspects of the NOS, José mentioned that students are reluctant to learn about the aspects of the NOS. Joana indicated that she had reservations with the constraints imposed in order to comply with the curriculum and Paula the fact that students do not link the different knowledges they construct. Both Paula and Joana also mentioned the lack of reflection from students as a limiting factor.

Paula mentioned that teaching on the NOS is relevant for students in understanding that science evolves, while José claimed that teaching on the NOS is important to develop critically thinking and informed citizens and to facilitate informed decision-making.

The three supervisors claimed that they teach about the NOS to students from when they are twelve to when they are eighteen. While Paula and Joana mentioned that the aspects of the NOS should be focused differently, according to students' ages (in a progressive way), José mentioned that there is no evolution in the instruction of the aspects of the NOS.

In the end of the interview, we asked several questions regarding their general knowledge about the NOS and models. Although school supervisors recognise that observation depends on the theoretical background of the observer, they showed a lack of knowledge concerning the philosophy of science, not distinguishing positivism from post-positivism (the three) and theories from models (Paula and Joana). Although the three supervisors believed that teaching models are simpler than scientific models, Joana displayed difficulties in distinguishing an analogous model from a teaching model.

6.4. Individual Analysis and Discussion of the Results

6.4.1. Sofia, Francisco and Their Supervisor (José)

Sofia

Although Sofia still exhibited some naïve views at the end of the intervention programme, she had improved her views both about models and the NOS. However, she neither used models nor taught aspects of the NOS in her classes. When asked about the reasons for not using models, Sofia said that she had not remembered to use models, which seems to be revealing of the lack of some reflection concerning her options. Nevertheless, Nevertheless, she recognized to feel confident and considered it important both to implement models and to teach on the NOS in science classes. Thus, she came to the conclusion that she would use models in science classes, as they are a fundamental complement to the understanding of scientific content.

When asked about the reasons for not teaching about the NOS, she responded that she gave priority to conceptual knowledge, thus not placing an emphasis on the education of the NOS. Although she also mentioned that the content was not the most appropriate, we verified that she skipped some issues in the textbook that were related to the history of science and the NOS. When asked about the reasons for not focusing on the history of science and the construction of scientific knowledge, she said:

> *I talked with my school supervisor and he told me not to talk about those aspects. He would do that later. It would be easier for me. (...) The content was already complicated, so we decided in that way.*

Moreover, when asked about the reason for not focusing on aspects of the NOS when teaching about the Engelmann experiment (which easily facilitates teaching on the NOS), she revealed, once more, a lack of reflection concerning her options, as she answered:

> *I do not remember to focus on aspects of NOS, I was only focused on the experiment.*

Sofia also mentioned that teaching on the NOS does not attract students, which may indicate some influence of her school supervisor, as he also said that students generally are not interested in discussing the aspects of the NOS and as he did not even teach about the aspects of the NOS in his classes.

Moreover, we verified throughout the interview that Sofia was, as she mentioned, mostly concerned with content knowledge transmission, for example:

> *I think that in the first classes, there were some difficulties in content knowledge transmission; it should be more detailed and rigorous.*

> *In science teaching I think that interaction is fundamental. In this interaction, scientific content transmission must be rigorous and detailed. For this transmission to be more efficient, I think that we must rely on laboratorial experiments, as well as on models (...). Models are important in science teaching, as they represent a complement to the subject under analysis and facilitate understanding of scientific phenomena or aspects. (...)*

Once more, we may say that this concern may be the result of some influence of her school supervisor, as she said:

> *Of course my school supervisor had influenced my work this year. Mainly regarding scientific content, as my school supervisor was extremely demanding and rigorous in that aspect.*

Nonetheless, she believed that she is going to teach about the NOS in her future practices, as she expressed that it is important that students understand the context when learning scientific content.

Sofia relied mostly on a traditional lecture-based learning approach, indicating that those types of classes are more comfortable for her.

Sofia believed that her school supervisor (José) had influenced her work, mainly regarding scientific content and by suggesting some resources and strategies (Table 6). Regarding certain demotivating factors, Sofia mentioned the pressure brought on by her supervisor, as well as her fatigue.

Francisco

Francisco had improved his views about models and had greatly improved his views about the NOS. However, he did not feel comfortable teaching on the NOS, as he did not feel confident, due to his lack of experience. Although he believed that he had taught on the NOS, he did not teach on the NOS in an explicit way (he did it in a very subtle and implicit way and did not include any objective concerning the NOS in his lesson plan), as he confirmed when asked about the reason why he did not deepen in a more specific way certain characteristics of science:

> *With the activity that I have conducted, I think that it was intrinsic, I showed a diversity of instruments (...) and they understand that there has been some evolution with electronic microscopes, I think that they understand it by themselves, there was no need to talk about it.*

As we may confirm, through the observation of his class, he only described events:

> Francisco: *I would like to do a historical contextualization of how scientific knowledge about the cell evolves. As you may imagine, in the past there were no methods to study small structures as cells. Here we may observe a timeline ... As you may see in 1950, Janssen constructed the first microscope (...). Lastly, in 1996 Campbell was responsible for all the work regarding the cloning of Dolly the sheep.*
>
> (Observation of Francisco's class)

After the description of the timeline, Francisco simply continued the class by asking questions about content knowledge. Furthermore, during the following interview, Francisco pointed out that he did not deepen the teaching of the aspects of the NOS and did not prompt the discussion among students about the aspects of the NOS, due to time constraints. He also indicated that the content may have influenced his teaching on the NOS, as he believed that the content that he taught was not the most appropriate (although we considered it a good subject with which to teach on the NOS). Moreover, Francisco also stated that students' characteristics may hinder teaching on the NOS. Francisco felt that he was going to teach on the NOS in his future classes, as he believed that education on the NOS is important, mainly for pre-university students, in order to better prepare them.

Francisco used models in his classes and felt confident in doing so. Models were used mainly for the understanding of scientific phenomena and concepts, and also for students to understand how scientists work. Although he prompted the construction of some models, he justified the need to use models in a demonstrative way because of time constraints. Francisco mentioned that students liked the modelling activities and that they, as a result, better understood content knowledge. Concerning the difficulties of using models, Francisco only mentioned that it may be challenging to choose the best model to use, as well as to guarantee that all students understand the modelling activity. One aspect that should be highlighted is that Francisco noticed that low-achiever students were more interested and achieved better results than high achievers during modelling activities.

Francisco believed that he is going to use models in his future classes, as models are important for students to clarify and strengthen ideas.

Francisco also pointed out that his school supervisor (José) influenced his work, mainly regarding scientific content and language accuracy (Table 6), referring to his relationship with his supervisor as a demotivating factor in his work during his internship.

Sofia, Francisco and José

Both Sofia and Francisco believed that their school supervisor had played an important role in their work, mainly regarding the accuracy of scientific content taught (Table 6). However, they also believed that the relationship between them and their supervisor contributed to their demotivation during their internship. In addition, their school supervisor (José) also expressed that both Sofia and Francisco exhibited weak scientific knowledge and showed a lack of interest in the activities. José also mentioned that they did not diversify the resources and materials that they used, using mainly PowerPoint presentations in their classes.

Although José believed that science instruction is fundamental for students to be scientifically literate and to solve problems, he recognized that he used models in classes mainly for students to understand scientific content and that he did not consider it important for students to construct models. Although he recognized the relevance for students to develop accurate views of the NOS, namely in order to facilitate informed decision-making, he recognized that he did not plan NOS teaching, as certain aspects of the NOS were taught as a result of "informal discussion". Moreover, as Sofia mentioned, José also believed that students are reluctant to learn about the aspects of the NOS.

Table 6. Teacher's Ideas Concerning NOS and the Use of Models in Classes.

Teachers / Observations	**Views about NOS**	**Views about Models**	**Reasons that Justify Their Practices Concerning NOS**	**Reasons that Justify Their Practices Concerning Models**	**School Supervisor's Influence on Prospective Teacher Work**
Sofia	Improved	Improved	Concept knowledge was prioritized. The content was not considered appropriate to teach NOS. Agreement with school supervisor to not teach NOS. Did not remembered to teach NOS. NOS instruction does not attract students.	Did not remembered to use models.	Yes (mainly concerning accuracy of scientific content and by making suggestions).
Francisco	Improved	Improved	Taught NOS implicitly. Did not feel confident to teach NOS. Time constraints limited NOS instruction. The content was not considered the most appropriate to teach NOS. Student's characteristic may hinder NOS instruction.	Time constraints limited how models were explored. Some difficulties revealed, such as, to guarantee that all students understand and the choice of the best model. Modelling activities were perceived as positive for students.	Yes (mainly concerning accuracy of scientific content)
Maria	Improved	Improved	The content was considered a limiting aspect to NOS instruction. Considered that students liked and understood NOS.	No difficulties in using models. Modelling activities were perceived as positive for students.	Considered that school supervisor did not influence her work.

Table 6. *Cont.*

Teachers \ Observations	Views about NOS	Views about Models	Reasons that Justify Their Practices Concerning NOS	Reasons that Justify Their Practices Concerning Models	School Supervisor's Influence on Prospective Teacher Work
Inês	Improved	Improved	Concept knowledge is prioritized. Time constraints, the content and characteristics of students were perceived as limiting factors. Considered that students understood NOS.	Some difficulties revealed concerning the materials that were used. Modelling activities were perceived as positive for students.	Yes (by discussing the planning and by making suggestions)
Carolina	Improved	Improved	Concept knowledge is prioritized. Time constraints and characteristics of students were perceived as limiting factors. Considered that NOS instruction does not attract students, but students understood NOS.	Some difficulties revealed, such as, students' management, the additional preparation required and how to guarantee that the model will work. Modelling activities were perceived as positive for students.	Yes (making suggestions)
Rita	Improved	Improved	NOS instruction considered difficult. Although student's characteristic may hinder NOS instruction, it is considered that students liked and understood NOS.	Some difficulties revealed, such as, the additional preparation required, to guarantee that all students understand and that the model will work. Modelling activities were perceived as positive for students.	Yes (making suggestions. Rita also revealed that she learnt by observing her supervisor' classes)

6.4.2. Maria, Inês and Their Supervisor (Paula)

Maria

Maria had improved her views both about models and the NOS, and she demonstrated that she felt confident teaching on the NOS and using models in her class.

Although Maria had superficially taught aspects of the NOS, she only pointed out the subject as a limiting aspect to education on the NOS.. She also expressed a belief that students enjoying learning about the NOS and that they understand the concepts:

> *They understand the idea (...) and they agreed with what has been said regarding the nature of science.*

Maria assumed that she will teach about the NOS in her future classes, as she considered it important that students understand the limitations of science.

Maria used both physical and digital models in her classes and made note of the fact that she did not have difficulties in using models in her classes. She also expressed that students liked to used models and that they had shown interest in the modelling activities. Maria also pointed out that students showed some surprise, as they were not used to modelling activities. Maria recognized that she will use models in her future teaching practices, as it facilitates teaching and learning processes and enables students to develop their inquiry skills.

She also revealed that she was very motivated, as she loves to teach. Maria was the only prospective science teacher that believed that her school supervisor, as well as the other teachers at the school, did not influence her work, indicating that she did everything by herself (Table 6).

Inês

Inês also significantly improved her views about models and the NOS, and she felt confident to teach on the NOS (although she recognized that it is not an easy task) and to use models in her classes.

Although Inês had mentioned that she did not have difficulties in teaching on the aspects of the NOS, she recognized that she gave more relevance to conceptual knowledge and she also mentioned several limiting factors, such as time constraints, the subject under study and the characteristics of the students. For example, Inês stated:

> *I didn't promote the debate between students regarding the nature of science, due to the lack of time and as I gave more relevance to conceptual knowledge.*

Concerning students' attitudes, Inês believed that students understood some aspects of the NOS. Inês expressed a belief that she would teach on the NOS in her future practices. Nevertheless, she added that it was only during her internship that she realized how time plays a role in limiting teaching practices, as it is difficult to integrate teachings on the NOS into the classes, while satisfying the requirements of the curriculum.

Inês used physical models and indicated that her difficulties related only to the material that did not work as it should. She also mentioned that students liked using models, that they had shown interest in the modelling activities and that they better understood the contents when using models.

Inês recognized that she is going to use models in her future teaching practices.

Inês showed that she was highly motivated, as she regarded her internship as a challenge and as a way of understanding things in practice that were previously discussed in the university, and she only mentioned her fatigue at the end of the internship as a demotivating factor.

Contrary to Maria, Inês felt that their school supervisor had had a huge influence in her work, as Inês always presented and discussed her planning with her school supervisor, who critically analysed Inês' work and suggested resources and strategies (Table 6). Concerning the other teachers of science, Inês stated that they did not influence her work inside her class; they only influenced Inês' work in extracurricular activities.

Maria, Inês and Paula

Only Inês expressed a belief that her school supervisor (Paula) had greatly influenced her work, as Inês presented her planning, and her supervisor discussed her planning with her and made some suggestions. Paula also showed that she thought that she had influenced both Inês and Maria, as she considered their work to be a sharing of information, resources, ideas, and activities.

Similar to Maria, Paula uses models in her classes for students to develop scientific content and inquiry skills. Paula also restricts the NOS to history of science and the tentativeness of scientific knowledge and recognized a lack of knowledge concerning the NOS and models, as she suggested the organization of some training programs for the in-service science teachers at her school.

6.4.3. Carolina, Rita and Their Supervisor (Joana)

Carolina

Carolina improved her views about models and the NOS and believed that she felt confident to teach on the NOS and to use models in science classes.

Although Carolina had taught certain aspects of the NOS, mainly the tentative nature of science, she mentioned some difficulties when doing so. In this way, she revealed that time limitations and the characteristics of students may influence teaching on the NOS:

> *Due to time constraints that we have (. . .). Also they are not capable of maintaining a discussion, they are not critical enough to do that.*

Additionally, Carolina also recognized that she gave more relevance to conceptual knowledge. Although Carolina had mentioned that understanding the evolution of scientific knowledge was a major objective in the beginning of the interview, her options were mainly justified, throughout the interview, with the purpose of guaranteeing students' understanding. She did not prompt the debate among students, and she only made a few references to aspects of the NOS during her classes. Although Carolina also mentioned that students do understand certain aspects of the NOS, she noted that they do not pay too much attention when talking about the NOS. However, she believed that she is going to prompt discussion on the NOS in her future classes, as she considered it important that students understand the tentative nature of scientific knowledge.

Carolina used both physical and digital models and mentioned some difficulties when using them, such as how to manage a high number of students when developing modelling activities, how to guarantee that the model will work and the additional preparation that the teacher must undertake. Carolina also indicated that students liked using models, that they better understood the contents when using models, and that they had shown interest in the modelling activities and remained more focused when using models. Although she revealed an informed view in the post-questionnaire and post-interview concerning the contribution of models in science teaching, she justified the use of models in science classes, mainly for students to develop conceptual knowledge. She also recognized that students may develop inquiry skills when using models, admitting that students may understand the contribution of models for the development of scientific knowledge in an implicit way. Carolina expressed that she was going to use models in her future practices, mainly for students to develop accurate scientific knowledge.

Carolina also showed that she was highly motivated during the internship, as she has a great desire to be a teacher and she loved all the interaction with the students, mentioning only one demotivating factor. She mentioned that the amount of time that prospective teachers must spend observing classes is demotivating, considering it a waste of time, as her school supervisor did not teach in line with what prospective teachers learnt in the university. However, she claimed that the school supervisor had played an important role, as she positively influenced her work. For example, her school supervisor had suggested resources and strategies, helping her establish a more realistic perspective of what happens in schools (Table 6).

Rita

Rita also improved her views on both models and the NOS (she was the prospective science teacher that revealed more informed views after the intervention programme), and she expressed that she felt confident to teach on the NOS (although she recognized that it is not an easy task) and to use models in her classes.

Although Rita had taught certain aspects of the NOS (she was the prospective science teacher that taught the larger number of aspects about the NOS), she believed that it is difficult to teach on the NOS, to explain how science works. Moreover, she claimed that students are not familiar enough with the NOS in order to talk about it, a fact which may hinder education on the NOS. Although Rita mentioned that students liked and understood the NOS, she also indicated that they exhibit some difficulties as they are not used to teachings on the NOS in science classes. In this way, she also believed that the continuous training of science teachers is crucial, in order to narrow the gap between what usually happens in school and what is advocated in science education literature:

> *I think that continuous teacher training is important, because there is a mismatch. For example, we teach as we were taught in our master's degree programme, we teach like that and students like it (. . .). However in-service teachers do not teach the nature of science. They include aspects of our day-to-day life; and science, technology, society and environmental education is highly developed, contrary to what happens with the nature of science instruction.*

Rita teaches on the NOS, mainly through debates and when using models. She expressed that she is going to incorporate education on the NOS in her future classes, as she believed that it is fundamental for students to understand science in order to learn scientific knowledge.

Rita used physical models, indicating some difficulties associated with their implementation. She mentioned that it is difficult to guarantee that all students understand the modelling activity and that the model will work. She also mentioned that teachers need additional preparation to use models. Nevertheless, Rita also stated that students liked and had shown interest in the activities with models. Although Rita emphasized the contribution of models in the development of conceptual knowledge, she also justified the use of models in science classes for students to develop accurate views of the NOS and of the nature of models (in an explicit way), as well as to develop inquiry skills and critical thinking. Hence, in the example provided, Rita tried to clarify the nature of models:

> *Rita: In your opinion, what is a model?*
>
> *Students: Something that provides us a basis, to answer certain questions . . .*
>
> *Rita: Hum. Ok . . . More . . . It may be something, in this case, for us to understand coastal erosion, which is a natural phenomenon. However, what is the difference between a scientific model and the model that we are going to use here in class?*
>
> *Students: . . .*
>
> *Rita: So, we are going to simply simulate coastal erosion, with some materials which I am going to provide, for you to better understand in the class how coastal erosion happens. But, scientists, as we are going to see later, to evolve and investigate use scientific models that may be used to predict phenomena.*
>
> (Observation of Rita' class)

Rita expressed that she is going to use models in her future classes, as she believed that models should be part of science teaching.

Rita believed that she was highly motivated during her internship, as she truly liked to teach. The only factor that she considered to be demotivating was the lack of interest shown by some students in some classes. Moreover, she believed that her school supervisor had influenced her in a positive way as, while Rita was observing her supervisor' classes, she learnt how to control classes and how to teach, even though she did not agree with every way in which her supervisor taught during classes. Furthermore, her supervisor had helped Rita in the selection of the most appropriate materials (Table 6). Rita also believed that she was influenced by other science teachers at the school, as they also suggested certain resources and strategies.

Carolina, Rita and Joana

Both Rita and Carolina expressed that their school supervisor had influenced their work in a positive way, though they claimed that there was a discrepancy between their supervisor's practices and what they learnt in the university. In this regard, Joana expressed that her influence is closely related to her experience, as she did not consider herself "the pinnacle of how to teach science, we experienced different things (. . .)". Joana displayed that she gave Rita and Carolina the freedom to plan their classes in a way which they considered to be more advantageous, and then Joana discussed this with both Rita and Carolina and gave them advice. Moreover, she gave Rita and Carolina the freedom to actively participate with students in her classes (when it made sense) from the beginning of their internship, which allowed them to prepare for dealing with unforeseeable events and to feel reassured. Similar to Rita, Joana also showed that students are not used to discussing the aspects of the NOS, and similar to Carolina, she believed that students show some lack of reflection.

In the same manner as their school supervisors, in general, these prospective science teachers gave more relevance to the tentative nature of scientific knowledge, as well as to the contribution of models to the development of students' conceptual knowledge. Nevertheless, prospective science teachers gave better answers to the general questions of the final interviews. Moreover, they taught on more aspects of the NOS and exhibited a better understanding of the contribution of models to science-teaching. For example, Rita focused on many aspects of the NOS and used models in classes in an effective way. Moreover, all prospective science teachers developed extracurricular activities with models, which demonstrated the relevance that they attribute to models.

7. Results Discussion

Being that this study is the final study of a larger research project, we may conclude that prospective science teachers improved their views about the NOS and models after attending the intervention programme. However, as demonstrated in other studies [11,30,67], the change of teachers' views does not mean that there is a direct translation of their views into their pedagogical approaches. In this study, we observe that prospective science teachers teach on the NOS and use models in very different ways, which indicates that there is no direct translation between teachers' views and their instructional practices.

Although prospective teachers show that they better recognized the relevance of education on the NOS and that the majority of them feel confident teaching on the NOS and using models, many prospective science teachers justify their options by giving priority to conceptual knowledge, perceiving the NOS as less important than science content. Moreover, Francisco only relies on implicit approaches to teach about the NOS. Furthermore, Sofia also demonstrated some lack of reflection concerning her options. For all the above mentioned, we believe that there is a need to promote reflection among prospective science teachers concerning the relevance of the NOS, and their practices and options, in order to contribute to a better use of models and the education of the NOS, as is argued by Bartos and Lederman [32].

Moreover, Sofia did not teach on the NOS as she agreed with her school supervisor, as he even told her not to teach on the NOS in order to simplify the lesson. Abd-El-Khalick et al. [30] highlight the need for prospective teachers to have planned opportunities to teach on the NOS in their internship. We also consider it fundamental that school supervisors understand the relevance of encouraging prospective science teachers to teach on the NOS.

Prospective science teachers have identified some limiting factors to teaching on the NOS and using models, such as time constraints, the need for better teacher preparation, the management of students' behaviour while using models, the inadequacy of content and students' characteristics. On the other hand, Rita showed that it is possible to teach on the NOS and to use models while being confident about her work, even though she felt that her practices were different from those that the students are used to.

For example, Carolina, as well as her school supervisor, mentioned that students were not critical enough to debate on the aspects of the NOS. We believe that it is important to encourage prospective science teachers to counter that situation, as NOS discussion is fundamental for students to develop their critical thinking and scientific literacy [13,17].

Regarding the age of students, Paula considered it important for students to start discussing aspects of the NOS in the years preceding the level she teaches. Accordingly, studies reveal that young students are more curious and more open to learning about the NOS [68].

It was mentioned that students were not accustomed to using models in classes, which highlights the need to improve teachers' views of models, as is also suggested by Turkoglu and Oztekin [52]. Rita mentioned that students were not used to discussing the NOS, which explains some difficulties shown by them. Likewise, she also stated that she considered the promotion of the continuous training of teachers to be very important. We believe in the notions suggested by Capps and Crawford [20] and Nouri et al. [69] that it is important to rigorously support teachers in valuing and implementing NOS instruction. If the education of the NOS and the use of models are recommended in national science education standard documents, it is then crucial to help in-service teachers and to narrow the gap between their practices and what is actually advocated in science education research. Therefore, one of the supervisors recognized the need for continuous training by suggesting the organization of a training initiative for the teachers at her school concerning the NOS and models.

Despite this gap, the majority of prospective science teachers believed that their school supervisor has a positive influence in their work. However, two of them also cited their relationship with their supervisor as a demotivating factor. Hence, it seems that José was very focused on content knowledge and also discouraged Sofia to teach on the NOS. On the other hand, Joana proved to be more open-minded and more interested in promoting a peaceful atmosphere. This may help prospective teachers, as they use models and teach on the NOS in an efficient way in their internship.

Although we have taught about the NOS in an explicit way to prospective science teachers and we emphasized the need to teach on the NOS in an explicit, embedded and reflective way, more steps must be undertaken in order to avoid the apparent tendency that prospective teacher have in thinking "that the NOS can be taught implicitly through student participation in science activities" [30] (p.432).

Although our study reiterates once more the effectiveness of explicit and reflected education on the NOS for improving teachers' views, it also shows different factors that mediate the translation of teachers' views into their practice.

Consequently, we consider it fundamental to promote teachers' continuous training regarding the NOS and models, especially for school supervisors that follow prospective teachers during an academic year. Moreover, we consider it crucial that prospective teachers better reflect on and justify their practices and options, being guided and encouraged by their supervisors. Furthermore, we also agree with Abd-El-Khalick et al. [30] concerning the indispensability of prospective science teachers having planned opportunities to teach on the NOS and to use models during their internships.

We think that the factors and suggestions that we have identified for the translation of prospective teachers' views on the NOS into their practice should be further investigated, namely more studies should be conducted regarding the influence of the school supervisor in the practices of prospective teachers.

Finally, it is important to highlight some limitations of this study, specifically the limited number of participants of the study. However, concerning the time constraints, it was only possible to observe the classes of these six prospective science teachers. Nonetheless, we consider that this study serves as an important contribution to furthering an understanding of the factors that mediate the translation of teachers' views into their practice.

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Informed Consent statement: All subjects gave their informed consent for inclusion before they participated in the study. Moreover, all institutions involved authorized this research project.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Interviews to Prospective science teachers.

Dimensions	Examples of Representative Questions	
Classes' objectives	1. What were the main objectives that you have established for this academic year? 2. Do you believe that you have accomplished them?	
General overview	1. Would you change something if you plan these classes again? 2. What aspects do you consider to be more important in science teaching? 3. Do you consider that your school supervisor has influenced your work during your internship? How? 4. Do you consider that the other science teachers at your school have influenced your work during your internship? How? 5. Do you consider that you were motivated to work during your internship? Why?	
Analysis of particular activities	1. In class *a*, you developed modelling activity *y*. 1.1. What did you want your students to develop? 1.2. What difficulties have you faced while implementing this activity? 1.3. How did students react to this activity? 2. We verified that you did not prompt the debate regarding NOS aspects. Can you justify your choice?/With this activity it might be easy to teach NOS. Why have you not done that? 3. According to the objectives you presented in the lesson plan, it would make sense to debate certain aspects of NOS. Why have you not done that?	
Scientific models	1. Did you use models in your classes?	
	1.1. What kind of models? 1.2. For what purpose? 1.3. How did you explore models in your classes? Why? 2. Do you consider that your students understood what a model is? 3. How did students react to modelling activities? 4. Did you take any precautions when using models in science classes? 5. What difficulties have you faced when using models?	1.1 If you did not use models explain why.
	6. Do you consider it important to use models in science classes? Why? 7. What do students develop through the use of models in classes? 8. Do you consider it important to discuss models' limitations and characteristics? 9. Do you feel confident to use models in science classes? 10. Do you consider using models in your future practices? Why? With what aims?	
Nature of Science	1. Do you believe that it is important to teach NOS? Why? 2. Did you teach NOS in your classes during the internship?	
	2.1. Which aspects? 2.2. How did you teach NOS? Why? 2.3. Which resources did you use to teach NOS? 2.4. Do you consider that your students understood certain aspects of NOS? 2.5. How did students react to NOS education activities? 2.6. What difficulties have you faced while teaching NOS?	2.1 If you did not teach NOS, explain why.
	3. We verified that you did not include objectives regarding NOS education in your lessons plans./We verified that you did not deeply explore NOS. Can you explain why? 4. Do you feel confident to teach NOS in science classes? 5. Do you consider teaching NOS in your future practices? Why? With what aims?	

Table A1. *Cont.*

Dimensions	Examples of Representative Questions
Annual Planning	1. We verified that prospective science teachers developed an activity for the school that resorted to models. What were the objectives of this activity?
General questions	1. "In science, observation depends on the theoretical framework of the observer". Do you consider that this sentence conveys a positivist or post-positivist perspective of science? 2. "A representation that results from the conceptual model of the scientist that has created it and that intends to represent an idea, an object, an event, process or system". Do you consider that this sentence corresponds to the definition of a scientific model or scientific theory? 3. Please complete this sentence with *analogous model* or *teaching model*: "A model that simulates the way certain phenomena and processes occur in nature, establishing analogies in geometric, dynamic and cinematic similarities is . . . ". 4. Do you consider that models in science (geology) teaching may/should be equal or different from those used in science? Why?

Appendix B

Table A2. Interviews to School supervisors.

Dimensions	Examples of Representative Questions
Professional characterization	1. Since when were you a teacher? 2. For how many years have you taught in this school? 3. What are your academic qualifications? 4. What subjects and levels do you teach?
Group work characterization	1. Do you believe there is a principle that guides biology and geology teachers' actions in your school? (Do you believe there are methodologies that are more frequently used by biology and geology teachers?) 2. How do you characterize your group work? Do you consider that biology and geology teachers work together? 3. Did prospective science teachers work together with the other teachers of biology and geology? 4. Do you consider that the work of prospective science teachers was influenced by the other teachers of biology and geology? 5. Do you consider that the work of prospective science teachers was influenced by you (school supervisor)? How? 6. Did you suggest resources and strategies to the prospective science teachers that worked with you?
Logistical conditions characterization	1. Do you consider it easy to organize meetings with teachers? 2. Are the classrooms well-equipped? Which equipment is needed to improve teaching quality? 3. What difficulties do you face to use school equipment?
General view of science education	1. In your opinion, what is the role of science education in the 21st century? 2. What are the main objectives that you establish for your students' development? 3. What methodologies do you mostly use in your classes? 4. What kind of activities and resources do you use in your classes?
Scientific models views	1. Do you usually use models in your science classes? What kind of models? Why? 1.1. How often do you use models in science classes? In what circumstances? 2. Do you believe it is important to use models in science teaching? Why? 3. What did you want your students to develop when using models? 4. How do you use models in your classroom? (Do you demonstrate models, or do you suggest that students construct models?) 5. Do you consider it important that students construct models? Why? What do they develop? 6. Do you think there are some restrictions on the use of models in science teaching? Which? 7. Which are the characteristics of a model to be used in science classrooms? 8. Which precautions should be taken when using models in science classrooms?

Table A2. *Cont.*

Dimensions	Examples of Representative Questions
Nature of Science views	1. Do you usually teach aspects of NOS (characteristics of science) in your science classes? If so, which aspects? 2. Do you consider it important to teach aspects of NOS/that students understand what science is and how it develops? Why? 3. How do you teach NOS? Which strategies, resources and activities do you use to teach NOS? 4. Do you consider that you face difficulties when trying to clarify your students' views of NOS? Which difficulties? 5. From which students' age do you teach NOS? How did the teaching of NOS evolve?
General questions	1. "In science, observation depends on the theoretical framework of the observer". Do you consider that this sentence conveys a positivist or post-positivist perspective of science? 2. "A representation that results from the conceptual model of the scientist that has created it and that intends to represent an idea, an object, an event, process or system". Do you consider that this sentence corresponds to the definition of a scientific model or scientific theory? 3. Please complete this sentence with *analogous model* or *teaching model*: "A model that simulates the way certain phenomena and processes occur in nature, establishing analogies in geometric, dynamic and cinematic similarities is . . . ". 4. Do you consider that models in science (geology) teaching may/should be equal or different from those used in science? Why?

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