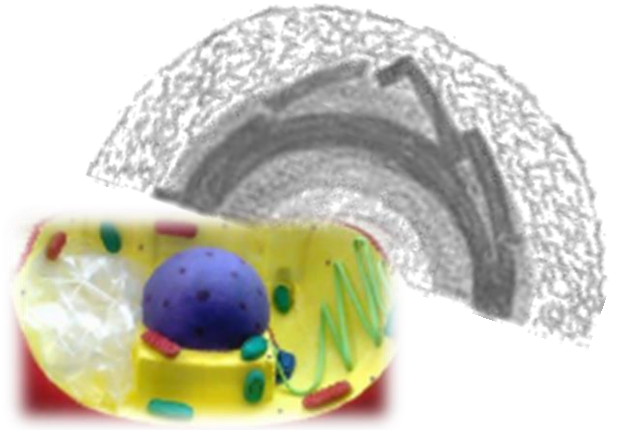




Developing prospective science teachers' views of the nature of science: The specific case of scientific models

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Doutoramento em Ensino e Divulgação das Ciências

Unidade de Ensino das Ciências

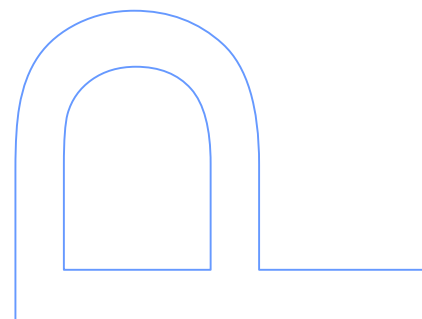
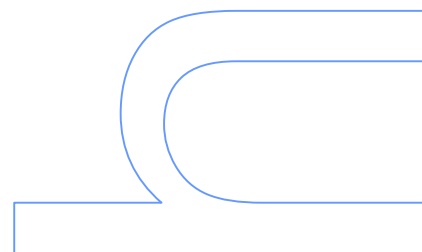
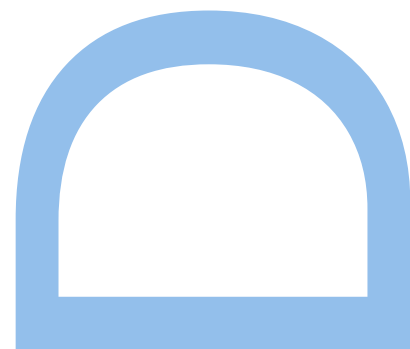
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DEVELOPING PROSPECTIVE SCIENCE TEACHERS' VIEWS OF THE NATURE OF SCIENCE: THE SPECIFIC CASE OF SCIENTIFIC MODELS

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Science Teaching)

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To my parents and to José

A escola de hoje é infinitamente melhor do que a escola de ontem. É mais aberta, mais inteligente, mais sensível à diferença. Mas não chega.

António Nóvoa, Evidentemente – Histórias da Educação

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Abstract

Scientific models are fundamental in scientific activity, being used to explain, describe, and predict natural phenomena. In this way, the use of models in science classes is of the utmost importance for students to develop scientific knowledge, their inquiry skills, and their views about the nature of science. The development of students' accurate views of the nature of science is, currently, considered a central goal in science education, in order to better prepare scientifically literate students. By developing accurate views of the nature of science, students better understand science and scientific knowledge; become better prepared to make informed decisions; and become more interested for science.

Although being relevant for science education, both nature of science and models are scarcely implemented in science classes. Indeed, studies also demonstrate that teachers themselves possess some lack of knowledge concerning the nature of science and models. Moreover, even when teachers possess informed views regarding those aspects, they do not give great relevance to the instruction of the nature of science and to an effective use of models. Bearing this in mind, we considered it relevant to improve science teachers views of the nature of science and models and regarding their relevance in science teaching, in order to contribute to its effective implementation in science classes.

In our study, we mainly worked with prospective science teachers and we intended to develop, implement, and evaluate an intervention programme (IP) that aimed to improve their views about the nature of science and about models (in science and for teaching). Afterwards, we also wanted to analyse the factors that mediate prospective science teachers' views into their practice, by observing prospective science teachers' classes and by interviewing them, as well as their school supervisors.

However, we started our study by a general description of Portuguese teachers (prospective and in-service teachers) and students' views regarding the nature of

science and models and of the way models and the nature of science are integrated in science teacher training and in Portuguese science textbooks.

Afterwards, we constructed and developed an intervention programme and we elaborated and evaluated distinct instruments of analysis, namely questionnaires, interviews, and short questionnaires to be applied to prospective science teachers, grids (to observe the classes), as well as the final interview scripts to be applied both to prospective science teachers and to their school supervisors.

Afterwards, we implemented the intervention programme, that lasted twenty-five hours. This intervention programme was applied to the students of the first year of the master in biology and geology teaching in their classes of Education of Geology II.

Before and after the intervention programme, we administered questionnaires and interviews, in order to evaluate the contribution of this intervention programme in the development of participants views about models and about the nature of science. After each class of the intervention programme, we also applied short questionnaires, to evaluate the views that participants recognize to have changed and developed.

To better understand the factors that mediate the translation of teachers' views into their teaching practices, we observe prospective science teachers' classes and we analysed their lessons plans and the learning activities and materials designed by them. Afterwards, we also administered final interviews to these prospective science teachers, to analyse their perceptions and the difficulties they face when implementing models and teaching NOS, as well as the reasons that justified their options. Moreover, we also interviewed their school supervisors to analyse their influence on prospective teachers' work, deepening the understanding of the factors that mediates the translation of teachers' views into their practices.

Although we have concluded, once more, that teachers, prospective teachers, and students possess some lack of knowledge regarding models and the nature of science, we also verified that the teachers that participated in this study have greatly improved their views after attending the intervention programme. However, teachers have shown that they valued and taught nature of science and models in a variety of ways during their internship, being multiple the factors which mediates the translation of their views into their classroom practices.

Throughout this study some of these factors will be presented and discussed. Nevertheless, one of the prospective science teachers as manage to surpass a diversity of constraints while teaching nature of science and using models in an effective way in the classroom.

Having in mind the positive impact of the intervention programme, we found that it would be relevant to apply this intervention programme to other prospective science

teachers, as well as to in-service teachers, namely the school supervisors. We also considered relevant to follow teachers while implementing models and while teaching nature of science, in order to optimize their work flow.

More effort should be done to narrow the gap between what is recommended in science education and what is actually done in practice. Therefore, we also consider that more research is needed, in order to promote a better understanding of the aspects of the nature of science, as well as of models. We also believe that further investigation is essential to better understand the factors which influence teachers' views of these aspects, as well as the factors which mediate the translation of teachers' views into their teaching practices.

Key-words: Teachers training, prospective science teachers, history of science, modelling, scientific models, nature of science, intervention programme,

Resumo

Os modelos científicos são fundamentais na atividade científica, sendo usados para explicar, descrever e prever fenômenos naturais. Neste sentido, o uso de modelos nas aulas de ciências é de extrema pertinência para que os alunos possam desenvolver conhecimento científico, as suas capacidades de investigação e as suas visões acerca da natureza da ciência. O desenvolvimento de visões adequadas acerca da natureza da ciência é, atualmente, considerado um objetivo central na Educação em Ciências, de forma a promover a literacia científica nos alunos. Ao desenvolverem estas visões, os alunos compreendem melhor a ciência e o conhecimento científico; ficam mais preparados para tomar decisões informadas; e tornam-se mais interessados pela ciência.

Apesar da natureza da ciência e os modelos serem fundamentais para a educação em ciência, ambos são escassamente aplicados em sala de aula. Na realidade, estudos revelam que os próprios professores possuem falta de conhecimentos relativamente à natureza da ciência e aos modelos. Por outro lado, mesmo quando os professores possuem visões adequadas sobre estes aspetos, estes não atribuem grande relevância ao ensino da natureza da ciência e ao uso dos modelos. Pelo exposto, consideramos fundamental melhorar as visões dos professores de ciências sobre a natureza da ciência e os modelos, assim como da sua relevância nas aulas de ciências, de forma a contribuir para a sua aplicação efetiva em sala de aula.

No nosso estudo, trabalhamos essencialmente com futuros professores de ciências e pretendemos desenvolver, aplicar e avaliar um programa de intervenção (PI) que tinha como objetivo melhorar as suas visões sobre a natureza da ciência e os modelos (na ciência e no ensino das ciências). Posteriormente, pretendemos também analisar os fatores que medeiam a transposição das visões dos futuros professores de ciências para as suas práticas de sala de aula, ao observar as aulas dos futuros

professores de ciências e ao entrevistá-los, assim como aos seus orientadores cooperantes (orientadores que acompanharam os estagiários nas escolas).

Começamos o nosso estudo por fazer uma descrição geral das visões dos professores (futuros professores e professores no ativo) e dos alunos portugueses sobre a natureza da ciência e os modelos, seguida de uma breve descrição da forma como os modelos e a natureza da ciência são integrados na formação dos futuros professores de ciências do país e nos manuais de ciências portugueses.

Seguidamente, procedeu-se à construção do programa de intervenção, assim como à elaboração e validação de diversos instrumentos de análise, nomeadamente dos questionários, entrevistas e pequenos questionários a serem aplicados aos futuros professores de ciências, das grelhas de observação de aulas, bem como dos guiões das entrevistas finais aplicadas quer aos estagiários, quer aos seus orientadores cooperantes.

Após a elaboração dos materiais e instrumentos de análise, procedeu-se à implementação do programa de intervenção, que teve uma duração de vinte e cinco horas. Este programa de intervenção foi dirigido aos estudantes do 1º ano do Mestrado em Ensino da Biologia e da Geologia, no âmbito da unidade curricular Didática da Geologia II.

Antes e após o programa de intervenção foram aplicados questionários e entrevistas, de forma a avaliar a contribuição deste programa no desenvolvimento das visões dos participantes acerca dos modelos e da natureza da ciência. Após cada aula do programa de intervenção, foram também aplicados pequenos questionários, com o intuito de analisar as conceções que os participantes consideraram ter alterado e desenvolvido.

Com vista a melhor compreender os fatores que medeiam a transposição das visões dos professores para as suas práticas letivas, observamos as aulas lecionadas pelos estagiários, futuros professores de ciências, e analisamos os planos de aula e atividades desenvolvidas por cada um deles. Posteriormente, efetuamos também entrevistas finais a estes futuros professores, de forma a analisar as suas perceções e dificuldades aquando da implementação de modelos e do ensino da natureza da ciência e as razões que justificaram as suas opções. Adicionalmente, os orientadores cooperantes foram também entrevistados, no sentido de analisar a influência destes no trabalho dos futuros professores, aprofundando a compreensão dos fatores que medeiam a transposição das visões dos professores para as suas práticas letivas.

Apesar de se concluir, uma vez mais, que os professores, futuros professores e alunos possuem algumas visões pouco adequadas sobre modelos e a natureza da ciência, verificou-se que os professores participantes no estudo melhoraram bastante

as suas visões, após a sua participação no programa de intervenção. No entanto, estes revelaram valorizar e ensinar a natureza da ciência e usar modelos de formas bastante distintas durante o seu estágio profissionalizante, sendo vários os fatores que medeiam a transposição das suas visões para a sua prática em sala de aula.

Neste estudo serão apresentados e discutidos alguns desses fatores, verificando-se, no entanto, que um dos estagiários conseguiu ultrapassar diversas condicionantes e ensinar a natureza da ciência e aplicar os modelos de forma eficiente em sala de aula.

Tendo em conta o impacto positivo do programa de intervenção, consideramos que seria relevante aplicar este programa de intervenção a outros futuros professores de ciências, mas também a professores que se encontrem no ativo, nomeadamente aos orientadores cooperantes. Julgamos também importante agilizar esforços para acompanhar os professores na implementação dos modelos e no ensino da natureza da ciência, de forma a otimizar o seu trabalho.

Mais esforços devem ser enveredados no sentido de estreitar o fosso existente entre o que é recomendado no ensino das ciências e o que é realizado na prática. Consideramos, assim, ser necessária mais investigação, de forma a facilitar a promoção de uma melhor compreensão dos aspetos da natureza da ciência e dos modelos. Mais investigação é, todavia, necessária para se compreender melhor os fatores que influenciam a visão dos professores sobre estes aspetos, assim como os fatores que medeiam a transposição das visões dos professores para as suas práticas letivas.

Palavras – chave: Formação de professores, futuros professores de ciências, história da ciência, modelação, modelos científicos, natureza da ciência, programa de intervenção.

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List of Abbreviations

BSc	Bachelor of Science
Cu	Cuestionario del encuestado
ECTs	European Credits Transfer System
En	Entrevista del respondiente
HSPPSTs	Portuguese prospective Science Teachers that study in a higher school of education
HSSs	High School Students
I	Interview' answer
IP	Intervention programme
NdC	Natureza da Ciência
NOS	Nature of Science
PI	Programa de Intervenção
PPSTs	Portuguese prospective Science Teachers
PT	Prospective teacher
Q	Questionnaire' answer
SM	Scientific models
STs	Science Teachers
UPPSTs	Portuguese prospective Science Teachers that study in a university
VNOS-C	Views of Nature of Science Questionnaire – Form C

CHAPTER I

Introduction

I.1. Theoretical Framework

Currently, it is advocated that, in science classes, students must not only develop scientific knowledge, but they must also develop their epistemological knowledge and inquiry skills. Indeed, in both international and national science education standards documents it is recommended that students develop an accurate view of science.

As scientific models are fundamental in scientific activity, the use of models in science classes also becomes a major contribution for a more realistic understanding of science.

As we intend to improve prospective science teachers' views regarding nature of science and models, we are going to briefly describe the two main concepts underpinning this thesis.

I.1.1. Nature of science

Nature of science (NOS) refers, in general terms, to the characteristics of science that are derived from how the knowledge is developed (Lederman, 1992/2006). Acevedo-Díaz & García-Carmona (2016) also believe that NOS is related to everything that characterizes science, as the construction of a special type of knowledge.

Although being difficult to define NOS, the development of accurate views of NOS is currently considered crucial in science education (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman, 2006; McComas, Clough & Almazroa, 1998). In fact, as science plays a major role in our current society, it becomes urgent that students and citizens in general understand science and its nature (McComas et al., 1998). Indeed, there are many reasons for students to develop accurate views of NOS, as it is believed that it is considered to be integral for students to be literate about science; 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 (Kampourakis, 2016; Lederman, 2007; McComas et al., 1998). Nevertheless, it is important to highlight that there is a lack of studies that strictly relates NOS knowledge with all these advantages (Kampourakis, 2016; Lederman, 2007).

Despite the relevance that it is attributed to NOS development in science classes, there is also a lack of consensus regarding the aspects of NOS that should be focused in classes (Acevedo-Díaz & García-Carmona, 2016).

However, it is argued that there are some aspects of NOS that are not controversial and that are accessible, robust, and relevant for secondary students (Abd-El-Khalick, 2006; Bell, 2006; Lederman et al., 2002)

In this way, Lederman et al. (2002) referred that students must understand that: (i) scientific knowledge is tentative, it may suffer changes according with new data or with the reinterpretation of existing data; (ii) scientific knowledge is empirical, being partially based on observations that depend on our perceptions and scientific instrumentations; (iii) scientific knowledge is partially subjective, as the work of scientists is influenced by their opinions, values, previous knowledge, experience, practice and expectations; (iv) science is not entirely rational, being the creativity and imagination fundamental for scientific knowledge development; (v) science is influenced by the context in which it is embedded and science also influences the context; (vi) science is based in inferences and theoretical entities, being crucial to understand the distinction between observation and inference; (vii) theories and laws are different types of knowledge, being both legitimate products of science; and (viii) there is no universal scientific method, as there is no recipelike stepwise procedure that all scientists follow when they do science.

In this study, we have adopted the abovementioned view concerning NOS, given its wide acceptance and its appropriateness as a starting point for both teachers and students to start thinking about NOS and to attain an understanding of various aspects of NOS (Bartos, & Lederman, 2014; Kampourakis, 2016).

However, and despite the relevance of NOS in science education, studies show that students do not develop accurate views of NOS (Bell et al., 2003; Praia et al., 2007). This may be related with inappropriate references to NOS in science textbooks and in other didactical materials, as well as with the reliance on implicit instruction of NOS (Bell, 2006). In fact, it should also be highlighted that it is argued that students' views of NOS are better developed through an explicit, reflective (Mesci & Schwartz, 2016; Acevedo Díaz, García-Carmona, & Aragón, 2016) and embedded NOS instruction (Koksal, Cakiroglu, & Geban, 2013).

Moreover, teachers are also crucial to science learning, intervening in a significant way in the educational experience of students (Matthews, 1990; McComas et al., 1998; Cachapuz, et al., 2004). In fact, studies demonstrate that science teachers do not possess accurate views of NOS (Bell et al., 2016; Lederman, 2007; Pavez et al., 2016; Wahbeh & Abd-El-Khalick, 2014). Furthermore, even if teachers present accurate views of NOS, teachers do not usually engage students in activities that promote students' accurate views of NOS (Abd-El-Khalick e colaboradores, 1998).

As there are many reasons that justify the relevance of including NOS in science classrooms (McComas et al., 1998; Torres & Vasconcelos, 2013), we believe that it is

fundamental that prospective science (Biology and Geology) teachers develop accurate views of NOS. Moreover, we also believe that it is crucial that prospective science teachers understand the relevance of NOS instruction and that they develop knowledge and abilities to teach NOS in their classes.

As an example, some historical episodes are considered to be fundamental for the development of accurate views of NOS (McComas, 2008). Moreover, history of science gives many examples of different historical models, disclosing a diversity of factors that influence the development of these models (Chamizo, 2013). In this way, resorting to historical episodes and to the analysis of the historical evolution of models is crucial for students to understand that science is a human activity, that changes during the course of time and that it is influenced by social and cultural factors (Torres, Moura, Vasconcelos & Amador, 2013).

Moreover, Gericke and Hagberg (2007) also referred that history of science and historical models are fundamental for understanding the role of scientific models in science.

Scientific models are extremely important to scientific knowledge development, being the understanding of the nature of models crucial for a holistic understanding of NOS.

I.1.2. Models in science

Scientific models are considered to be fundamental in scientific activity, being not only products of science, but also tools and processes of science, which aim to explain or predict target phenomena (Cheng & Lin, 2015). Chamizo (2013) argue that one of the main activities of scientists is to evaluate which models fit better with the available evidences, seeking for the best explanation for some phenomena (Chamizo, 2013; Driver, Newton, & Osborne, 2000). Koponen and Tala (2014) claim that “models are central knowledge structures in science and vehicles for developing, representing and communication ideas” (p. 1143). Passmore, Gouvea and Giere (2014) also state that “models are at the centre of the day-to-day work of science; they are the functional units of scientific thought” (p.1174).

Despite the variety of scientific models definitions found in the literature (Chamizo, 2013; Giere, 2010; Gilbert & Ireton, 2003; Oh & Oh, 2011; Schwarz & Gwekwerere, 2007), their relevance in science is undeniable. In general terms, we may say that scientific models are representations of different aspects of the world, which are developed according to a specific goal (Chamizo, 2010; Chamizo, 2013; Giere, 2010). Scientific models may represent a variety of entities, such as objects, phenomena,

processes and ideas (usually referred to as “target”), in a way that simplifies what is represented (Oh & Oh, 2011). In fact, according to the *Intentional Conception of Scientific Representation* proposed by Giere (2010), models result from the objectives, interpretation and knowledge of the scientist, being considered intentional and simplified representations. As a result, models are not copies of reality, but representations which are similar to the world only to the intended degree of accuracy and according to modeller interpretation. Having in mind this intentional conception of scientific representation, it becomes obvious that multiple models exist to study different aspects of the same target, as the scientists specify which aspects they intend to study [(...) agents specify which similarities are intended(...)], as claim by Giere (2010, p. 274)]. In the same way, multiple models may also exist to study the same aspect of the world, as scientists may have different ideas and may rely on different resources to build models (Oh & Oh, 2011).

Scientific models may change along with the scientific knowledge development. If scientific knowledge is tentative and may change according to new data and to the reinterpretation of existing evidence (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), it seems obvious that scientific models (that play a crucial role in scientific knowledge construction and development) also evolve (Oh & Oh, 2011). Having this in mind, *historical models* were consensus models (i.e., models that have gained acceptance among scientific community) that were produced in specific historical context and that were later superseded by other models (Gilbert, Boulter, & Elmer, 2000; Justi, 2000).

A model is also considered to be a mediator connecting a theory and a phenomenon, as its construction from data provides useful insight for the development of a theory. Also, we can better understand theories when they are reified into a model, which may map the theory onto the natural world (Oh & Oh, 2011).

Regarding the theory-to-model relationship, Winsberg (2001) stated that theory guides model development. However, in some cases, in the absence of established theories and of well-known targets, models are considered to be, essentially, tools for thinking, reasoning and exploring theoretical ideas (Koponen & Tala, 2014). In fact, scientists may design models that contain objects thought not to exist in the real world, through inferences. Scientists may thus design, invent and infer new realities, in order to obtain new information about phenomena, whose processes are not observable (Halloun, 2007; Oh & Oh, 2011). For example, through the Standard Model of particle physics, which describes the composition of the world around us at a subatomic level, scientists theorized about the existence of a subatomic particle that gives mass to particles (Higgs boson). Almost fifty years later, a particle consistent with that particle predicted by the Standard Model was observed at CERN's Large Hadron Collider.

Scientific models are thus fundamental research tools (Cheng & Lin, 2015), which represents, describes, explain and predict particular phenomena (Baetu, 2014; Oh & Oh, 2011). Scientific models prompt visualization, which supports creativity and favours understanding. Moreover, they function as auxiliary resources in the communication and dissemination of science.

There is a wide variety of typologies of models. For example, Justi (2000) presented a typology where models were considered to be historical or hybrid, while Chamizo (2013) presented one that divides models into two types: mental models and material models, where the latest can be symbolic, experimental or iconic. When describing the interaction between the real world, mental models, material models and modelling, Chamizo (2013) pointed out a unique feature of chemical modelling: the construction of new artificial substances that consequently change the real world.

Undoubtedly, different models may be used with different purposes, depending on a diversity of factors, namely the scientific area we are talking about. For example, in biology, model organisms play a major contribution to the development of knowledge regarding the causes and mechanisms of biological phenomena (Baetu, 2014).

In Physics, Galileo represents a turning point between ancient and modern science in the western world, given his revolutionary methodological contribution by considering idealized models of phenomena (Halloun, 2007; Nola, 2004). His mode of inquiry consisted mainly of a cycle of model construction, analysis and corroboration (Halloun, 2007).

In geology, Sibley (2009) highlights the addition of retrodiction as an important role of models in geology, taking into account the relevance of making inferences about past events in this scientific area.

1.1.2.1. Geoscientific Models

As described above, scientific models are extremely important in scientific knowledge construction and development. In geology, models and analogical reasoning acquire an even greater relevance as this scientific area heavily deals with processes and forces that cannot be directly perceived (Frodeman, 1995; Jee et al., 2010).

Despite the undeniable importance of models in geological research, its use was heavily contested from the very beginning, as geology was mainly considered a field science (Brandstetter, 2011; Oreskes, 2007; Vasconcelos & Torres, 2015). However, James Hall (1761-1832), who is considered the father of experimental geology, tried to bring geology and modelling experiments into the laboratory, since the early 19th century.

In order to explain the origin of the folds that he observed in mountain ranges, Hall constructed a model, known as “Hall’s compression box” (Figure I.1.1). In this box, he placed layers of cloth that represented the strata and that were compressed horizontally by two wooden boards, reproducing the formation of folded structures (Graveleau, Malavieille, & Dominguez, 2012; Oreskes, 2007).

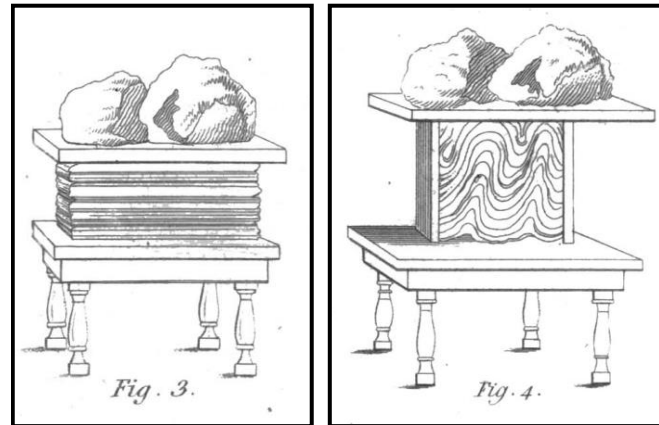


Figure I.1.1. Hall's first model.

Extracted from: Hall (1815, plate IV.).

In spite of being successful in representing these folded structures, the use of those laboratory methods in geology was highly criticised, namely by his teacher James Hutton (1726-1797). In fact, fifty years passed until other geologists resumed Hall’s work. Lyell (1871), Favre (1878), Daubrée (1879), Reade (1886) and Cadell (1888) are examples of some relevant geologists that developed different kinds of experiments to study diverse aspects of folded structures and to study mountain-building processes (Graveleau et al., 2012; Oreskes, 2007). Through geological presuppositions and the establishment of scaling laws in the 20th century, it became possible to guarantee the physical realism of experiments and achieve significant results with modelling experiments (Brandstetter, 2011; Graveleau et al., 2012).

In fact, modelling experiments are widely used not only in the understanding of mountain belt evolution, but also in the understanding of other phenomena, such as tsunamis and earthquakes and their effects on buildings and coastlines. Model experiments are presently important tools for geological research and are used to demonstrate theories, make hypotheses plausible, test explanations and to access the inaccessible. Currently, geological models are also intimately associated with the desired to predict the future. However, it is essential to stress that many models and predictions in geology are complex and deal with many uncertainties, as it is impossible to fully test them (Oreskes, 2007). The recognition of these uncertainties is considered to be important to “understand the nature of scientific modelling as well as to make relevant

public policies” (Oh & Oh, p. 1120). Contrary to what happens in other fields of knowledge (where predictions are important in the formulation of scientific knowledge, given the possibility to test them) geological predictions have mainly a social character (generated by social and political pressures) rather than epistemic (Oreskes, 2007).

I.1.2.2. Biological Models

According to Baetu (2014), there are two main categories of biological models (i) experimental models, and (ii) conceptual models. Experimental models are those models that include physical objects, such as organisms, cells, or in vitro experimental setups, that are used in experiments for scientists to gain knowledge concerning causes and mechanisms related to biological phenomena. On the other hand, conceptual models comprise explanations and explanatory hypotheses of mechanisms, structures, and mathematical models.

Upmeier zu Belzen and Krüger (2010, cited by Krell, Upmeier zu Belzen & Krüger, 2012) presented three different purposes of models in biology: (i) models can be used to describe a phenomenon; (ii) models can be used to explain relations of variables/parameters of the phenomenon; and (iii) models can be used to test or to generate hypotheses about a phenomenon.

Model organisms (Figure I.1.2) are extensively used in biological research, being crucial both to biomedical and to basic biology research (Ankeny, 2007; Hubbard, 2007).

A model organism is a non-human species that is extensively studied to understand specific biological processes and concepts. Models organism serve as exemplars which lead to the production of knowledge that can be transferred to other examples and entities, including humans (Creager, Lunbeck, & Wise, 2007).



Figure I.1.2. Example of an organism model – nude mouse used in cancer research.

Credits: Ana Oliveira, 2015

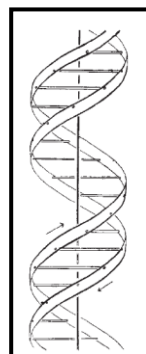


Figure I.1.3. DNA model proposed by Watson & Crick.

Extracted from: Watson & Crick (1953, p. 737).

An example of a fundamental structural model that played an important role in biological and genetical research is the model for the structure of DNA (Figure I.1.3). Watson and Crick, in 1953, proposed the DNA double-helical model for the structure of DNA, because of a diversity of works previously performed, and due to new advances and techniques in modelling (Pray, 2008).

I.1.3. Models in science education

Regarding the relevance of scientific models in science, models and modelling are fundamental for students to reflect scientists' activities and to develop competences that are in accordance with the assumptions of an inquiry-based learning approach (Vasconcelos, Moura, Torres, Moutinho, & Lima, 2015). In fact, modelling activities prompt the development of important inquiry skills, such as observing, questioning, hypothesizing, predicting, collecting, data-analysing and conclusion-formulating (Akerson, White, Colak, & Pongsanon, 2011).

Models and modelling activities in science classes are fundamental for students to develop accurate mental models, as visual representations are considered to be auxiliary resources to the reasoning with our internal representations, i.e., our mental models. However, models and modelling activities are also important for students to develop inquiry competences and to understand different aspects of the nature of science (NOS), including the relevance of models in science (Torres & Vasconcelos, 2015). As Justi and Gilbert (2002-2003) highlighted, models and modelling activities prompt the learning: (i) *of science* - as students come to know the major models that are the products of science (that correspond to scientific conceptual knowledge); (ii) *of how to do science* - by creating and testing their own models and (iii) *about science* - by constructing an adequate view of the nature of models and by being able to appreciate the role of models in the accreditation and dissemination of the products of scientific enterprise.

As models and modelling are important aspects of science, the understanding of the nature of models contributes to a deeper understanding of NOS (Cheng & Lin, 2015). Crawford and Cullin (2004) argue that models and modelling activities in science classes may prompt the understanding of NOS as students may better realize the tentative nature of models, the role that creativity plays in the construction of models, the multiplicity of models and the iterative aspect of modelling.

Torres et al. (2013) also underline the relevance of analysing historical models as a contribution to the understanding of science as a human activity that changes over the course of time, as there are many aspects that influence models and scientific knowledge construction. As mention by Justi (2000), the analysis of different historical models in

association with the description of the historical context in which they were developed show “that scientists were normal individuals who communicated their ideas to others, dealt with technological limitations, and who constructed both good and not-so-good ideas” (p. 225), emphasising the non-linear and dynamic evolution of scientific knowledge. Furthermore, Gericke and Hagberg (2007) point out the relevance of historical models as contributors to the understanding of the role of scientific models in scientific knowledge construction.

There are many studies that uncover the positive aspects of resorting to models and to modelling in science classes. For example, Halloun (2007) reveal that modelling activities applied in secondary school and university physics courses promote: better conceptual understanding of scientific knowledge; better performance in the exams; better views about NOS; better learning styles and more equitable learning. Also, this author claim that students develop stable inquiry skills, tools and learning styles that may be used in other situations and courses. Moreover, Koponen and Tala (2014) underline the relevance of models in science education not only as tools to demonstrate consensual scientific ideas, but also as tools for creative thinking and for knowledge construction.

Haugwitz and Sandmann (2010) in a study with models of the heart and the blood vessels also conclude that building models collaboratively simplifies the learning process, fosters the learning of conceptual knowledge and promotes the interest of the students.

Moutinho et al. (2014a), in a study conducted with geological models applied to 126 secondary students, also exhibit that modelling activities help students in the restructuration of their mental models and in their approach to scientific models, contributing to scientific knowledge construction and significant learning. Bolacha et al. (2012) also point out the relevance of models in geoscience education, as they prompt a better understanding of deep time and the development of important skills in geology, such as the ability to imagine geological movements and sections. In fact, as geological research relies heavily on models, using them in geoscience education acquires an even greater importance (Gilbert, & Ireton, 2003; Oh & Oh, 2011).

Despite the relevance attributed to models and modelling in science education, some studies reveal that teachers do not systematically resort to models, revealing a limited knowledge regarding the role of models in science and for teaching (Khan, 2011; Van Driel & Verloop, 1999; Wang, Chi, Hu, & Chen, 2014). As mentioned by Van Driel and Verloop (1999, p.1141) “teachers usually present the models to be learned as static facts” and do not give students the opportunity to actively construct and revise models.

I.2. Scope and Motivation

In national biology and geology syllabus of middle and secondary school, it is recommended the use of models in science classes and the development of accurate views of NOS (Amador *et al.*, 2001; Galvão *et al.*, 2001).

However, many studies show that students and even teachers do not possess accurate views of NOS and of models. Furthermore, teachers do not value NOS instruction and do not systematically use models. Nevertheless, in science education models may play an important role to the learning of scientific contents and to the development of inquiry skills and of accurate NOS views.

If it is currently intended that students in biology and geology classes reflect scientist activities for students to develop their scientific and epistemological knowledge, as well as their inquiry skills, we believe that it is crucial that teachers develop accurate views regarding models in science and in science teaching, as well as regarding NOS, and that they understand the relevance of NOS instruction and the use of models in science classes.

Although being a necessary condition, the improvement of teachers' views regarding NOS and models do not guarantee NOS instruction and the use of models in teachers' classes. As a consequence, it will be fruitful to explore the factors that mediate the translation of teachers' knowledge into their teaching practices (Abd-El-Khalick, *et al.* 1998).

Reis and Galvão (2004) suggest different factors that mediate the translation of teachers' views of NOS and their practices, such as the national curriculum, the national exams, their previous experiences with scientific practices and their own educational objectives.

Nevertheless, we believed that more studies are needed in order to better understand the factors that mediate the translation of teachers' knowledge concerning NOS and models into their teaching practices.

I.3. Objectives and main stages

With this research, we intend to develop prospective science teachers' views regarding NOS, models, and modelling in order to promote an efficient and explicit NOS instruction, as well as an appropriate use of models in their future teaching practices. Also, we intend

to better understand the factors that influence the translation of teachers' conceptions into their teaching practices.

The main objectives of these research are to:

- (i) Apply an Intervention Programme concerning NOS (emphasising the role of models in the construction of scientific knowledge and in scientific learning and teaching and by providing opportunities for students to construct didactic materials that imply NOS instruction and the use of models);
- (ii) Evaluate prospective science teachers' views regarding NOS and models both before and after the intervention programme;
- (iii) Analyse how prospective science teachers teach NOS and use models in their teaching practices during their internship;
- (iv) Analyse the factors that mediate the translation of teachers' knowledge concerning NOS and models into their teaching practices, with the aim of improving teaching practices.

Having these objectives in mind, the main research questions of this investigation are:

- 1) What are prospective science teachers' conceptions of NOS, models, and modelling prior to the intervention programme?
- 2) What are prospective science teachers' conceptions of NOS, models, and modelling after the intervention programme?
- 3) Do prospective science teachers emphasize NOS instruction, the use of models and modelling in their teaching after the intervention programme?
- 4) Which factors/constraints influence NOS teaching, the use of models and the implementation of modelling activities in science classrooms?

The study relied on a qualitative methodology and was undertaken in different main stages.

First stage

In order to attain a general overview of NOS and scientific models knowledge of Portuguese teachers and students, we administered a closed questionnaire to in-service Portuguese science teachers and to Portuguese science students. We also evaluated Portuguese prospective science teachers' views from different institutions of higher education of the country. Also, to better understand to what extent prospective science

teachers deal with these issues in their training, we analysed the syllabus of Biology and Geology Education subjects of seven Portuguese universities.

Second stage

This stage relates to the implementation of the intervention programme to the main sample of our research (students that were enrolled in the master in Biology and Geology Teaching in Middle and Secondary Schools in 2013/2014 and 2014/2015 academic years). This intervention programme was implemented during 2013/2014 academic year and aimed to improve prospective science teachers' conceptions regarding NOS and scientific models and also their conscious awareness for the inclusion of these issues in their teaching practices.

After each class, a short questionnaire was administered, to analyse the main concepts that were developed and altered.

Questionnaires and semi-structured interviews were administered before and after the implementation of the intervention programme in order to evaluate the evolution of prospective science teachers' conceptions regarding NOS and scientific models.

Third Stage

In order to evaluate the translation of prospective teachers' conceptions developed during the IP into their classroom practices, a very diverse set of data sources were used. We observed the classes lectured by the prospective teachers in their internship (that took place in 2014/2015 academic year).

We also collected their lesson plans, their portfolios and the learning activities and materials designed by them. After the analysis of all this data, prospective science teachers were interviewed once more, in order to verify the previous analysis and to understand the factors that mediate/constrain the translation of teachers' conceptions into their teaching practices. Prospective teachers' supervisors (that work with them in schools) were also interviewed in order to understand how they influence prospective teachers' work.

I.4. Outline of the thesis

This thesis comprises V chapters, corresponding the first chapter to a general introduction and the last chapter to the main conclusions. Chapters II to IV are presented in the form of articles, which in the whole describe the research carried out with the aim

of responding to the research questions. Chapter I also includes parts of published papers in the general introduction.

Chapter I is the introductory chapter and comprises the theoretical framework, the scope and motivation, and the objectives and main stages sections. At the end of this chapter, the contents of the thesis are outlined.

Chapter II correspond to a general description of Portuguese teachers and students' views regarding the nature of science and models, and to a description of how nature of science and models are integrated in the syllabus of Portuguese prospective science teachers' training, as well as in science textbooks. In view of this, we administered a closed questionnaire to in-service Portuguese science teachers and to Portuguese science students to analyse their views of the nature of science and models (*sub-chapter II.1*). Additionally, we evaluated Portuguese prospective science teachers' views of the nature of science and models from different institutions of higher education of the country (*sub-chapter II.2*), and we also analysed the syllabus of Biology and Geology Education subjects of seven Portuguese universities, to better understand to what extent prospective science teachers deal with these subjects in their training (*sub-chapter II.3*). This chapter ends with a brief historical analysis of how nature of science and models are explored in Portuguese science textbooks, by analysing the specific example of the Earth's structure model (*sub-chapter II.4*).

Chapter III aims at validating the questionnaires which were subsequently used to evaluate prospective science teachers' views of the nature of science and of models. *Sub-chapter III.1* is devoted to the validation of the questionnaire to evaluate the views of the nature of science and *sub-chapter III.2* to the validation of the questionnaire to evaluate the views about models. The last sub-chapter (*sub-chapter III.3*) describes the intervention programme that was applied to the prospective science teachers.

Chapter IV focuses on the main results obtained. The *sub-chapter IV.1* primarily presents the results regarding the improvement of prospective science teachers' views about NOS, and the *sub-chapter IV.2* primarily presents the results regarding the improvement of prospective science teachers' views about models, as a consequence of the intervention programme. The *sub-chapter IV.3* is devoted to the analysis of the short questionnaires that were administered after each class of the intervention programme and that were related to the main concepts that were developed and altered.

Sub-chapter IV.4 mainly analyses prospective science teachers opinions concerning their change of views concerning NOS and models. *Sub-chapter IV.5* and *sub-chapter IV.6* present the results after the observation of the lessons of prospective science teachers. *Sub-chapter IV.5* presents the results of the final interviews that were administered to prospective science teachers and describes and analyses the main perceptions of prospective science teachers when implementing modelling activities and when teaching NOS during their internship and the reasons that justify their options. *Sub-chapter IV.6* presents not only the results of the final interviews that were administered both to prospective science teachers and to their school supervisors, but also the results obtained through the analysis of questionnaires and interviews (applied to prospective science teachers before and after the intervention programme); of prospective science teachers' lesson plans and portfolios, of videotape and of observations of classroom instruction (which were analysed according to a grid). In this last sub-chapter we intend to analyse how prospective science teachers teach NOS and use models in science classes and the factors that mediate the translation of their views into their teaching practice.

Chapter V is the final chapter in which the main conclusions drawn are outlined and future research topics within the subjects addressed along this text are briefly pointed out.

A list of the papers and proceedings that constitute the basis of the chapters I to IV included in this thesis is given below:

Torres, J., Moutinho, S. & Vasconcelos, C. **(2015)**. Nature of science, scientific and geoscience models: Examining students and teachers' views. *Journal of Turkish Science Education*, 12 (4), 3-21. DOI: 10.12973/tused.10148a. **(chapter II)**

Torres, J. & Vasconcelos, C. **(2015)**. Nature of science and models: Comparing Portuguese prospective teachers' views. *Eurasia Journal of Mathematics, Science & Technology Education*, 11 (6), 1473-1494. DOI: 10.12973/eurasia.2015.1407a. ISSN: 1305-8223. **(chapter II)**

Torres, J. & Vasconcelos, C. **(2014)**. Os modelos e a modelação na formação inicial de professores de Biologia e de Geologia. *Comunicações Geológicas*, 101, Especial III, 1391-1394. ISSN: 0873-948X. **(chapter II)**

Torres, J. & Vasconcelos, C. **(2016)**. Views of nature of science: Adaptation of a questionnaire for Portuguese prospective science teachers. *Journal of Science Education*, 17 (2), 48-52. ISSN: 01245481. **(chapter III)**

Torres, J. & Vasconcelos, C. **(2017)**. Desarrollo y validación de un instrumento para analizar las visiones de los profesores sobre modelos [Development and validation of an instrument for analysing teachers' views about models]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 4 (1), 181-198. **(chapter III)**

Torres, J. & Vasconcelos, C. **(2016)**. Models in Geoscience classes: How can teachers use them? In Vasconcelos, C. (Ed.). *Geoscience Education: Indoor and Outdoor*. p. 25-41. Springer: Switzerland. ISBN: 978-3-319-43318-9 (hardcover) ISBN: 978-3-319-43319-6 (ebook). **(chapter I, III, and IV)**

Torres, J. & Vasconcelos, C. **(accepted, to be published in 2016)**. Models in science and for teaching science: Data from an intervention programme. *International Journal of Learning and Teaching*. ISSN: 1986-4558. **(chapter IV)**

Torres, J. & Vasconcelos, C. **(major revisions)**. Prospective Science Teachers' views of nature of science: Data from an intervention programme. *International Journal of Science Education*. **(chapter IV)**

Torres, J. & Vasconcelos, C. **(submitted)**. Models and nature of science: What mediates its implementation in Portuguese science classes?. *Journal of Research in Science Teaching*. **(chapter IV)**

Proceedings:

Torres, J. & Vasconcelos, C. **(2014)**. Aplicação de um programa de intervenção em História da Ciência dirigido a estudantes do Mestrado em Ensino da Biologia e da Geologia. In C. R. Gomes, A. Rola & I. Abrantes (Eds.), E-book do colóquio II - História das Ciências para o Ensino – Atas do Colóquio II, 105-125. Coimbra: Universidade de Coimbra. Faculdade de Ciências e Tecnologia. Departamento de Ciências da Terra. ISBN: 978-989-98914-1-8. **(chapter I, III and IV)**

Torres, J. & Amador, F. **(2015)**. Os modelos da estrutura interna da Terra nos manuais escolares: Uma perspetiva histórica. In I. Malaquias, A. Andrade, V. Bonifácio, H. Malonek (orgs.) (2015), *Perspetivas sobre Construir Ciência*, UA Editora: Universidade de Aveiro. ISBN: 978-972-789-475-8. **(chapter II)**

Torres, J., Amador, F. & Vasconcelos, C. **(2016)**. Developing prospective science teachers' views of nature of science: The scientific models. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto & K. Hahl (Eds.), *Electronic Proceedings of the ESERA 2015 Conference. Science Education research: Engaging learners for a sustainable future, Part 6* (co-ed. M. Izquierdo & V. Vesterinen), (pp. 820-827). Helsinki, Finland: University of Helsinki. ISBN 978-951-51-1541-6 **(chapter I and IV)**

Torres, J., Moura, R. & Vasconcelos, C. **(2016)**. Is it that simple to implement models and nature of science in Geoscience classes? 16th International Multidisciplinary Scientific GeoConferences SGEM2016. Albena, Bulgaria. **(chapter IV)**

The papers and proceedings that were included in this thesis had the contribution of co-authors other than the author of this thesis. However, the author of this thesis is the first author of each paper and proceedings and had played the major role in the development of the research.

Nonetheless, the contributions of the co-authors were crucial for the development of the research:

Clara Vasconcelos (Faculty of Sciences of the University of Porto and Institute of Earth Sciences), was the main thesis supervisor and assisted and supported all work developed for this thesis.

Filomena Amador (Universidade Aberta) was the co-supervisor of this work and assisted the work which is more related to the history of science.

Rui Moura (Faculty of Sciences of the University of Porto and Institute of Earth Sciences) contributed as expert in Geosciences and in the dissemination of my work, namely in conferences.

Sara Moutinho (Faculty of Sciences of the University of Porto and Institute of Earth Sciences) mainly collaborated in data collection.

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CHAPTER II

General Description

II.1. Science students and teachers' views about nature of science and models

NATURE OF SCIENCE, SCIENTIFIC AND GEOSCIENCE MODELS: EXAMINING STUDENTS AND TEACHERS' VIEWS

Joana Torres, Sara Moutinho & Clara Vasconcelos

Journal of Turkish Science Education, 12 (4), 3-21.

II.1.1. Abstract

This study investigates Portuguese science teachers' and Portuguese high school students' views regarding nature of science, scientific models and Geoscience models and explores the relations between their views. It also examines how Portuguese science teachers value and use models in science classroom. A survey was applied to 145 science teachers and 415 students of the last year of secondary school, who answered to 14 multiple choice questions. Descriptive analyses showed that teachers and students hold intermediate views regarding nature of science and scientific models. Some errors were also detected concerning Geoscience models. T-test analyses showed significant differences between teachers and students' views, as teachers gave globally more informed answers. Authors considered that more attention should be given to teachers training regarding those issues and that more research is needed in order to understand how teachers deal with nature of science teaching and how they value and use models in classes.

Keywords: Nature of Science; Scientific Models; Geoscience Education; Science Teachers' Views; High School Students' Views.

II.1.2. Introduction

Scientific literacy has been recognized as a crucial learning outcome, in order to prepare students to take decisions and to act as informed citizens regarding scientific, personal and societal issues (Praia, Gil-Pérez, and Vilches 2007; Smith, Loughran, Berry, and Dimitrakopoulos 2012). Hodson (1998) argues that scientific literacy, as well as Science Education, must imply the learning *of* science - acquiring and developing conceptual and theoretical knowledge; the learning *to do* science – engaging in and developing expertise in scientific inquiry and problem-solving and the learning *about* science - developing an understanding of the nature and methods of science, appreciation of its history and development. In fact, many educational reforms highlight both the development of scientific literacy and of informed views of Nature of Science (NOS), being the last one a fundamental component of scientific literacy (Abd-El-Khalick 2006; McComas and Olson 1998). Indeed, Portuguese Science Education standard documents also emphasizes the importance of developing NOS understanding and of developing scientific literacy as a way to understand, reflect and act in our world.

In spite of all the relevance that NOS understanding has to scientific literacy and Science Education, many studies disclose that students possess inadequate views of NOS (Bell 2006; Bell, Blair, Crawford, and Lederman 2003; Lederman 1992; Praia et al. 2007). This can be due to inadequate references to NOS in science textbooks and in other curricular materials and also to the reliance on implicit approaches to NOS instruction (Bell 2006; McComas, Clough, and Almzroa, 1998). However, it is remarkable how teachers play an important role in students' educational experience (Matthews 1990; McComas et al., 1998), failing to emphasize NOS aspects to their students. Bearing this in mind, some studies reveal that teachers, although having an adequate understanding of NOS, normally do not give too much attention in the design and development of learning activities that prompt a suitable construction of their students' NOS views (Abd-El-Khalick, Bell, and Lederman 1998; Buaraphan 2012). In fact, as McComas et al. (1998) argued "... an understanding of the nature of science is a necessary, but insufficient condition, for purposeful teaching to facilitate student understanding of the nature of science" (p.20). Reis and Galvão (2004) suggest a diversity of factors that influence teachers' translation of their views about NOS and of their conceptions regarding the teaching and learning of science into their classroom practices, such as the curriculum, the national exams, their previous experiences with scientific activities and their own educational goals.

Scientific Models (SM) are considered to have an important role not only in scientific practice but also in Science Education, being a powerful tool for engaging

students in thinking about science (Halloun 2007; Justi and Gilbert 2002; Justi 2009; Oh and Oh 2011). Apart from promoting the development of adequate understandings of nature of models, as well as of NOS, in science classroom, models can facilitate the understanding of complex knowledge and phenomena, can foster the construction of adequate mental models and can engage students in inquiry activities. Thus, Portuguese Science Education standard documents also highlight the resort to models in science classes, especially in Geoscience classes. As Geoscience research heavily resorts to models and analogical thinking we consider essential the use of Geoscience models in Geoscience classes promoting science classes' activities that reflect scientists' activities.

Within this framework, we considered important to assess science teachers and K-12 students' views on NOS and SM and to analyse the relationship, if any, between their views. Moreover, we also wanted to examine how science teachers deal and use models in the classroom, as well as to evaluate students' and teachers' knowledge regarding some Geoscience models referred in the Portuguese curriculum.

II.1.3. Theoretical Background

II.1.3.1. Nature of Science and Science Education

Nature of Science (NOS) "is a fundamental domain for guiding science educators in accurately portraying science to students" (McComas et al. 1998, p.4). In fact, NOS describes how science works, what science is, how scientists operate and how science relates with society, merging aspects of history, sociology, philosophy and psychology of science (McComas et al. 1998).

Regardless all the debates regarding NOS concepts among philosophers, historians, sociologists of science and science educators, there is a general consensus of NOS concepts that are important and should be focused in science classes for the development of students' science views and scientific literacy (Abd-El-Khalick, et al. 1998; Abd-El-Khalick 2006; Bell 2006; McComas and Olson 1998). Abd-El-Khalick et al. (1998) have suggested some characteristics of the scientific enterprise that are suitable and accessible for K-12 students, relevant for their daily lives and not contentious (Abd-El-Khalick et al. 1998; Lederman, Abd-El-Khalick, Bell, and Schwartz 2002; Liu and Lederman 2007). These characteristics include the views that scientific knowledge is tentative (it changes as new evidences are found and as existing evidences are reinterpreted); empirically based (based on and/or derived from observations of the natural world that are filtered through our perceptions and instrumentations); subjective (theory-laden); partly the product of human inference, imagination and creativity and that

is socially and culturally embedded. The distinction between observation and inference, the inexistence of a general and universal scientific method and the functions of and relationships between theories and laws are other important aspects referred by the authors.

Understanding NOS is considered to be central for achieving scientific literacy and also for the improvement in science teaching and learning process. In fact, there are many reasons to include NOS in science curriculum. For example, McComas et al. (1998) argued that it helps students in learning science content and in understanding how science operates; it increases interest in science and enhances informed decision making and it could assist teachers in understanding students' views and in implementing effective educational actions. Matthews (1989/ 1990) stated that NOS also prompt the development of critical thinking and promote a greater awareness of the achievement of science and intellectual excitement that science involves. Moreover, the development of NOS understanding is also related to the development of argumentation skills and to the construction of stronger counterarguments (Khishfe 2012).

As McComas et al. (1998) argued teachers have the central role of providing an accurate description of the function, processes and limits of science, instead of engaging students in deep discussions that are characteristic of philosophers of science. Besides, each NOS aspect could be focused at different levels of complexity in science classes depending on students level (Lederman et al. 2002).

However, and despite all the benefits of developing NOS understandings in science classes, many studies reveal that students do not possess an adequate view of NOS (Bell 2006; Bell et al. 2003; Lederman 1992; Praia et al. 2007; Khishfe 2012).

II.1.3.2. Scientific Models and Science Education

Schwarz et al. (2009) defined a Scientific Model (SM) "as a representation that abstracts and simplifies a system by focusing on key features to explain and predict scientific phenomena" (p. 633). Despite all model definitions found in the literature and all the diversity of models, we must say that a model is a representation of a target, and it is considered a mediator connecting a theory and phenomenon (Giere 2004; Oh and Oh 2011). Models can also represent a variety of targets which are represented for some purpose (Giere 2004; Giere 2010; Oh and Oh 2011). In fact, a model does not copy reality; it consists of a representation of reality that varies with our purposes (Matthews 2007).

Models and modelling play a central role not only in scientific enterprise but also in Science Education (Halloun 2007; Justi and Gilbert 2002; Oh and Oh 2011), being the

understanding of models an important issue of one's understanding of science (Gobert et al. 2011). Models are powerful tools that scientists use in developing scientific knowledge. As a result, models and modelling activities in science classes may contribute to the understanding of many aspects of scientific inquiry and of different aspects of NOS, as they contribute to the understanding of the tentativeness of models; of the role that creativity plays in the construction of models and of the multiplicity of models, among others (Crawford and Cullin 2004).

In fact, models and modelling are essential to achieve the three main Science Education aims suggested by Hodson (1998). Models and modelling activities allow students to: (i) learn *of* science - as students come to know the major models that are the products of science; (ii) learn how *to do* science - by creating and testing their own models and (iii) learn *about* science - by constructing an adequate view of the nature of models and by being able to appreciate the role of models in the accreditation and dissemination of the products of scientific enquiry (Justi and Gilbert 2002; Justi and Gilbert 2003).

Although all the reported positive effects of model-based approaches, it is crucial that teachers clearly understand the value and nature of models and modelling for the purpose of using models in science classrooms in an effective way (Oh and Oh 2011). Based on a literature review, Oh and Oh (2011) identified five relevant subtopics that teachers of science must know concerning the nature of models and modelling: *meaning of a model, purposes of modelling, multiplicity of scientific models, change in scientific models and uses of models in the science classroom*. Concerning the last subtopic, these authors also emphasize the need for students to participate in student-centred modelling activities, in order to make their learning more meaningful.

However, some studies unveil that teachers reveal limited and naïve views about models in science and for teaching and that they do not usually rely on models and modelling activities in their classes (Crawford and Cullin 2004; Justi and Gilbert 2002; Khan 2011; Wang et al. 2014). Therefore, in our study, we aimed to analyse both Portuguese science teachers and high school students' views regarding some NOS aspects, emphasizing the aspects related to models nature. Giving the relevance of teachers in students NOS understandings, we also wanted to compare science teachers and high school students' views regarding those aspects.

II.1.3.3. Geoscience Models and Science Education

Although SM are undoubtedly important in Science Education, we must say that they play an even greater role in Geoscience Education, as this scientific area heavily

depends on a diversity of models (Oh and Oh 2011). In fact, geoscientists resort to comparisons and SM as they deal with processes and forces that cannot be directly perceived (Jee et al. 2010). In this way, Portuguese Geoscience Curriculum highlights the use of models in Geoscience classes and it suggests a diversity of Geoscience models, such as the earth's internal structure model and the solar system model (Torres, Moura, Vasconcelos, and Amador 2013a).

The use of models, especially the simulation of geological phenomena, contributes to the development of different competencies which are fundamental in Geoscience learning and thinking, as it contributes to a better understanding of deep time, as well as to the development of spatial vision (Bolacha, Moita de Deus, and Fonseca 2012). Additionally, the analysis of the historical evolution of scientific models is crucial for students to understand science construction and evolution; constraints, contexts and issues that limit, influence or promote scientific knowledge development and the importance of different data in models design. Moreover, models can be really useful for teachers in classroom to demonstrate how things work and to explain sophisticated knowledge (Oh and Oh 2011). However, the use of models in classroom should overtake the traditional way that only emphasis the learning of science (Torres, Moutinho, Almeida, and Vasconcelos 2013b).

Considering that teachers are those who determine a considerable part of students' educational experience, it is important that they have a clear and valid notion of models and their nature in order to use models effectively in science classes (Oh and Oh 2011; Torres et al. 2013a).

II.1.4. Research Purpose

The main purpose of this study was to examine Portuguese science teachers and Portuguese high school students' views on nature of science and scientific models and to explore the relationship, if any, between their views.

Additionally, we intended to analyse how Portuguese science teachers value and use models in science classroom. Moreover, due to the relevance that Geoscience models have in Geoscience research and education, we also aimed to evaluate and compare Portuguese science teachers and Portuguese high school students' knowledge regarding some Geoscience models recommended in Portuguese curriculum.

Consequently, our main research questions were:

- (i) *What are the Portuguese Science Teachers and Portuguese High School Students' views on Nature of Science and Scientific Models? Are their views related?*

- (ii) *How do Portuguese Science Teachers value and use models in science classroom?*
- (iii) *How well do Portuguese Science Teachers' and Portuguese High School Students' know Geoscience Models? Is their knowledge related?*

II.1.5. Methods

This research is included in a broader study that mainly aims to improve teachers' views regarding Nature of Science (NOS) and Scientific Models (SM) and consequently students' views and learning.

In this first stage of the research, which mainly intends to evaluate Portuguese science teachers and Portuguese high school students' views of NOS and SM, a survey research was performed. With this purpose, a questionnaire was constructed and administered both to high school students of the last year of high school and to middle and high school science teachers (teachers that teach students with ages ranging from 10 to 17) from different schools of Portugal. A descriptive and statistical analysis was developed after data collection.

The paper questionnaire was applied to high school students in classes either by their teachers or by one member of the research team. This instrument was also administrated to teachers, on paper or by digital support. When using the digital one, we also asked teachers to collaborate with us and to request their colleagues to participate in the study.

II.1.5.1. Sample

Table II.1.1. Students characterization (n=415).

Gender		Age		Failed in school	Main future courses desired	
Female	Male				Course	%
f (%)	f (%)	Mean	SD	f (%)		
239	176	17.27	0.55	55 (13.3)	Medicine	31.2
(57.6)	(42.4)				Psychology	17.6
					Do not know	15.6
					Primary Teaching	11.8

Legend: f- frequency; % - percentage.

In this study, participants comprised two groups. Four hundred and fifteen high school students, with ages ranging from 16 to 19 (Table II.1.1), and one hundred and forty five science teachers, with ages ranging from 23 to 63 (Table II.1.2), from different regions of Portugal answered the questionnaire.

Table II.1.2. Teachers characterization (n=145).

Gender		Age		Qualifications		
Female	Male					
f (%)	f (%)	Mean	SD	f	%	
125 (87.4)	18 (12.6)	43.71	9.1	BSc	94	64.8
				MSc	38	26.2
				PhD	1	0.7
				BSc + other qualification	10	6.9
				MSc + other qualification	2	1.4

Legend: f- frequency; % - percentage.

II.1.5.2. Instrument

The questionnaire focused mainly on science teachers and high school students' views on NOS, SM and Geoscience models and was designed by two authors of the research team after a deep study and analysis of relevant literature and research. It only focused in some aspects concerning NOS understanding, as we wanted to achieve a general overview regarding both science teachers and high school students' views. We also wanted to essentially analyse their views regarding NOS, emphasizing their views related to scientific models (epistemological views and content knowledge about Geoscience models).

Table II.1.3. Topics under analysis regarding NOS and SM issues.

Issue	Topic under analysis	Authors of reference
NOS	Tentativeness of scientific knowledge	Lederman et al. (2002); Liu & Lederman (2007).
	Creativity and imagination in science	Lederman et al. (2002); Liu & Lederman (2007).
	Scientific theories and laws	McComas (1998); Lederman et al. (2002); Liu & Lederman (2007).
SM	Theories, phenomena and models	Oh & Oh (2011).
	Scientific models nature	Abd-El-Khalick et al. (1998); Oh & Oh (2011).
	Definition of scientific model	Danusso et al. (2010).
	Scientific models in science classes	Justi & Gilbert (2002).

The questionnaire had some initial questions in order to gather personal socio-demographic data of the respondents and the main questionnaire comprised 11 closed questions and 3 semi-open questions.

The first part of the questionnaire comprised 7 closed questions that were elaborated based on recent literature regarding NOS and SM. The questions refer to 3 different topics regarding NOS and to 4 topics about SM (Table II.1.3).

The general format of each of these questions comes from the Views on Science-Technology-Society (VOSTS) questionnaire structure, developed by Aikenhead and Ryan (1992) (VOSTS questionnaire is available on: <http://www.pearweb.org/atis/tools/15>).

Regarding each topic presented, teachers and students were asked to choose only one of seven options that best match their opinion. The seven options provided included: (i) four statements that reveal different points of view concerning each topic and that were derived from major results obtained in other previous studies and (ii) three neutral statements that represent other possible responses: 'I have difficulties in understanding the above sentences'; 'I do not have enough knowledge to make a choice' and 'None of the options reflects my point of view'.

We tried to diminish some ambiguity problems, using choices that derived from results of other studies. Also, the three neutral options may avoid the selection of a random answer that could distort students and teachers' opinions and consequently the results and may also contribute to a better and a deeper understanding of the results.

The following 3 semi-open questions, which comprised the second part of the questionnaire, were mainly related to the use of models in science classes. High school students and science teachers were asked about the way models and simulations are used in science classrooms and teachers were requested to justify their decisions, by writing their own reasons.

After a review of the literature, the first two parts of the questionnaire were content validated by two Science Education experts. It suffered some adjustments in order to make each option simpler and more concise. To better validate the questionnaire, the first two parts of the questionnaire were initially administered to a preliminary sample (Torres et al. 2013b). However, no difficulties were detected during the fulfilment of the questionnaire. Moreover, concerning the first seven questions almost all respondents chose one of the main four options provided. Only an average of 7.9% selected one of the 3 other neutral options. This means that the main options provided were understood and that they generally fitted the views of the majority of respondents that answered the questionnaire.

The last four closed questions intended to evaluate high school students and science teachers' knowledge regarding four Geoscience SM recommended in national curriculum. In these last four questions, teachers and students were asked to choose one option from the five provided. The five options provided included: (i) 1 correct

answer; (ii) 3 wrong answers and (iii) 1 neutral (I do not know) answer. This third part of the questionnaire was content validated with the support of both, literature revision and two Science Education experts.

Having in mind that the students who participated in the study were already attending the last year of the secondary school and the aim of comparing teachers and students views, the questions of the questionnaires administered were the same (except for questions related to the use of models in science classes, as we can see in tables II.1.7 and II.1.8).

II.1.6. Data Analysis

II.1.6.1. Nature of Science and Nature of Models

To analyse science teachers and high school students' answers regarding NOS and SM, a preliminary descriptive statistic was made using SPSS 21 version. For each question, science teachers and high school students were asked to choose one option of 7 possible answers that best match their opinion. These 7 possible answers were classified into different categories: "uninformed", "informed", "naïve" and "neutral", as presented in table II.1.4 and II.1.5. Informed answers correspond to answers which were closer to contemporary views and uninformed answers to answers that do not match and that deviate the most from those views. Naïve answers were those that do not completely match those views. For each question, there are one informed, one uninformed, 2 naïve and 3 neutral possibilities.

After this descriptive analysis it was performed a t-test to compare the results obtained by science teachers with the ones obtained by high school students. For this purpose, answers were scored from -1 to 2, according to the correspondent category. To "uninformed" answers it was attributed the worst score (-1) and to "informed" answers it was attributed the best score (2). "Naïve" answers were scored with 1 point and the "neutral" responses were scored with 0 points. After this score process, a t-test was performed.

II.1.6.2. Scientific Models in Science Classes

Concerning the use and valorization of models in science classes, a content analysis had to be previously made to science teachers justifications that support their choice regarding the use of models in science classrooms. This content analysis which involved the definition of different categories and codes was performed by two researches

separately. Afterward, categories and codes attributed to each answer were compared and discussed in order to guarantee a homogeneous and reliable codification of data. After that, a descriptive statistical analysis was also undertaken concerning science teachers and high school students' answers, by presenting the percentage of the selected answers and of the main justifications provided.

II.1.6.3. Geoscience Models

To evaluate science teachers and high school students' knowledge regarding Geoscience SM, 4 different SM that students learn through their school training were chosen and a descriptive study was undertaken. Science teachers and high school students' answers were classified into "wrong", "correct" and "neutral" categories. Correct answers were valued with 1 point, wrong answers with -1 point and neutral answers (I do not know) with 0 points. Afterward, a t-test was performed in order to compare the results obtained by science teachers and by high school students regarding Geoscience models.

II.1.7. Results

II.1.7.1. Nature of Science and Nature of Models

The answers given to the 7 closed questions regarding nature of science and models nature are presented in the tables II.1.4 and II.1.5.

As shown in table II.1.4, science teachers and the majority of high school students do not considered scientific knowledge absolute. However, the bulk of both science teachers and high school students held a naïve view concerning its tentative aspect.

On the subject of creativity and imagination, the majority of respondents considered that they are needed in the development of scientific knowledge. Still, a considerable percentage of them considered that creativity and imagination are only needed in some stages of the research. Concerning theories and laws definition, the majority of science teachers and high school students held naïve or even uninformed views about it.

In general terms, it is possible to verify that both science teachers and high school students held intermediate views regarding NOS.

Regarding the relation between theories, phenomena and models, 79,3% of science teachers recognized that a model is a representation of phenomena and serves as a 'bridge' connecting a theory and a phenomenon. On the other hand, a high

percentage of high school students (45,6%) held an uninformed view about this issue, mixing up models with theories (Table II.1.5).

Table II.1.4. Category and rate of responses regarding NOS aspects.

Question and answer options	Category of answer	%	
		STs	HSSs
Q1 – Regarding scientific knowledge, you consider that ...			
Scientific knowledge is absolute and correct, being a proven truth.	Uninformed	0	3.9
Scientific knowledge, although reliable, is tentative and never certain.	Informed	31	39.8
Scientific knowledge change solely with new information and advanced technology.	Naïve	55.9	50.8
Scientific knowledge is tentative due to insufficient evidence for proving their validity.	Naïve	5.5	3.1
I have difficulties in understanding the above sentences.	Neutral	0	0
I do not have enough knowledge to make a choice.		0	0.5
None of the options reflects my point of view.		7.6	1.9
Q2 – Relating to creativity and imagination, you think that...			
They are not necessary in the construction of scientific knowledge.	Uninformed	1.4	5.8
Only make sense in planning and design stage.	Naïve	6.2	15.2
They are needed in the development of scientific knowledge.	Informed	67.6	50.4
They are needed during all the research except in the data collection stage.	Naïve	24.8	22.9
I have difficulties in understanding the above sentences.	Neutral	0	1.0
I do not have enough knowledge to make a choice.		0	1.0
None of the options reflects my point of view.		0	3.9
Q3 – Regarding theories and laws, you consider that...			
Theories and laws are different kinds of knowledge and one cannot become the other.	Informed	7.6	6.3
Theories evolve to laws with the evidence accumulation.	Naïve	37.9	39.2
Laws reflect a proven knowledge and so they are more certain than theories.	Naïve	9.0	28.1
Laws are the explanations of phenomena and theories constitute descriptions of patterns related to observational phenomena.	Uninformed	35.9	22.0
I have difficulties in understanding the above sentences.	No answer	1.4	1.0
I do not have enough knowledge to make a choice.		2.1	1.9
None of the options reflects my point of view.		6.2	1.5

Legend: %- percentage; STs– Science Teachers; HSSs- High School Students.

Table II.1.5. Category and rate of responses regarding Scientific Models.

Question and answer options	Category of answer	%	
		STs	HSSs
Q4 – Concerning the relation between theories, phenomena, and models, you believe that...			
A model is a representation of phenomena or processes and serves as a 'bridge' connecting a theory and a phenomenon.	Informed	79.3	40.0
A model is a fundamental theory to understand a phenomenon and to formulate future theories.	Uninformed	11.7	45.6
A phenomenon can be represented only by a unique model.	Naïve	0.7	1.7
A model represents all the aspects of a phenomenon.	Naïve	1.4	3.4
I have difficulties in understanding the above sentences.	Neutral	1.4	3.4
I do not have enough knowledge to make a choice.		3.4	3.2
None of the options reflects my point of view.		2.1	2.7
Q5 – Relating to models, you think that...			
Scientific models are a copy of reality.	Uninformed	5.6	13.6
Scientific models are immutable.	Naïve	1.4	2.7
Scientific models result from inference.	Informed	67.1	53.5
Models created by scientists are all proven.	Naïve	3.5	10.4
I have difficulties in understanding the above sentences.	Neutral	1.4	2.7
I do not have enough knowledge to make a choice.		0	4.6
None of the options reflects my point of view.		21.0	12.6
Q6 – Do you consider a scientific model as...			
A reference to which a phenomenon has to be compared to help understanding it scientifically.	Uninformed	12.1	21.7
An abstract representation which reproduces the behaviour of a phenomenon using suitable parameters.	Informed	29.3	22.4
The set of rules and schemes which identify a given phenomenon and allow understanding it.	Naïve	37.9	37.8
An abstract tool to analyse reality designed from the observation of that reality.	Naïve	14.3	10.7
I have difficulties in understanding the above sentences.	Neutral	0.7	2.7
I do not have enough knowledge to make a choice.		2.9	2.7
None of the options reflects my point of view.		2.9	2.0
Q7 – The use of models in the classroom...			
Only contributes to the understanding of complex natural phenomena.	Naïve	7.6	23.2
Contributes to a better learning of science, about science and to do science.	Informed	88.2	67.9
Requires more traditional teaching methodologies.	Naïve	2.8	3.4
Does not contribute to the understanding of the Nature of Science.	Uninformed	0	0.5
I have difficulties in understanding the above sentences.	Neutral	0	0.7
I do not have enough knowledge to make a choice.		0	1.7
None of the options reflects my point of view.		1.4	2.7

Legend: %- percentage; STs– Science Teachers; HSSs- High School Students.

The bulk of respondents considered that scientific models result from inference. However, still 13,6% of high school students considered that scientific models are a copy of reality.

Science teachers as well as high school students did not possess a consistent definition of SM, as only 29,3% of science teachers and 22,4% of high school students answered in an informed way to question number 6. Although the majority of science teachers and high school students recognized that the use of models in science classes contributes to a better learning *of* science, *about* science and *to do* science, 23,2% of high school students considered that the use of models only contributes to the understanding of complex natural phenomena.

Globally, it is possible to verify that both science teachers and high school students possess intermediate views regarding SM. However, it also seems that science teachers hold better views on this issue than students.

Table II.1.6. Means obtained and T-test analysis (Q1-Q7).

Group	Mean	Std. Deviation	t-statistic	
			t	p-value
HSSs (n=415)	6.98	2.698	-7.865	0.000**
STs (n=145)	8.76	2.215		

Legend: HSSs – High School Students; STs – Science Teachers; p- p value (x** - p < 0,01).

When comparing students and teachers informed answers regarding NOS and SM, it is possible to verify that teachers globally gave more informed answers, except for question 1. We may also suppose that questions with better results for teachers are also for students and that questions with worst results for teachers are also for students, excluding question number 4.

However, when comparing the answers given by teachers with the answers given by students to these 7 questions, it was verified that teachers had better results and obtained a higher mean (Table II.1.6). When applying a t-test, it was verified that there is a statistically significant difference between the two means obtained both by teachers and students (Table II.1.6).

II.1.7.2. Scientific Models in science classes

Regarding the use of models in science classes, the majority of science teachers and high school students reveal that both models and analogue models (considered in this

paper as simulations), are used from time to time in science classes (Table II.1.7 and II.1.8).

Table II.1.7. STs answers concerning the use of models in science classes.

Question	Answer Options	Mains Justifications Presented		
How often do you use scientific models in Science Classes?	Never	3.5	It is not suitable for students' level.	100
	Sometimes	96.5	It helps in the understanding of phenomena and processes.	52.6
			Its use is content dependent.	13.7
			Its use allows an approach to reality.	7.4
How often do you use analogue models (simulations) in Science Classes?	Never	6.3	It is not suitable for students' level.	60.0
			Due to students' age.	20.0
			Lack of material.	20.0
	Sometimes	93.8	It leads to a better understanding of the evolution of natural phenomena.	37.2
			Allow us to observe phenomena that are impossible to observe naturally due to spatial and temporal constraints.	7.0
			Its use is content dependent.	7.0
In science classes, how do you mostly use models?	You present the models that you have.	9.6	Conditioned by time.	7.6
			Conditioned by students' age.	3.0
	You suggest students to construct their own models.	4.2	Students learn more.	0.0
			Students test the model while presenting it.	5.0
			It helps in phenomena understanding.	5.0
	Both options.	6.2	Limited by time.	9.0
			It implies an autonomous process of knowledge construction.	9.0
			To facilitate the understanding of certain phenomena.	5.5

Legend: %- percentage; STs–Science Teachers.

As shown in table II.1.7, science teachers use models and simulations as they mainly help in the understanding of phenomena and processes and they lead to a better understanding of the evolution of natural phenomena, respectively. Teachers that never use models in science classes are mainly (80%) teachers of youngest students (students' age ranging from 10 to 12) and the bulk of teachers (77,8%) that never use simulations are also teachers of students of this age group.

It is possible to verify that science teachers and high school students present different answers concerning the way that models are used in science classes. In fact,

the majority of high school students referred that teachers present their own models; while science teachers indicated that they present their own models and that they also suggest students to construct models (Table II.1.7 and II.1.8).

Table II.1.8. HSSs answers concerning the use of models in science classes.

Question	Answer Options	%
How often scientific models were used in Science Classes?	Never	5.6
	Sometimes	94.4
How often analogue models (simulations) were used in Science Classes?	Never	18.9
	Sometimes	81.1
In science classes, how models were used mostly?	Teachers present their models to students.	58.7
	Teachers suggest students to construct their own models.	6.4
	Both options.	34.9

Legend: %- percentage; HSSs- High School Students.

II.1.7.3. Geoscience Models

The answers related to Geoscience models are presented in tables II.1.9 to table II.1.12.

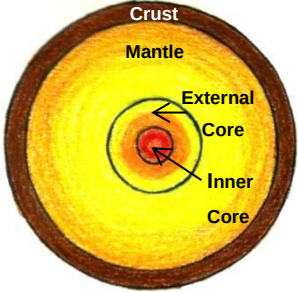
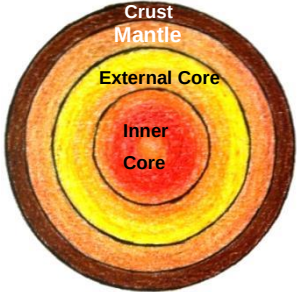
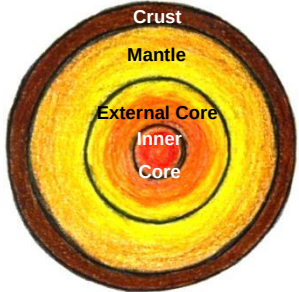
In relation to Earth's internal structure model, specifically to layers depth, the majority of science teachers (64%) answered correctly, while the majority of high school students (60,2%) answered incorrectly to this question (Table II.1.9).

Concerning Solar System models, it is possible to verify that the majority of both science teachers and high school students answered correctly to this question. However, science teachers presented a higher rate of correct answers, when comparing with high school students correct answers (Table II.1.10).

Regarding tectonic plates model it is also possible to verify that the bulk of science teachers and high school students answered correctly to this question. Furthermore, science teachers also presented a higher rate of correct answers (83,6%), when comparing with high school students correct answers (68%) - Table II.1.11.

Table II.1.9. STs and HSSs answers regarding Earth's structure model – Layers depth.

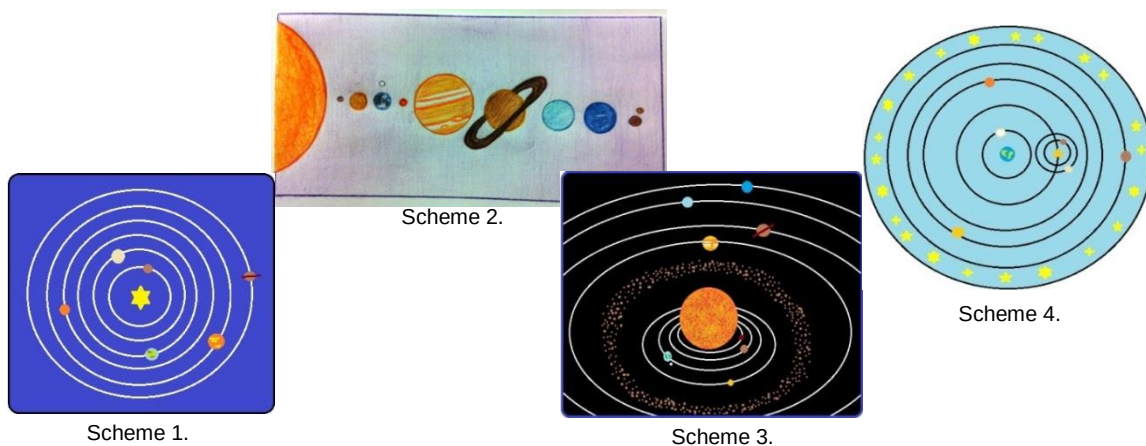
Evaluation Issue		Earth's internal structure model (Layers depth)		
Question		What is the scheme that represents the best the earth's interior?		

		Category of answer	%	
			STs	HSSs
Answers	Scheme 1	Wrong	7.9	44.0
	Scheme 2	Wrong	2.9	11.4
	Scheme 3	Correct	64.0	35.7
	No one is correct.	Wrong	16.5	4.8
	I do not know.	Neutral	8.6	4.1

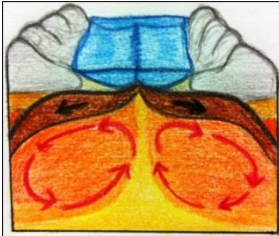
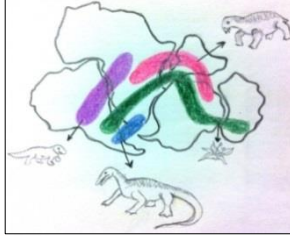
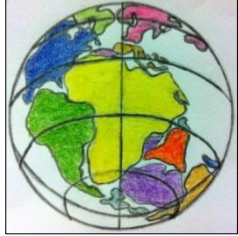
Table II.1.10. STs and HSSs answers regarding Solar System Model.

Evaluation Issue		Solar System Model	
Question		Sort the schemes in chronological order, according to the historical evolution of the different solar system models.	



		Category of answer	%	
			STs	HSSs
Answers	1 → 2 → 3 → 4	Wrong	0	1.2
	4 → 1 → 3 → 2	Wrong	23.7	17.6
	1 → 4 → 2 → 3	Wrong	4.3	16.4
	4 → 1 → 2 → 3	Correct	66.9	59.2
	I do not know.	Neutral	5.0	5.6

Table II.1.11. STs and HSSs answers regarding Tectonic Plates Model.

Evaluation Issue		Model of Tectonic Plates		
Question		Identify the arguments in favor of Continental Drift Model and the arguments in favor of Tectonic Plates Model.		
				
Scheme 1.		Scheme 2.		
		Scheme 3.		
				
Scheme 4.		Scheme 5.		
Answers		Category of answer	%	
			STs	HSSs
	Schemes 1 and 4 represent the arguments in favor of the model of tectonic plates and schemes 2, 3 and 5 represent the arguments in favor of continental drift model.	Correct	83.6	68.0
	Schemes 1 and 4 represent the arguments in favor of continental drift model and schemes 2, 3 and 5 represent the arguments in favor of the model of tectonic plates.	Wrong	2.9	8.6
	All schemes represent the arguments in favor of continental drift model.	Wrong	0	7.8
	All schemes represent the arguments in favor of the model of tectonic plates.	Wrong	4.3	7.1
I do not know.	Neutral	9.3	8.6	

On the subject of Mountain Chain Formation models, the majority of science teachers and high school students failed to recognize that convection does not have a direct relation with mountain formation. The bulk of science teachers and high school students considered that scheme 2, which was indeed a model presented in the 19th century for representing this process, was the scheme that does not represent a model of mountain chain formation (Table II.1.12).

Table II.1.12. STs and HSSs answers regarding Mountain Chain Formation Models.

Evaluation Issue		Mountain Chain Formation Models		
Question		Identify the scheme that does not represent a model of mountain chain formation.		



Scheme 1.



Scheme 2.



Scheme 3.



Scheme 4.

		Category of	%	
		answer	STs	HSSs
Answers	Scheme 1.	Wrong	9.4	2.0
	Scheme 2.	Wrong	69.8	77.8
	Scheme 3.	Correct	7.2	8.0
	Scheme 4.	Wrong	7.9	7.8
	I do not know.	Neutral	5.8	4.4

When comparing science teachers and high school students' answers, it seems that science teachers have a better knowledge and consequently more correct answers concerning Geoscience models. It was verified that science teachers obtained better results and that there is a statistically significant difference between the two means obtained by science teachers and high school students, when applying a t-test (Table II.1.13).

Table II.1.13. Means obtained and T-test analysis (Q11-Q14).

Group	Mean	Std. Deviation	t-statistic	
			t	p-value
HSSs (n=415)	-0.35	1.692	-7.233	0.000**
STs (n=145)	0.70	1.430		

Legend: HSSs –High School Students; STs – Science Teachers; p- p value (x** - p < 0,01).

II.1.8. Discussion

NOS, SM and Geoscience models are fundamental issues in science classes, as well as in Geoscience classes. According to its relevance, this study investigated science

teachers and high school students' views about those aspects and a possible relation between their views.

Regarding nature of science and nature of models aspects, science teachers had better results than high school students which may be related to the lack of relevance and attention that teachers provide to this aspects in classes, as argued by Abd-El-Khalick et al. (1998) and McComas et al. (1998). However, it is also important to notice that although science teachers reveal a better understanding about those aspects, the majority of science teachers still present naïve views on the subject of the tentativeness of scientific knowledge and of the relation between theories and laws. These results are similar to those obtained by Liu and Lederman (2007). Moreover, science teachers did not possess a consistent definition of scientific models as it is suggested in the literature regarding teachers' views on models (Justi and Gilbert 2002/2003; Justi 2009). In order to better teach NOS aspects and to better use models in science classrooms, the researchers consider that it is of utmost importance to improve science teachers' views regarding those aspects.

In fact, although the majority of science teachers recognized that the use of models in science classes contributes to a better learning *of science*, *about science* and *to do science* in question number 7, only 1 teacher (teacher number 32) mention that reason to justify the use of models in subsequent questions. He justifies the use of models referring: "For the same reason that I have mentioned in question number 7 (It contributes to a better learning *of science*, *about science* and *to do science*)" and he justifies the use of simulations stating: "the use of simulations in science classes contributes to a better learning *of science*, *about science* and *to do science*, since the adaptations and limitations of simulations are clear for students". Indeed, the majority of science teachers revealed in their justifications that they use models mainly to facilitate the understanding of phenomena and processes and simulations to promote a better understanding of the evolution of natural phenomena, which reflects their emphasis on the value of models in the learning *of science* over their value in the learning *to do science* and *about science*. These results are aligned with Crawford and Cullin (2004) findings, as no intentions to teach *about models* were revealed. In the same way, a substantial percentage of high school students (23,2%) considered that the use of models only contributes to the understanding of complex natural phenomena (question number 7). Bearing this in mind, it is important that science teachers develop their understanding regarding models in order to take full advantage of using them in science classrooms.

Although the majority of high school students have agreed with the majority of science teachers, revealing that models and simulations are used from time to time in

science classes, they disagreed with science teachers when referring to the way models are used in classes. In fact, students' answers lead us to suppose that science teachers do not give students as much autonomy as they presume, as the majority of high school students refer that teachers mainly show them the models, while the majority of science teachers mention that they not only present the models, but also suggest students to construct their own models. Science teachers recognized that students' construction of models stimulates a better learning and an autonomous process of knowledge construction and it also facilitates the understanding of certain phenomena. However, they also assumed that they are conditioned by time and students' age. As it is intended to mirror scientists' activities in science classrooms, it is imperative that teachers provide students activities where they have an active role. Practical activities like, for example, modelling promotes their development of scientific content as well as epistemological knowledge and inquiry competencies.

Concerning Geoscience models, science teachers had more correct answers than high school students, being the difference between science teachers' answers and high school students' answers statically significant. However, the majority of both participants failed in recognizing historical mountain chain formation models, which may indicate a certain lack of knowledge regarding historical issues. A greater reliance on historical models may contribute to a deeper understanding of science dynamics and also to the understanding of different NOS aspects.

II.1.9. Conclusions and Educational Implications

NOS and SM are considered key elements in Science Education, not only in national but also in international curricula. Nevertheless, some studies reveal that students do not generally develop an adequate view regarding these issues. This may be related to many factors such as educational resources; teachers' aims; and teachers' views concerning these issues.

In view of this, the aim of this study was to analyze and to compare Portuguese science teachers' and Portuguese students' views of NOS and SM. Results show that although both participants hold intermediate views regarding NOS and SM, science teachers showed a better conceptual knowledge. However, questions where science teachers failed the most are also the questions where high school students had worst results. Both participants failed mainly in questions related to scientific theories and laws, to SM definition and to historical mountain chain formation models.

Regarding the use of SM in science classes, there are two very interesting findings. First of all, SM are used in science classes mostly as an auxiliary resource to the

understanding of phenomena or scientific processes. Secondly, it seems that students do not have such an active role as it was supposed when modelling.

These results have some implications for the teaching and learning of NOS and for the use of SM in science classes. In fact, there is a need to improve Portuguese science teachers' view regarding NOS so as to become more consistent with contemporary NOS views. Moreover, it is also important that Portuguese science teachers become more aware of the benefits and importance of teaching NOS in science classes. Portuguese science teachers also need to develop their understandings about SM and about their full potential in order to use them effectively. Due to modelling activities importance in Geoscience research, this issue has a more relevant meaning in geoscience teachers' training. As such, authors considered that it will be important to improve science teachers views concerning NOS and SM either in their initial training or in their continuous training. Additionally, more research is also needed in order to understand how teachers deal with NOS and SM in classes and to understand which factors restrain and mediate their practices.

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II.2. Prospective science teachers' views about nature of science and models

NATURE OF SCIENCE AND MODELS: COMPARING PORTUGUESE PROSPECTIVE TEACHERS' VIEWS

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II.2.1. Abstract

Despite the relevance of nature of science and scientific models in science education, studies reveal that students do not possess adequate views regarding these topics. Bearing in mind that both teachers' views and knowledge strongly influence students' educational experiences, the main scope of this study was to evaluate Portuguese prospective teachers' views of nature of science, models and earth's structure models and to analyse if their views differ (by comparing prospective primary teachers' with prospective middle and secondary school teachers' views). A questionnaire was applied to 65 prospective science teachers who were enrolled in different Portuguese institutions of higher education. Descriptive analysis showed that although the majority of the participants revealed intermediate views of nature of science, a high percentage of them hold uninformed views regarding the other topics of analysis. Some differences between prospective middle and secondary teachers' views and prospective primary teachers' views were also found.

Key Words: Geoscience Education; History of science; Nature of Science; Prospective Teachers' Views; Scientific Models.

II.2.2. Introduction

Scientific models are considered to be crucial not only in scientific practice, but also in science education (Halloun, 2007). In fact, models and modelling play a central role in making and understanding science (Danusso, Testa & Vicentini, 2010), making science learning more meaningful and favouring the construction of appropriate mental models (Oh & Oh, 2011). Moreover, according to Justi and Gilbert (2002, 2003) models and modelling allow students to: (i) learn of science, as students may learn significant scientific and historical models; (ii) learn to do science, as students may create and evaluate their own models and (iii) learn about science, since students may develop an adequate view of the nature of models, as well as of the nature of science, and be able to appreciate the role of models in the accreditation and dissemination of the products of scientific enquiry. In fact, understanding scientific models becomes a crucial element of understanding how science works (Schwartz & Lederman 2005).

Nature of Science (NOS) describes what science is, how it works, how scientists operate and how society influences and is influenced by the scientific enterprise, merging aspects of history, sociology, philosophy of science and psychology (McComas, Clough & Almzroa, 1998). Despite all the controversies concerning the definition of NOS, there is a general agreement of important components of NOS that should be focused in science classes because they play a fundamental role in scientific literacy development (Khishfe & Lederman, 2006).

State of the literature

- The development of adequate views of nature of science is considered to be fundamental for students to understand the potential and limits of science, while contributing to scientific literacy development;
- Modelling is considered of utmost importance in Science Education, as it helps students to construct and develop consistent mental models. Also, it supports students understanding of scientific models role in science. In Geoscience Education, modelling activities have an even greater relevance, as Geosciences research heavily resort to models;
- It is still revealed that students do not hold adequate views of scientific models, science and its nature.

Contribution of this paper to the literature

- Given the relevance and students lack of knowledge regarding nature of science and scientific models, we intended to examine prospective teachers' views of these topics;
- This study compares prospective teachers' views of different educational levels;
- It also correlates prospective teachers' views of nature of science and models with their knowledge regarding an important Geoscientific model – the Earth's structure model.

Despite all the relevance attributed to models and NOS, some studies reveal that students do not develop adequate views of these topics (Bell, Blair, Crawford & Lederman, 2003; Park, 2013; Schwartz & Lederman, 2005). For example, Reis and Galvão (2007) concluded that Portuguese secondary students reveal some lack of knowledge with regard to the nature of science. Even Portuguese university students do not hold adequate views of NOS, as it was shown by Afonso and Gilbert (2010). Figueiredo and Paixão (2010), in a study conducted with university students from two Portuguese cities, also revealed that these students do not possess the more adequate views regarding NOS, revealing that no substantiated differences were found between science students and humanities students and between students in the beginning and in the end of scientific courses. Authors also argue that even teachers do not reveal consistent views of NOS (Bennàssar, GarcíaCarmona, Vázquez & Manassero, 2010b; Dogan & Abd-El-Khalick, 2008), models and their use in science classes (Khan, 2011). As suggested by Duarte (2004), Portuguese science teachers convey inadequate descriptions of science in their classes. However, as scarce studies were performed, more studies are needed concerning nature of science and models in Portuguese science education. Bearing in mind that teachers strongly influence students' experience, we consider essential to assess prospective science teachers views of NOS and scientific models.

II.2.3. Purpose of the study

The use of scientific models, modelling activities and the development of correct views of NOS are considered to be crucial issues in science education. In fact, the Portuguese Science Curriculum emphasizes the need of providing science students with an accurate image of science and it recommends the use of models in science classes, especially in Geosciences classes. However, curriculum innovations and recommendations do not necessarily mean that teachers are provided with the necessary tools and pedagogical training regarding those topics. Indeed, little is known about science teachers' and prospective science teachers' views of NOS and scientific models, as well as the variables that influence their views. Consequently, as teachers' views strongly influence students' educational experiences and knowledge construction, our main research questions were:

- i. What are the Portuguese prospective Science Teachers' (PPSTs) views of NOS and Scientific Models?
- ii. How do PPSTs perform on a knowledge test on Earth's structure models?

- iii. What are the correlations between PPSTs' views of NOS, scientific models and Earth's structure models, and PPSTs' views of NOS, scientific models and Earth's structure models in different institutions of higher education?

For this purpose, we constructed a questionnaire with 22 closed questions related to PPSTs' views of NOS; models and Earth's structure models. We decided to analyse Earth's structure models knowledge, as geological models are very important in science and geoscience education, but also since this specific model is extensively suggested in the Portuguese compulsory science curriculum. This model is also crucial to basic geoscience knowledge and its historical development is so rich that it is of utmost importance to teach NOS aspects. However, not much is known regarding teachers' Earth's structure models knowledge and how this model is used in science classes. Although some allusions to its historical development are found in science textbooks, we consider that the full advantages of them are not taken in order to discuss NOS aspects. Considering that PPSTs' views of NOS, scientific models and Earth's structure models will influence the quality of science education, it is important to evaluate PPSTs' views regarding these topics in order to contribute to the development of effective teachers training programs. In this context, we also considered important to analyse relations between and variations of PPSTs' views that could result from their training.

II.2.4. Nature of science, scientific models and earth's structure models

II.2.4.1. Nature of science

In a society strongly influenced by science and technology, it is crucial that our students develop scientific literacy in order to be capable of understanding our surrounding world, taking decisions and acting as informed citizens regarding scientific, personal and social issues (Smith, Loughran, Berry & Dimitrakopoulos, 2012). Hodson (1998) argued that scientific literacy as well as science education implies: (i) the 'learning of science' – development of conceptual and theoretical knowledge; (ii) the 'learning of how to do science' – development of scientific enquiry and problem solving activities; and (iii) the 'learning about science' – understand the nature and methods of science and appreciate its history and development. In fact, many educational reforms provide recommendations for students to develop adequate NOS views and a solid scientific literacy (Abd-ElKhalick, 2006; McComas & Olson, 1998). Indeed, Portuguese science education standard documents highlight the importance of developing scientific literacy and adequate views of NOS, in order to assure that students become critical, informed and

active. NOS knowledge is thus a crucial foundation for science learning, being a prerequisite to develop scientific literacy (McComas et al., 1998). There are many reasons to include NOS in science curricula, as it is important that students understand the conjectural and hypothetical nature of scientific knowledge, its limits and its aims (Driver, Leach, Millar & Scott, 1996). In fact, McComas et al. (1998) suggested that NOS knowledge enhances the learning of science content and the understanding of how science operates; increases interest in science and promotes informed decision making. Additionally, Matthews (1989, 1990) stated that NOS prompts the development of critical thinking and a greater awareness of the achievement of science and intellectual excitement that science involves. Moreover, the teachers' interest in NOS could also assist them in understanding students' views and difficulties and in implementing effective educational actions (McComas et al., 1998).

Despite all the controversies concerning the definition of NOS, some authors claim that there are some aspects about science that are not controversial and that are accessible and relevant for secondary school students (Abd-El-Khalick, Bell & Lederman, 1998; McComas & Olson, 1998; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). These characteristics include the views that scientific knowledge is tentative; empirically based; theory-laden; the product of human inference, creativity and imagination; and socially and culturally embedded (Abd-El-Khalick et al., 1998; Lederman et al., 2002; Liu & Lederman, 2007). Furthermore, observations are limited by our perceptions and scientific activity involves creativity and imagination and is influenced by scientists' beliefs, experiences, training, expectations and social context. The distinction between observation and inference and between scientific theories and laws is also considered to be very important in students' understanding of science. It should be noted, however, that these NOS aspects could be focused at different levels of complexity and must be adequate to the context and students' grade level (Lederman et al., 2002). This study adopts the above mentioned consensus view regarding the nature of science, as this view is in line with many of the science educational studies and with the contemporary philosophy of science perspectives and as the authors considered it suitable as a start for students and even for science teachers to develop an authentic picture of science. Many studies highlight the need for students to develop adequate views about science (Matthews, 2009; McComas & Olson, 1998; Abd-El-Khalick & Lederman, 2000), being fundamental for them to understand the function, processes and limits of science (McComas et al., 1998). As a consequence, it is important that teachers not only develop contemporary views about NOS but also emphasize the value of NOS in their teaching, so as to translate these views into effective classroom practice (Sorensen, Newton & McCarthy, 2012).

II.2.4.2. Scientific models

Despite the heterogeneity of models' typologies and the diversity of models' definitions, we may consider in general terms that a model is a representation of a target, which is built according to a particular portion of that target and with specific purposes (Chamizo, 2013). Giere (2004) advocated that models are the primary representational tools in science and that scientists use them to represent aspects of the world for various purposes. In this way, according to this intentional conception of models, it seems logical that multiple models may exist to study the same target. A model may also be considered a bridge between a theory and a phenomenon, as a scientific theory does not have a direct correspondence to real-world phenomena which are too complex (Koponen, 2007). Indeed, a phenomenon can be organized into a model that provides useful insight to the development of theories (Oh & Oh, 2011). One of the main activities of scientists is to build models and to test which models best fit the evidence available and what is the most plausible explanation for some phenomena (Chamizo, 2013; Matthews, 2007). Moreover, models are considered to have a fundamental role in scientific explanations, as well as in science education. In fact, models are considered essential to achieve the three main science education aims suggested by Hodson (1998), being crucial in developing scientific understanding of the natural world. The use of scientific models and modelling activities is considered to be helpful for students to build their own mental models and to develop scientific knowledge, while understanding how science operates and how scientists work. Hence, it is important that students play an active role and build their own models, in a way that allows them to gain insight into the activities of scientists (Henze, van Driel & Verloop, 2007). This kind of activities also contributes to the understanding of models, of how and why they are used, as well as of their strengths and limits. Consequently, the use of models and modelling activities together with a critical reflection on the role and nature of models in science will contribute to the understanding of the main products and processes of science and to the understanding of NOS (Schwartz & Lederman, 2005). Because of the benefits of using models in science classes, it is important that their use goes beyond emphasizing the learning of scientific knowledge related to an accepted scientific model. In this way, it becomes essential that teachers have not only a good knowledge of important scientific models that are currently accepted, but also a good knowledge about models (Danusso, Testa & Vicentini, 2010; Moutinho, Moura & Vasconcelos, 2014). In this regard, Oh and Oh (2011), based on a theoretical review of the literature, pointed out 5 topics of the nature of models and their uses in science classes that they considered to be fundamental for science teachers to understand: (i) Meanings of a model; (ii) Purposes of modelling; (iii)

Multiplicity of scientific models, (iv) Change in scientific models; and (v) Use of models in the science classroom. History of science provides us many examples of many different historical models, unveiling different aspects which influence the processes of development of successive models (Chamizo, 2013). In fact, models change as scientific knowledge develops, being the study of these historical models and modelling activities fundamental for students to understand that science is a human activity, which changes over time and is influenced by social and cultural issues (Buaraphan, 2012; Torres, Moura, Vasconcelos, & Amador, 2013).

II.2.4.3. Scientific models in geoscience education

As geoscience deals with processes and forces that cannot be directly perceived, geological research heavily relies on diverse models and geoscientists frequently reason by analogy. Therefore, models play a fundamental role in the context of earth science education and geoscience students are exposed to a diversity of models in their classes (Jee et al., 2010; Sibley, 2009). In fact, in geoscience classes, models provide resources that may clarify important features of the target and enable students and teachers to manipulate variables. However, concerning the specific characteristics of geological knowledge, teachers and students must be aware of some difficulties that could arise from the use of models in geoscience education, especially those related with physical and temporal dimensions. Indeed, Portuguese geology education standard documents recommend the critical use of models in classes, which allow students to discuss hypotheses, understand models limitations and compare them with real data. The Earth's internal structure model is one example of the several models suggested in the Portuguese science curriculum, which is addressed throughout the academic career of Portuguese students. This model has a high potential in science classes, as it is relevant to the development of geoscientific knowledge and to NOS instruction and discussion. In fact, bearing in mind its historical development (which is briefly focused in the next section), it is possible to discuss in classes that science is dynamic and tentative and influenced by social and cultural factors, namely religion. Also, as different models of Earth's structure are suggested it is simple to discuss the subjective character of science and the influence of the theoretical framework of scientists. As it is impossible to have access to Earth's interior it becomes fundamental to debate how inference, imagination and creativity are important in model and scientific knowledge construction and development. The Earth's interior model plays an important role as an auxiliary in the development of tectonic plates theory, being possible to discuss the relation between theory and model. Also, this representation constitutes a good example of the intentional

conception of models and models multiplicity, taking into account its rheological and compositional representation.

II.2.4.4. Earth's structure model

II.2.4.4.1. History of Earth's structure model evolution

From the sixth century A.C., many philosophers started to wonder about the functioning of nature, which led to deep changes in the way humans think. Ionian philosophers exemplified by Thales, Anaximander and Anaximenes represent a turning point, from which logical thinking emerges from a mythological world, where everything had a divine nature and explanation (Cushing, 1998; Koestler, 1989). For Thales the planet Earth originated from water and was the centre of the Universe, being like a round disc that floated on water (Dreyer, 1953; Koestler, 1989). In the 14th century the planet was still not very well known, as it was restricted to Europe, North Africa and Asia. In this way, maritime discoveries (from 15th to 17th century) were important to broaden the knowledge about Earth, showing the existence of more continents and inhabitants in different areas of the planet (Deparis, 2001). Descartes was the first philosopher to imagine and describe the Earth's interior and to provide an explanation for the formation of the Earth (Deparis, 2001). For Descartes, the core of the Earth was isolated from the surface and, as a result, surface phenomena were only the result of external causes (Deparis & Legros, 2000). On the other hand, in 1665, Kircher presented another model which explained volcanic eruptions as a result of the release of the 'interior fire'. After these two models, authors, such as Burnet, Woodward and Whiston (at the end of the 17th century) presented some Earth's interior models that intended to reconcile an explanation of Earth's formation with a scientific explanation of the divine deluge (Deparis & Legros, 2000; Deparis, 2001). At the end of the 18th century and beginning of the 19th century, geology evolved as a separate branch of science and the study of the structure of the Earth's interior consequently became more specialized. Since the 19th century, many models emerged taking into account different factors, such as the physical state of materials, temperature and pressure. Many controversies arose between geologists and physicists regarding temperature and pressure, physical state of materials and the composition of the Earth's interior. The development of seismology and other scientific areas was fundamental for the current knowledge of the Earth's structure (Deparis & Legros, 2000; Deparis, 2001). However, as referred by Deparis (2001, p.11), 'the task is far from being over, the depths of the Earth do not yet reveal all its secrets'.

II.2.4.4.2. Currently accepted Earth's structure model

The study of seismic waves generated much of our knowledge of the internal constitution of the Earth, as it enables us to infer its properties (Allègre, 1983; Kearey, Klepeis & Vine, 2009). Globally, we may consider that the Earth has a concentric structure and is divided into three concentric layers: core, mantle and crust (Allègre, 1983; Wyllie, 1976). In general terms, the limits of these layers correspond to discontinuities in the velocity of seismic waves. Mohorovičić discontinuity is the boundary between the crust and the mantle and it is situated at an irregular depth and Gutenberg discontinuity marks the boundary between the core and the mantle. Concerning rheological layering, the lithosphere is the outermost layer of the Earth, comprising the crust and the uppermost mantle. The asthenosphere lies under the lithosphere and is a much weaker layer that reacts to stress in a fluid manner (Figure II.2.1).

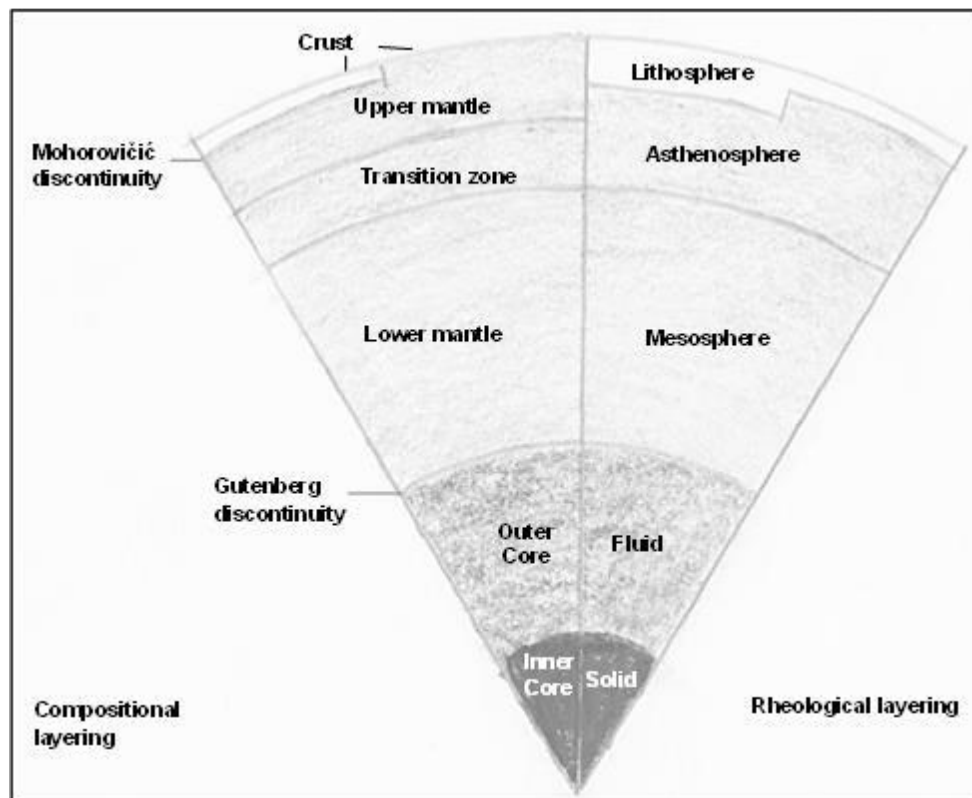


Figure II.2.1. Earth's structure model – an example of physical and chemical model.

Adapted from: Kearey, Klepeis & Vine 2009 (p. 52)

Credit: Marta Queiroz, 2015

The lithosphere is divided into plates and the relative movements of plates take place upon the asthenosphere (Kearey, Klepeis & Vine, 2009; Wyllie, 1976). Regarding Earth's core, its average density is higher than Earth's average density and it comprises a solid inner core surrounded by a liquid outer core.

In general terms, density and temperature increase with depth and the propagation velocity of seismic waves also increases as the average density increases (Wyllie, 1976).

II.2.5. Methodology

To evaluate PPSTs' views of NOS and scientific models and their scientific knowledge regarding one geoscience subject – Earth's structure models - a descriptive study was developed. For this purpose, a questionnaire was administered to two groups of PPSTs enrolled in different institutions of higher education of the country. One group is comprised of PPSTs that will teach in middle and secondary schools and the other of PPSTs that will teach in primary schools.

II.2.5.1. Sample and context of the study

The targeted participants consisted of PPSTs, who were pursuing the master's in Biology and Geology Teaching in different public universities of the country and who were pursuing the master's in Primary Teaching in one public higher school of education - table II.2.1. In Portugal, PPSTs that will be teaching in middle and secondary schools study in Universities (UPPSTs) and PPSTs that will be teaching in primary schools study in Higher Schools of Education (HSPSTs). Despite their different courses, UPPSTs and HSPSTs possess Biology, Geology and pedagogical background. In this way, the authors considered important that both primary, and middle and secondary school teachers hold adequate views of NOS and scientific models, as all of them will have a great impact on students' constructs about science, scientific practice and models. Prospective teachers that will be teaching Natural Sciences (Biology and Geology) in middle and secondary school (to students with ages ranging from 12 to 18) must have a BSc degree in Biology or in Geology and a master degree in Biology and Geology Teaching. Furthermore, in order to attend this master, the prospective teachers that have a BSc degree in Biology must also complete at least 50 ECTS-credits (European Credit Transfer and Accumulation System) related to Geology subjects and those that have a BSc degree in Geology must complete 50 ECTS related to Biology subjects. Prospective middle and secondary school teachers must also complete 6 ECTS in Biology subjects, 6 ECTS in Geology subjects and 24 ECTS in Science Education (12 in Biology Education and 12 in Geology Education) in their master.

Prospective teachers that will be teaching in primary schools (to students with ages ranging from 6 to 12) must have a BSc degree in Primary Teaching and a master degree in Primary Teaching. Both BSc and master degree in Primary Teaching include Biology

and Geology subjects, as these prospective teachers will also teach, among other subjects, Natural Sciences. In fact, they have to complete at least 15 ECTS-credits in Natural Sciences (Biology and Geology) subjects in their BSc degree and 7.5 ECTS-credits in Natural Sciences subjects in their master degree. Moreover, they also have to attend to Science Education subjects (5 ECTS-credits) in their master.

Although many studies reveal that the nature of science is not well understood by teachers, most of the research focused on secondary science teachers. As a result, we considered relevant to analyse both UPPSTs' and HSPPSTs' views of NOS and scientific models. As Earth's structure model is a compulsory model to teach in Portuguese primary, middle and secondary school we opted to evaluate UPPSTs' and HSPPSTs' knowledge regarding this model.

Table II.2.1. Sample characteristics

Gender		Age Range	BSc Degree	
			University 1 (n = 20)	
Females	15 (75%)	21-48	Biology (Biosciences)	16 (80%)
Males	5 (25%)		Geology	2 (10%)
			Biology and Geology	1 (5%)
			Without answer	1 (5%)
			University 2 (n = 4)	
Females	2 (50%)	22-30	Biology and Geology	3 (75%)
Males	2 (50%)		Without answer	1 (25%)
			University 3 (n = 4)	
Females	2 (50%)	21-24	Biology and Geology	4 (100%)
Males	2 (50%)			
			University 4 (n = 4)	
Females	3 (75%)	22-39	Biology	4 (100%)
Males	1 (25%)			
			Higher school of Education (n= 33)	
Females	32 (97%)	21-38	Primary Teacher training	33 (100%)
Males	1 (3%)			
			Total (n=65)	
Females	54 (83.1%)	21-48	Biology (Biosciences)	20 (30.8%)
Males	11(16.9%)		Geology	2 (3.1%)
			Biology and Geology	8 (12.3%)
			Primary Teacher training	33 (50.8%)
			Without answer	2 (3.1%)

A total of 65 PPSTs, with ages ranging from 21 to 48 (mean of 24.34; SD = 4.90), voluntarily participated in the study (table II.2.1).

II.2.5.2. Instrument

A questionnaire was developed in order to evaluate PPSTs' views of NOS and scientific models and their scientific knowledge regarding Earth's interior models. It was mainly

constituted by closed questions in order to make it possible to be administered to PPSTs in different parts of the country. Also, with this study we wanted to get some general results in order to evaluate the need to continue with studies of this nature. At the beginning of the questionnaire there were some questions so as to gather personal socio-demographic data of the respondents. The main questionnaire comprised 22 closed questions: 5 related to NOS and 4 to scientific models (first part of the questionnaire) and 13 to Earth's interior models (second part). The first part of the questionnaire was constructed based on recent literature regarding NOS and scientific models. The first 5 questions were mainly based on relevant papers such as Lederman et al. (2002); Liu and Lederman (2007); McComas (1998) and McComas et al. (1998) and were related to 5 different topics regarding NOS: (i) Science definition; (ii) Science and context; (iii) Tentativeness of scientific knowledge; (iv) Creativity and imagination in Science; and (v) Scientific theories and laws. The four questions regarding models were also based on important papers such as Abd-El-Khalick et al. (1998); Danusso et al. (2010); Justi and Gilbert (2002/2003) and Oh and Oh (2011) concerning four topics about scientific models: (i) Definition of scientific models; (ii) Theories, phenomena and models; (iii) Scientific models nature; and (iv) Scientific models in science classes. The general format of each of these questions comes from the Views on Science-TechnologySociety (VOSTS) questionnaire structure, developed by Aikenhead and Ryan (1992) (VOSTS questionnaire is available on: <http://www.pearweb.org/atis/tools/15>). In this way, for each topic presented, PPSTs were asked to choose only one of seven options which best match their opinion. The options provided included four main statements that revealed different points of view concerning each topic and that were derived from major results obtained in other previous studies, and the remaining three neutral statements represented other possible responses: 'I have difficulties in understanding the above sentences'; 'I do not have enough knowledge to make a choice' and 'None of the options reflects my point of view'. By doing this, we tried to diminish some ambiguity problems, using choices that derived from results of other studies. Moreover, the three neutral options may avoid the selection of a random answer that could distort PPSTs' opinions and consequently the results and may also contribute to a better and deeper understanding of the results. After its construction, the first part of the questionnaire was both content validated and validated by two science education experts. It suffered some adjustments in order to make each option simpler and more concise. After that, the first part of the questionnaire was validated once more by two science education experts, of which only one had participated in the first validation stage. At the end, two more questions were added in order to better understand PPSTs' views of NOS and the order of some questions was changed so that the questionnaire would be more logical. This

part of the questionnaire was initially administered to a preliminary sample of 19 PPSTs (Torres et al., 2013) and no difficulties were detected during the fulfilment of the questionnaire. Moreover, almost all PPSTs chose one of the main four options provided. Only an average of 7.6% selected one of the 3 other neutral options. This means that the main options provided were understood and that they generally fitted the views of the majority of PPSTs that answered the questionnaire. The other 13 remaining questions (second part of the questionnaire) were about historical evolution of Earth's interior models (3 questions) and about currently accepted Earth's structure model and principles (10 questions), mainly based on relevant literature such as Deparis (2001), Deparis and Legros (2000) and Kearey et al. (2009). PPSTs were also asked to choose one option from seven. These options comprised one informed answer, three uninformed answers and three additional neutral options, such as: 'I have difficulties in understanding the above sentences'; 'I do not have enough knowledge to make a choice' and 'None of the options reflects my point of view'. The structure of these questions is also similar to those of the VOSTS questionnaire and the four main options provided also reflect major difficulties regarding Earth's structure models and principles and its historical evolution. This part of the questionnaire was content validated with the support of literature revision and by two geoscience education experts and one geophysics expert. It was also administered to 19 PPSTs (Torres et al., 2013) and no difficulties were detected. In the same way, almost all PPSTs agreed with one of the main four options provided. Only an average of 8,9% chose one of the 3 other neutral answers.

VOSTS questionnaire has already been adapted to Spanish and Portuguese languages (COCTS – Cuestionario de Opiniones sobre Ciencia, Tecnología y Sociedad) and administered to both students and teachers from many Ibero-American countries at different stages of their career (Bennàssar, García-Carmona, Vázquez and Manassero, 2010a). A total of 30 questions were chosen in order to be appropriate to the needs and research requirements of the different countries. In general terms, it was verified that neither the scientific degrees of students, neither the experience of in-service teachers plays a significant contribution in the improvement of NOS understanding (Bennàssar et al., 2010b). Nevertheless, our questionnaire only adapted the general structure of the questions used in VOSTS and not its own questions, as we wanted to essentially analyse PPSTs views regarding NOS, emphasizing their views related to scientific models (epistemological views and content knowledge about Earth's interior models).

II.2.5.3. Procedures

The questionnaire, on paper, was administered by one member of the research team or by one university teacher in Geoscience Education Classes, during the second semester of the 2012/2013 academic year, more specifically at the end of the semester. At that moment, students had almost finished their curricular component and would start their internship in schools in the following year. Students voluntarily participated and took, approximately, seventeen minutes to fill in the questionnaire. The questionnaire had 22 closed questions related to their views of Nature of Science, scientific models and Earth's structure models.

II.2.5.3.1. Descriptive analysis

Nature of science and scientific models: To evaluate PPSTs' views of NOS and Scientific Models a descriptive statistical analysis was undertaken and the data collected was introduced in version 21 of SPSS. Each answer that reflects PPSTs' views regarding each evaluated component of NOS and Scientific Models was compared with previously defined contemporary views and generally classified into 'Informed', 'Naïve' and 'Uninformed' categories. 'Informed' answers were those that best match contemporary views, 'Naïve' answers were those that do not completely match those views and 'Uninformed' answers were those that do not match and that deviate the most from those views. 'I have difficulties in understanding the above sentences'; 'I do not have enough knowledge to make a choice' and 'None of the options reflects my point of view' answers were considered to be neutral. Results from PPSTs', UPPSTs' and HSPPSTs' views were presented separately.

Earth's Structure Model: To evaluate PPSTs' knowledge regarding the historical evolution of Earth's structure models and the currently accepted Earth's structure model and principles, a descriptive statistical analysis was also undertaken and the data collected was introduced in version 21 of SPSS. In this specific case, answers were considered to be 'Informed', 'Uninformed' or neutral ('I have difficulties in understanding the above sentences'; 'I do not have enough knowledge to make a choice' and 'None of the options reflects my point of view'). In this case, results were also presented by specifying all participants' views, as well as UPPSTs' and HSPPSTs' views.

Global Understanding: In order to attain a global understanding of participants' views of NOS and Scientific Models and knowledge of Earth's structure models, we classified PPSTs' understanding of each of the topics evaluated into 3 categories:

'Informed', 'Intermediate' and 'Uninformed'. These categories were defined for each topic, according to the number of questions and the kind of options that were provided. Each participant's global view of NOS and Scientific Models and each participant's global knowledge of historical evolution of Earth's structure models and currently accepted Earth's structure model and principles was established according to table II.2.2.

Table II.2.2. Global view of nature of science and scientific models categories and global knowledge of historical evolution of earth's structure models and current accepted earth's structure model and principles categories.

Category \ Issue	NOS (5 questions about this issue)	Scientific Models (4 questions about this issue)	Historical evolution of earth's structure models (3 questions about this issue)	Current accepted earth's structure model and principles (10 questions about this issue)
Informed view	4 to 5 informed answers and none uninformed.	3 to 4 informed answers and none uninformed.	2 to 3 informed answers and none uninformed.	8 to 10 informed answers.
Intermediate View	3 to 4 informed answers and a maximum of 1 uninformed. 2 informed answers and none uninformed.	3 informed answers and 1 uninformed answer. 2 informed answers and none uninformed.	2 informed answers and 1 uninformed answer. 1 informed answer and none uninformed answer.	5 to 7 informed answers.
Uninformed View	3 informed answers and 2 uninformed answers. 0 to 2 informed answers and one or more uninformed.	0 to 2 informed answers and one or more uninformed.	1 informed answer and one or more uninformed. All answers are uninformed.	1 to 4 informed answers.

Statistical analysis: The statistical analysis comprised a correlational analysis and a chi square test and was performed with version 21 of SPSS.

A correlational analysis was used to determine the influence of the global understanding level of each topic evaluated in the understanding level of all the remaining evaluated topics. Additionally, it was also analysed the relation between PPSTs' institutions of higher education and the global understanding of each topic. These analyses were performed through the calculation of Spearman's rank correlation coefficient.

In order to deeply understand the influence of the variable higher education institution in PPSTs' views regarding NOS, Scientific Models, historical evolution of Earth's structure models and Earth's structure models and principles, a univariate analysis was undertaken in relation to each question. In this chi-square statistical analysis, PPSTs' views were the dependent variable and higher education institution was the independent variable.

II.2.6. Results

II.2.6.1. Descriptive analysis

II.2.6.1.1. NOS and scientific models

The answers given to the 9 closed questions about NOS and models are presented in the tables below (table II.2.3 and table II.2.4).

The following section will provide information about the participants' views of NOS and models, establishing a comparison between all participants views and the views of PPSTs that study in a university (UPPSTs) and in a higher school of education (HSPSTs).

Nature of science: Participants' understandings of NOS are presented in table II.2.3. As shown, when asked about the definition of science, the majority of PPSTs held the informed perspective that science is 'a human attempt to explain the world and phenomena'. University Portuguese prospective science teachers (UPPSTs) had a greater percentage of informed answers, as 36.3% of higher school Portuguese prospective science teachers (HSPSTs) held naïve views concerning this aspect.

Almost all PPSTs recognized that different contexts influence science (question 2). Although the majority of UPPSTs assumed that scientific knowledge is not definite, some UPPSTs (34.4%) and the majority of HSPSTs believed that scientific knowledge changes only with new information and technology, showing a naïve perspective about this matter.

Regarding creativity and imagination, almost all respondents (66.2%) recognized their need in the development of scientific knowledge. However, 24.6% of participants held naïve views about this issue, assuming that creativity and imagination are only needed in some stages of scientific knowledge construction.

Concerning the relationship between theories and laws, a high number of respondents held an uninformed (43.8%) or naïve (40.7%) view about this topic and only 7.8% recognized that theories and laws are different kinds of knowledge and that one cannot become the other. In fact, a high percentage of PPSTs believed that a hierarchical relationship exists between scientific theories and laws, assuming that theories evolve to laws.

Table II.2.3. Category and rate of responses regarding nature of science aspects.

Question and Answer options	Category of answer	%		
		U	HS	TI
Q1 – In your opinion, science is...				
An objective knowledge, based on experimental evidences.	Naïve	12.5	24.2	18.5
Equivalent to technology.	Uninformed	0	3.0	1.5
A human attempt to explain the world and phenomena.	Informed	71.9	54.5	63.1
An unquestionably knowledge, based on experimental evidences and objective observations.	Naïve	6.3	12.1	9.2
I have difficulties in understanding the above sentences.	Neutral	0	0	0
I do not have enough knowledge to make a choice.		0	0	0
None of the options reflects my point of view.		9.4	3.0	6.2
Without meaning*		0	3.0	1.5
Q2 – In Science...				
Different belief systems do not influence the use of scientific knowledge and the way scientific research is conducted.	Naïve	6.3	0	3.1
Social, political and economic contexts influence scientific knowledge development.	Informed	84.4	78.8	81.5
Different belief systems influence the use of scientific knowledge but do not influence the way scientific research is conducted.	Naïve	6.3	6.1	6.2
Everything is objective and neutral.	Uninformed	0	3.0	1.5
I have difficulties in understanding the above sentences.	Neutral	0	3.0	1.5
I do not have enough knowledge to make a choice.		0	6.1	3.1
None of the options reflects my point of view.		0	3.0	1.5
Without meaning*		3.1	0	1.5
Q3 – Regarding scientific knowledge, you consider that ...				
Scientific knowledge is definite and correct, being a proven truth.	Uninformed	0	6.1	3.1
Scientific knowledge, although reliable, is tentative and never certain.	Informed	50.0	33.3	41.5
Scientific knowledge change solely with new information and advanced technology.	Naïve	34.4	51.5	43.1
Scientific knowledge is tentative due to insufficient evidence for proving their validity.	Naïve	3.1	9.1	6.2
I have difficulties in understanding the above sentences.	Neutral	0	0	0
I do not have enough knowledge to make a choice.		0	0	0
None of the options reflects my point of view.		12.5	0	7
Q4 – Relating to creativity and imagination, you think that...				
They are not necessary in the construction of scientific knowledge.	Uninformed	0	0	0
Only make sense in planning and design stage.	Naïve	6.3	15.2	10.8
They are needed in the development of scientific knowledge.	Informed	78.1	54.5	66.2
They are needed during all the research except in the data collection stage.	Naïve	15.6	12.1	13.8
I have difficulties in understanding the above sentences.	Neutral	0	0	0
I do not have enough knowledge to make a choice.		0	3.0	1.5
None of the options reflects my point of view.		0	12.1	6.2
Without meaning*		0	3	1.5
Q5 – Regarding theories and laws, you consider that...				
Theories and laws are different kinds of knowledge and one cannot become the other.	Informed	12.5	3.1	7.8
Theories evolve to laws with the evidence accumulation.	Naïve	28.1	40.6	34.4
Laws reflect a proven knowledge and so they are more certain than theories.	Naïve	6.3	6.3	6.3
Laws are the explanations of phenomena and theories constitute descriptions of patterns related to observational phenomena.	Uninformed	40.6	46.9	43.8
I have difficulties in understanding the above sentences.	Neutral	3.1	0	1.6
I do not have enough knowledge to make a choice.		3.1	0	1.6
None of the options reflects my point of view.		6.3	0	3.1
Without meaning*		0	3.1	1.6

Legend: % - percentage; U – UPPSTs; HS – HSPSTs; TI – Total (PPSTs).

Scientific models: Concerning scientific models (table II.2.4), a considerable percentage of UPPSTs (34.4%) recognized a model as a representation of a phenomenon, while 36.4% of HSPPSTs considered it as a reference to which a phenomenon has to be compared. Moreover, 38.5% of respondents held a naïve view of models by considering it as a set of rules and schemes and the result of reality observation.

In question number 7, almost all students held informed views about the relation between theories, phenomena and models. In fact, they considered that a model is a representation of phenomena or processes and serves as a 'bridge' connecting a theory and a phenomenon. However, 20% of participants considered that models are equivalent to theories, failing in recognizing the relevance of models in the construction of scientific knowledge and in the development of new theories. Almost all students considered that scientific models result from inference – 72.3%.

Although 84.6% of respondents reckoned that the use of models in the classroom contributes to a better 'learning of science', 'about science' and 'to do science', 15.6% of UPPSTs considered that it only contributes to the understanding of complex natural phenomena.

II.2.6.1.2. Earth's structure models

Regarding Earth's structure models, some problems were detected concerning their historical evolution and also the currently accepted Earth's structure model and principles. The following sections will provide information about the participants' knowledge regarding these two topics by specifying PPSTs', UPPSTs' and HSPPSTs' answers.

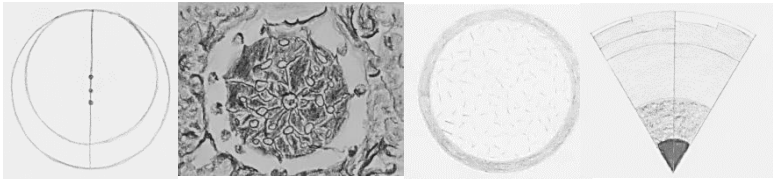
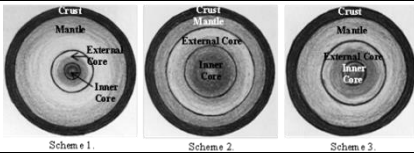
Historical evolution of Earth's structure models: Although the majority of respondents (54.7%) have correctly arranged the historical models in chronological order, only 33.8% answered correctly to the tenth question (table II.2.5). Moreover, when asked about the contributions to the historical evolution of Earth's structure models, the bulk of PPSTs (35.9%) mentioned 'technological advance and accumulation of new information', failing to recognize some important issues in scientific knowledge construction, such as different ways of looking at existing evidence. In fact, only 29.7% of respondents answered correctly to this question.

Table II.2.4. Category and rate of responses regarding scientific models issues.

Question and Answer options	Category of answer	%		
		U	HS	TI
Q6– Do you consider a scientific model as...				
A reference to which a phenomenon has to be compared to help understanding it scientifically.	Uninformed	9.4	36.4	23.1
An abstract representation which reproduces the behaviour of a phenomenon using suitable parameters.	Informed	34.4	24.2	29.2
The set of rules and schemes which identify a given phenomenon and allow understanding it.	Naïve	18.8	27.3	23.1
An abstract tool to analyse reality designed from the observation of that reality.	Naïve	28.1	3.0	15.4
I have difficulties in understanding the above sentences.	Neutral	6.3	3.0	4.6
I do not have enough knowledge to make a choice.		3.1	0	1.5
None of the options reflects my point of view.		0	3.0	1.5
Without meaning*		0	3.0	1.5
Q7 – Concerning the relation between theories, phenomena and models, you believe that...				
A model is a representation of phenomena or processes and serves as a ‘bridge’ connecting a theory and a phenomenon.	Informed	71.9	48.5	60.0
A model is a fundamental theory to understand a phenomenon and to formulate future theories.	Uninformed	18.8	21.2	20.0
A phenomenon can be represented only by a unique model.	Naïve	0	0	0
A model represents all the aspects of a phenomenon.	Naïve	0	9.1	4.6
I have difficulties in understanding the above sentences.	Neutral	0	15.2	7.7
I do not have enough knowledge to make a choice.		3.1	0	1.5
None of the options reflects my point of view.		6.3	3.0	4.6
Without meaning*		0	3.0	1.5
Q8 – Relating to models, you think that...				
Scientific models are a copy of reality.	Uninformed	6.3	3.0	4.6
Scientific models are immutable.	Naïve	0	0	0
Scientific models result from inference.	Informed	71.9	72.7	72.3
Models created by scientists are all proven.	Naïve	3.1	6.1	4.6
I have difficulties in understanding the above sentences.	Neutral	3.1	3.0	3.1
I do not have enough knowledge to make a choice.		6.3	3.0	4.6
None of the options reflects my point of view.		9.4	12.1	10.8
Q9 – The use of models in the classroom...				
Only contributes to the understanding of complex natural phenomena.	Naïve	15.6	0	7.7
Contributes to a better learning of science, about science and to do science.	Informed	78.1	90.9	84.6
Requires more traditional teaching methodologies.	Naïve	0	0	0
Does not contribute to the understanding of the Nature of Science.	Uninformed	0	0	0
I have difficulties in understanding the above sentences.	Neutral	0	0	0
I do not have enough knowledge to make a choice.		0	0	0
None of the options reflects my point of view.		6.3	3.0	4.6
Without meaning*		0	6.1	3.1

Legend: % - percentage; U - UPPSTs; HS – HSPSTs; TI - Total (PPSTs).

Table II.2.5. Questions and informed answers concerning historical evolution of earth's structure models (Q10-Q12) and concerning current accepted earth's structure model and principles (Q13-Q22).

Question	Informed Answer	%		
		Un	Hs	TI
Q10 – With earth's structure historical models...	It was intended to understand earth's interior, explain known geological phenomena and other phenomena, as the divine deluge. 2, 1, 3 and 4.	28.1	39.4	33.8
Q11 – Arrange the following historical models in chronological order...		54.8	54.5	54.7
Q12 – The study of earth's structure models shows that its historical evolution depended on...	Science and technology development, events like maritime discoveries and the emergence of anomalous data/new ideas, as well as different ways of looking at existing evidence.	32.3	27.3	29.7
Q13 – Regarding the current accepted earth's structure model...	Materials density and temperature increase with depth and propagation velocity of seismic waves increases as medium density also increases.	43.8	22.6	33.3
Q14 – Earth's internal structure may be represented by...	A physical and chemical model, being the lithosphere and asthenosphere layers of the physical one.	56.3	69.7	63.1
Q15 – Regarding Mohorovičić discontinuity...	It is accepted that it is a boundary, of irregular thickness, between Earth's crust and a rigid zone of mantle.	37.5	6.1	21.5
Q16 – Regarding lithosphere, it is advocated that...	It comprises the crust and the upper mantle. Lithosphere-asthenosphere boundary is due to a change in rocks properties as pressure and temperature increases with depth.	71.9	51.5	61.5
Q17 – Asthenosphere is...	A low-velocity zone, constituted by rocks with plastic properties and with certain mobility.	75.0	24.2	49.2
Q18 – Regarding the current accepted earth's structure model...	Earth's core density is higher than earth's density and comprises an inner core solid surrounded by an outer core liquid.	68.8	25.0	46.9
Q19 – Regarding outer earth's core, it is advocated...	That S-waves do not travel through it and P-waves diminishes their velocity supporting the idea that it is in the liquid state. The rotation of liquid metals (iron and nickel) in the outer core creates the Earth's magnetic field.	84.4	9.1	46.2
Q20 – Regarding those 3 schemes, identify which represent the current accepted model...	Scheme 3. 	46.9	57.6	52.3
Q21 – Earth's interior heat...	Earth's internal heat comes from a combination of residual heat from planetary accretion and the heat produced through radioactive decay, being the heat flux ten times higher than the average in the mid-ocean ridges.	59.4	15.2	36.9
Q22 – To study the earth's internal structure it was the important contribution...	Of data from meteorites study and from the study of the propagation velocity, reflexion and refraction of seismic waves.	78.1	24.2	50.8

Legend: % -percentage of informed answers; Un -University students; Hs -Higher School of Education students; TI -Total.

Currently accepted Earth's structure model and principles: Concerning the currently accepted Earth's structure model, the majority of respondents failed to recognize that material density, temperature and propagation velocity of seismic waves increase with depth (table II.2.5). The majority of PPSTs also failed to characterize Mohorovičić discontinuity, as merely 21.5% answered correctly to the question regarding

this discontinuity (Q15). In question number 21, only 36.9% indicated the informed answer concerning the Earth's internal heat.

In fact, in ten questions regarding the Earth's interior model, only 4 questions were correctly answered by the majority of students (more than fifty percent of respondents). However, when comparing UPPSTs' with HSPSTs' answers it is possible to verify that 7 questions were correctly answered by the majority of UPPSTs while only 3 answers were correctly answered by the majority of HSPSTs.

II.2.6.1.3. Global understanding

The global understanding of participants regarding NOS, Scientific Models, historical evolution of Earth's structure models and the currently accepted Earth's structure model and principles is presented in the table below (table II.2.6).

Table II.2.6. Global understanding of participants regarding nature of science, scientific models, historical evolution of earth's structure model and current accepted earth's structure model and principles.

Evaluated Issue	Categories	% of answers		
		Un	Hs	TI
NOS	Informed	15.6	3.0	9.2
	Intermediate	68.8	57.6	63.1
	Uninformed	15.6	39.4	27.7
Scientific Models	Informed	36.9	43.8	30.3
	Intermediate	26.2	28.1	24.2
	Uninformed	36.9	28.1	45.5
Historical evolution of earth's structure model	Informed	9.4	21.2	15.4
	Intermediate	21.9	15.2	18.5
	Uninformed	68.7	63.6	66.1
Current accepted earth's structure model and principles	Informed	25.0	0.0	12.3
	Intermediate	53.1	21.2	36.9
	Uninformed	21.9	78.8	50.8

Legend: % - percentage; Un – University students; Hs – Higher School of Education students; TI – Total.

In global terms, PPSTs hold an intermediate view of NOS and it seems that UPPSTs hold better views concerning this topic. On the other hand, it seems that HSPSTs have a more informed view regarding scientific models. However, results were somewhat fragmented over the three categories established in this topic. The majority of PPSTs and also the majority of UPPSTs and HSPSTs hold an uninformed view concerning the historical evolution of Earth's structure models. Although the bulk of PPSTs hold an uninformed view regarding the currently accepted Earth's structure model and principles, the majority of UPPSTs hold an intermediate view about this topic.

II.2.6.2. Statistical analysis

II.2.6.2.1. Correlational analysis

Results presented in table II.2.7 shows us that the global understanding level of each topic evaluated do not influence the global understanding level of all the remaining topics evaluated, as it is not possible to establish a significant relation between them.

Table II.2.7. Correlational analysis (Spearman's rank correlation coefficient).

	Global Understanding Level of NOS	Global Understanding Level of SM	Global Understanding Level of HM	Global Understanding Level of ESM	Higher Education Institution
			C (p)		
Global Understanding Level of NOS	---	0.165 (0.189)	-0.159 (0.206)	0.140 (0.267)	-0.288 (0.022*)
Global Understanding Level of SM		---	-0.019 (0.882)	0.043 (0.732)	-0.148 (0.247)
Global Understanding Level of HM			---	-0.004 (0.0975)	0.066 (0.606)
Global Understanding Level of ESM				---	-0.612 (0.000**)

Legend: NOS –Nature of Science; SM –Scientific Models; HM –Historical evolution of earth's structure model; ESM -Earth's structure model; C –correlation coefficient; p - p value (x^* - $p < 0.05$; x^{**} - $p < 0.01$).

Indeed, no significant relation was found between epistemological knowledge and the Earth's structure model knowledge, contrarily to what was expected. In fact, it was expected that adequate NOS and nature of models knowledge would have had a positive influence on Earth's structure model knowledge. As suggested by McComas et al. (1998) and Peters (2012), well informed views of NOS may favour the science content knowledge acquisition. Also, Park (2013), in a study with high school students of South Korea, concluded that students with better content knowledge possess more accurate views regarding scientific models nature. However, the results obtained, especially those related to HSPSTs, are somewhat peculiar. The results presented on table II.2.6 show that although 43.8% of HSPSTs hold an informed view about scientific models and 57.6% and intermediate view regarding NOS, 0% of them possess an informed view and 21,2% an intermediate view regarding Earth's structure model knowledge. This result may reflect the lack of knowledge of HSPSTs regarding the Earth's structure model.

Actually, it is possible to establish a statistical significant relation between higher education institutions and the currently accepted Earth's structure model and principles knowledge ($p < 0.01$), indicating that HSPSTs hold a worst knowledge regarding these topics and consequently that UPPSTs had a better knowledge. It is also possible to

establish a statistical significant relation between higher education institutions and NOS views ($p < 0.05$), indicating that UPPSTs' NOS views were more consistent with contemporary NOS views.

II.2.6.2.2. *Chi Square test*

Univariate analysis was undertaken (chi square test) to investigate the influence of higher education institutions in PPSTs' views concerning each answered question.

As previously verified, results indicated that there were no significant differences between students' knowledge regarding scientific models and historical evolution of Earth's structure models ($p > 0.05$).

Table II.2.8a. Univariate analysis of views [concerning nature of science (Q1-Q5)] held by students with higher education institution.

Informed Answers						
Item		Q1	Q2	Q3	Q4	Q5
Un	f (%)	23 (71.9)	27 (84.4)	16 (50.0)	25 (78.1)	4 (12.5)
Hs		18 (54.5)	26 (78.8)	11 (33.3)	18 (54.5)	1 (3.1)
TI		41 (63.1)	53 (81.5)	27 (41.5)	43 (66.1)	5 (7.8)
χ^2		2.095	0.337	1.858	4.034	1.953
p		0.148	0.562	0.173	0.045*	0.162

Legend: f – frequency of informed answers; % - percentage of informed answers; Un – University students; Hs – Higher School of Education students; TI – Total; χ^2 - chi-square; p- p value (x^* - $p < 0.05$; x^{**} - $p < 0.01$).

Regarding NOS views (table II.2.8a), it was possible to verify that UPSTs gave more informed answers in all questions concerning this topic (Q1-Q5). However, the difference was only statistically significant ($p < 0.05$) in question number 4.

Concerning Earth's structure models and principles, UPPSTs gave more informed answers than HSPSTs (table II.2.8b), being the differences in questions number 15, 17, 18, 19, 21 and 22 statistically significant ($p < 0.01$).

Table II.2.8b. Univariate analysis of views [concerning current accepted earth's structure model and principles (Q13-Q22)] held by students with higher education institution.

Informed Answers											
Item		Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22
Un	f (%)	14 (43.7)	18 (56.2)	12 (37.5)	23 (71.9)	24 (75.0)	22 (68.7)	27 (84.4)	15 (46.9)	19 (59.4)	25 (78.1)
Hs		7 (22.6)	23 (69.7)	2 (6.1)	17 (51.5)	8 (24.2)	8 (25.0)	3 (9.1)	19 (57.6)	5 (15.1)	8 (24.2)
TI		21 (33.3)	41 (63.1)	14 (21.5)	40 (61.5)	32 (49.2)	30 (46.9)	30 (46.1)	34 (52.3)	24 (36.9)	33 (50.8)
χ ²		3.175	1.261	9.502	2.845	16.746	12.298	37.051	0.746	13.642	18.872
p		0.075	0.261	0.002**	0.092	0.000**	0.000**	0.000**	0.388	0.000**	0.000**

Legend: f – frequency of informed answers; % - percentage of informed answers; Un – University students; Hs – Higher School of Education students; TI – Total; χ^2 - chi-square; p- p value (χ^* - $p < 0.05$; χ^{**} - $p < 0.01$).

II.2.7. Conclusions

With these results, we may conclude that PPSTs hold, in general terms, intermediate views of NOS. Indeed, some naïve and even uninformed views concerning NOS aspects were identified, especially regarding the relation between theories and laws. These results are consistent with the findings achieved by Liu and Lederman (2007). Regarding scientific models, some inconsistencies were found in relation to models' definition and some naïve views were revealed concerning models' nature.

Although the majority of PPSTs have correctly arranged the historical models in chronological order, the majority of PPSTs revealed an uninformed view regarding the historical evolution of Earth's structure model. We believe that a deeper understanding of historical Earth's structure models will be essential as PPSTs will be able to introduce history and nature of science in a more comprehensible, interesting and fruitful way. Indeed, PPSTs also failed to recognize NOS components when referring to specific themes, such as the Earth's structure models. For example, the majority of PPSTs have not identified the features that influenced the historical evolution of Earth's structure model. As so, it seems that PPSTs are not well prepared to teach NOS, especially in a contextualized way. On the topic of Earth's structure models, some uninformed views were detected, especially related to the Mohorovičić discontinuity; material density, temperature and propagation velocity of seismic waves in the interior of the Earth; and Earth's internal heat.

Globally, UPPSTs held more informed views than HSPSTs students, being more prepared to deal with epistemological issues and also with the Earth's internal structure model. This finding warns for the need to better prepare HSPSTs regarding epistemological issues and scientific knowledge, having in mind the influence they will

have over their students' scientific educational experiences from early years in school. As we have referred above, results reveal a great lack of HSPSTs' knowledge regarding Earth's structure model. This finding may corroborate even more with the need of further scientific background in primary school teachers training.

If it is suggested in the Portuguese curriculum to include NOS and models in science classes, it is fundamental that Portuguese teachers know why and how to accomplish it. In fact, in the Portuguese curriculum it is highlighted the need for students to develop adequate and contemporary views of NOS and the need to use models in science classes, particularly in geoscience classes. However, no specific guidelines were provided on how to implement NOS instruction and on how to use models (only some models were suggested and some recommendations were made regarding model limitations). According to this fact and to the results obtained in this study, the authors consider that it would be important to deepen Portuguese science teachers' views about NOS and scientific models in both initial and continuous teaching professional development. Hence, it is also fundamental that Portuguese science teachers recognize the role of models in science, as well as in science teaching. As argued by Khan (2011), teachers need to improve their views regarding scientific models and their use in science classes, in order to implement modelling activities in classes, taking the full advantages of all its potentials.

The Earth's structure model is an example of a powerful model to teach NOS aspects (which obviously include the nature of models) in science classes given its historical evolution and mandatory character in pre-university education. Thus, we consider it crucial to deepen PPSTs understanding of NOS, models, as well as of the Earth's structure model, for the purpose of achieving a better teaching of NOS, especially in an explicit, embedded and reflective way.

The authors consider that it would also be important to broaden this research to a larger sample (including in-service science teachers) and to study the translation of prospective and in-service teachers' views about NOS and models into classroom practice. This would be an invaluable asset to understand how different factors may influence these teachers' classroom practice and to guarantee a good training regarding those topics. In fact, as referred by Abd-El-Khalick et al. (1998), accurate teachers' views do not necessarily guarantee the translation of teachers' conceptions into classroom practices.

Within this specific research project, our final aim is to propose a change in prospective science teachers training programmes. To do so, we will implement an intervention programme to prospective science teachers that are enrolled in the curricular year of their master in teaching and we will evaluate the changes in their views.

Moreover, we will observe their classes during their internship, in order to better understand the factors that mediate the translation of their views and knowledge into their classroom practices. In a study with Portuguese secondary school teachers, Reis and Galvão (2004) suggest that many factors may mediate teachers' conceptions and their practice, such as: (i) national curriculum; (ii) national exams; (iii) teachers' previous experiences with scientific activities and (iv) own educational objectives. However, we consider that more research is needed in order to fully understand the factors that influence the translation of prospective science teachers' views of NOS and models into their classroom practice.

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II.3. Syllabus analyses: Initial teacher training

MODELS AND MODELLING IN BIOLOGY AND GEOLOGY TEACHERS' INITIAL TRAINING (OS MODELOS E A MODELAÇÃO NA FORMAÇÃO INICIAL DE PROFESSORES DE BIOLOGIA E DE GEOLOGIA)

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Comunicações Geológicas, 101, Especial III, 1391-1394.

II.3.1. Abstract

Experimental modelling in Geology has started with Hall in the beginning of the 19th century, when he simulated in laboratory the formation of folds, by using a thick series of pieces of cloth confined vertically and compressed horizontally between two wooden boards. In science education, models and modelling contribute not only to a better learning of scientific knowledge but also to the learning of “how to do science” and of the nature of science. However and, despite all the evidences of model-based teaching effectiveness, there are many studies that unveil that teachers do not include modelling activities in their classes, revealing a limited knowledge of the role of models in science and teaching. As a result, we intended to analyse the syllabus of Geoscience Education subject of seven Portuguese universities, in order to understand to what extent prospective science teachers deal with these issues in their training. In general terms, results reveal that models and modelling issues are only recommended in Geoscience Education syllabus of two universities and nature of science aspects in Geoscience Education syllabus of five. As it is suggested to teach nature of science and to use models in Geology secondary curriculum, authors think that it would be useful to incorporate these issues in the syllabus and themes of Geology Education for science teachers training.

Key-words: Geology Teaching, Teachers Training, Modelling, Scientific Models, Nature of Science.

II.3.2. Resumo

A modelação análoga experimental perscrutou o seu caminho na investigação geológica no início do século XIX, quando Hall simulou em laboratório a formação de dobras usando tecidos confinados verticalmente e comprimidos horizontalmente com a ajuda de pedaços de madeira. No ensino, os modelos e a modelação, para além de contribuírem para uma melhor aprendizagem do conhecimento científico, desempenham papel preponderante na compreensão do empreendimento científico e da própria natureza da ciência. No entanto, e, apesar do ensino orientado para a modelação apresentar já evidências que suportam a sua eficiência, vários são os estudos que revelam que os professores não incluem atividades de modelação em salas de aula, revelando mesmo um conhecimento limitado acerca do papel dos modelos na ciência e no ensino. Pelo exposto, com este trabalho pretendemos analisar as fichas da unidade curricular de Didática da Geologia de sete universidades do país, no sentido de compreender em que medida os futuros professores de Biologia e de Geologia abordam estas temáticas na sua formação. De forma geral, os resultados revelam que relativamente à temática dos modelos e da modelação esta só é referida nas fichas das unidades curriculares em apenas duas das universidades consultadas e que relativamente à da natureza da ciência esta é referida em cinco. Uma vez que a compreensão da natureza da ciência e a utilização de modelos são aspetos relevados nos programas nacionais de Geologia do ensino secundário, considerámos que seria pertinente incorporar estas temáticas nas unidades curriculares em análise.

Palavras-Chave: Ensino da Geologia, Formação de Professores, Modelação, Modelos Científicos, Natureza da Ciência.

II.3.3. Referencial teórico e justificação do estudo

Os modelos científicos têm um papel preponderante na investigação científica, assim como na educação em Ciências (Halloun, 2007; Justi & Gilbert, 2002). Apesar da existência de várias definições de modelos e de vários tipos de modelos, um modelo é considerado, de forma geral, a representação de um alvo com fins específicos (Giere, 2004; Oh & Oh, 2011), constituindo a ferramenta representacional primária na ciência (Giere, 2004). Os modelos permitem descrever, explicar e prever vários aspetos da realidade, reificando-os (Halloun, 2007).

Na investigação geológica, o uso de modelos e a modelação em laboratório remontam ao início do século XIX com James Hall, sendo este considerado o fundador da Geologia Experimental. Hall, em 1815, com o intuito de replicar a formação de grandes estruturas e explicar a origem das dobras que observava ao longo da costa oriental da Escócia, construiu modelos de montanhas (Brandstetter, 2011; Graveleau et al., 2012).

O recurso à experimentação foi largamente contestado, quer por questões de representatividade, quer pelo facto de não ser possível provar a ocorrência de um fenómeno na natureza, apesar de ser possível demonstrar que uma causa proposta pode produzir um efeito observável. No entanto, ultrapassadas muitas questões relativas às questões de similaridade, através de pressupostos geológicos e da utilização de leis de escala, muitos outros geólogos continuaram e melhoraram o trabalho de Hall ao longo de vários anos (Brandstetter, 2011; Graveleau et al., 2012; Oreskes, 2007).

A nível educacional, os modelos são considerados ferramentas pedagógicas poderosas que permitem ajudar os alunos no desenvolvimento de capacidades associadas com o processo de investigação científica, sendo pretendido que a modelação reflita a atividade dos cientistas (Halloun, 2007; Justi, 2009). Os modelos e atividades de modelação são, assim, fundamentais para a elucidação de uma imagem autêntica da ciência e para a construção de modelos mentais adequados (Koponen, 2007, Oh & Oh, 2011), contribuindo para a aprendizagem *da ciência; de como fazer ciência e sobre ciência* (Justi & Gilbert, 2002). De facto, os alunos aprendem *a ciência* ao desenvolver conhecimentos acerca dos principais modelos científicos; aprendem *sobre como fazer ciência*, ao criar, expressar e testar os seus próprios modelos; e aprendem *sobre ciência*, ao desenvolver conceções adequadas acerca da natureza da ciência (NdC) e da natureza dos modelos, compreendendo o contributo destes no desenvolvimento e disseminação do conhecimento científico (Justi & Gilbert, 2002). A utilização de modelos históricos no ensino das ciências revela-se também fundamental

na compreensão da NdC, uma vez que a sua análise permite compreender que a ciência é uma atividade humana, que se altera ao longo do tempo, sendo influenciada por fatores sociais e culturais que limitam, influenciam e promovem o desenvolvimento do conhecimento científico (Torres et al., 2013). Neste sentido, os currículos de Geologia nacionais sugerem o recurso à modelação como estratégia fundamental no ensino desta área científica que, pelas suas características, recorre substancialmente ao uso de modelos e analogias (Oh & Oh, 2011). Na realidade, o uso de modelos nas aulas de Geologia, especialmente de simulações de processos geológicos, é de capital importância para o desenvolvimento de diferentes capacidades inerentes à aprendizagem e raciocínio geológico (Bolacha et al., 2012). Não obstante, o uso de modelos em sala de aula deve ser feito com precaução, sendo função do professor alertar para as características e limitações dos modelos, bem como para as diferenças e semelhanças entre o modelo e o sistema alvo (Jee et al., 2010). Deste modo, procura-se evitar que os alunos se baseiem em demasia nos modelos e que construam modelos mentais discordantes com os modelos científicos aceites.

Apesar de toda a importância atribuída aos modelos e ao desenvolvimento de atividades de modelação em sala de aula, verifica-se que os professores não só não as aplicam de forma sistemática, como também revelam um conhecimento parco nesse domínio (Khan, 2011). Também são muitos os estudos que demonstram que os alunos não desenvolvem conceções adequadas acerca da NdC, podendo este facto dever-se à falta de conhecimentos dos professores e sobretudo à pouca relevância que os professores atribuem à promoção de atividades acerca da NdC, sendo esta abordada essencialmente de forma implícita (Bell, 2006). De facto, é atualmente defendido que a NdC deva ser abordada de forma explícita, contextualizada e refletida (Koksal et al., 2013), sendo o uso de modelos e as atividades de modelação determinantes para que os alunos pensem sobre ciência e que desenvolvam o seu pensamento crítico e científico.

Pelo exposto, considerámos relevante analisar as fichas das unidades curriculares de Didática da Geologia ou de unidades curriculares equivalentes, com a finalidade de compreender em que medida os futuros professores de Biologia e de Geologia são preparados ao nível do seu conhecimento acerca da NdC, mas também ao nível da sua transposição didática. Por outro lado, pretendemos verificar se os modelos e atividades de modelação são também abordados na formação dos futuros professores, como um contributo para a compreensão da ciência, mas também para a compreensão da natureza da ciência e para o desenvolvimento de capacidades de investigação e desenvolvimento do pensamento científico e crítico.

II.3.4. Metodologia

Com este trabalho pretendemos obter alguns indicadores da relevância atribuída à NdC, particularmente aos modelos científicos e a atividades de modelação, na formação inicial de professores de Biologia e Geologia em Portugal. Para isso, foram recolhidas as fichas da unidade curricular de Didática da Geologia, ou de unidades curriculares equivalentes, dos mestrados em ensino de Biologia e de Geologia no 3º ciclo do ensino básico e do ensino secundário, das sete universidades diferentes que contemplam este mestrado. As fichas das unidades curriculares foram posteriormente analisadas, com base numa lista de verificação construída e validada para o efeito. A maioria das fichas analisadas é referente a unidades curriculares semestrais do ano letivo de 2012/2013. No entanto, por questões inerentes à universidade, uma das fichas cedidas é relativa ao ano letivo de 2011/2012.

II.3.5. Resultados

No sentido de cumprir o objetivo proposto, foram analisadas 13 fichas de unidades curriculares de Didática da Geologia (com esta ou designação análoga), de 7 mestrados em Ensino de Biologia e de Geologia no 3º ciclo do ensino básico e do ensino secundário. Apesar de em 6 dos mestrados a unidade curricular existir nos dois semestres, num dos mestrados apenas existe num. A análise irá, assim, contemplar as unidades curriculares dos dois semestres (quando existentes) de forma conjunta, sendo possível obter uma caracterização geral do programa desta unidade curricular de cada mestrado.

De acordo com a análise realizada (tabela II.3.1), é possível verificar que em apenas duas universidades é referida a abordagem aos modelos científicos, sendo pretendido que se compreenda a modelação como estratégia fundamental no ensino da Geologia. Pelo contrário, nas restantes cinco não há referência a modelos nem a atividades de modelação, facto que constitui indicador de que a modelação experimental não tem papel preponderante na formação dos futuros professores.

Relativamente à NdC, verifica-se que em cinco das universidades é dada importância à componente epistemológica na formação de professores de Biologia e de Geologia, pretendendo-se que estes desenvolvam visões contemporâneas da ciência e da sua natureza. No entanto, em apenas três se objetiva a reflexão acerca da importância da História da Ciência para a compreensão da construção do conhecimento científico e empreendimento científico. Além disso, é também possível constatar que em nenhuma das universidades é indicada a importância de uma abordagem explícita,

refletida e contextualizada da NdC em sala de aula, de forma a garantir uma transposição didática mais efetiva.

Tabela II.3.1. Aspetos analisados nas fichas das unidades curriculares.

Unidades Curriculares Módulos				1		2		3		4		5		6		7	
				I	II	I	II	I	II	I	II	I	II	I	II	I	II
Conteúdos	Natureza da Ciência	Conteúdos Programáticos/Objetivos	1. Desenvolvimento de visões contemporâneas da Natureza/Ciência/Reflexão acerca da NdC	X		X	X			X						X	
			2. Importância da NdC no Ensino das Ciências	X		X										X	
			3. Importância de uma abordagem explícita, refletida e contextualizada da NdC														
			4. Importância da História da Ciência para a compreensão da construção do conhecimento científico	X	X					X						X	X
		Bibliografia	5. Bibliografia NdC		X	X	X			X							X
	Modelos e Modelação	Conteúdos Programáticos/Objetivos	6. (Importância dos) Modelos Científicos na Geologia (nas Ciências)	X												X	
			7. Modelação como estratégia fundamental no ensino da Geologia (das Ciências)	X												X	
			8. Modelação e modelos históricos na compreensão da NdC														
		Bibliografia	9. Bibliografia Modelação		X												X
Metodologias	Construção de Modelos/Recurso à Modelação			X*													X*

*Embora não se encontre na secção da metodologia, nos objetivos é indicada a construção de modelos (projeto de modelação em Geologia).

II.3.6. Conclusões

De acordo com os resultados obtidos, podemos concluir que na formação dos futuros professores de Biologia e de Geologia é fraca a relevância atribuída aos modelos e às atividades de modelação. Da mesma forma, pouca importância é atribuída à história da ciência, aos modelos e à modelação como potenciadores da compreensão da NdC. Refira-se que foi apenas analisada a ficha da unidade curricular de Didática da Geologia, podendo os docentes das diversas universidades utilizar algum recurso didático que, por limitação proveniente do número imposto de caracteres no preenchimento destas fichas, não estivesse referido. Não obstante, a ausência à sua referência como metodologia ou estratégia didática no documento analisado, é indicador de que não é uma temática de exploração primordial. Se pretendemos que as atividades de sala de aula de Geologia espelhem a atividade dos cientistas, parece-nos relevante a importância do recurso à modelação na formação inicial de professores desta área científica.

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Torres, J., Moura, R., Vasconcelos, C., Amador, F., 2013. Nature of Science, models and earth structure model: Portuguese prospective science teachers' views. SGEM2013 Conference Proceedings, Albena, Bulgária, 8p.

II.4. Models and nature of science in science textbooks: A historical perspective

EARTH'S INTERNAL STRUCTURE MODELS IN SCIENCE TEXTBOOKS: A HISTORICAL PERSPECTIVE (OS MODELOS DA ESTRUTURA INTERNA DA TERRA NOS MANUAIS ESCOLARES: UMA PERSPETIVA HISTÓRICA)

Joana Torres & Filomena Amador

In I. Malaquias, A. Andrade, V. Bonifácio, H. Malonek (orgs.) (2015), *Perspetivas sobre Construir Ciência*, UA Editora: Universidade de Aveiro.

II.4.1. Abstract

Models and modelling are considered to be fundamental in science teaching, as they contribute to the learning of scientific content, as well as to the understanding of how to do science and of nature of science. In the same way, historical models are also crucial tools for science teaching and its analysis is relevant for the construction of an adequate image of science. As earth's internal structure model is suggested in Geoscience curriculum, we tried to describe and analyse the different phases of earth's internal structure models teaching in Portugal. For this purpose, we analysed science textbooks, from the beginning of the XX century, according to different dimensions and categories of analysis. Although earth's internal structure approaches developed throughout the century, we verified that there were some mismatches between scientific knowledge production and its inclusion in science textbooks. In science textbooks from the beginning of the XXI century, we have found some references regarding nature of science and nature of models. However, we realized that these topics are covered in distinct ways.

Keywords: History of Geology; Models, Historical Models; Earth's internal structure model; Science Textbooks; Nature of Science

II.4.2. Resumo

Os modelos assim como o próprio processo de modelação são considerados elementos fundamentais no ensino das ciências, contribuindo para a compreensão do conhecimento científico, de como se faz ciência e da natureza da ciência. Da mesma forma, também os modelos históricos se revelam ferramentas cruciais no ensino das ciências, sendo a sua análise relevante para a eventual correção de concepções incorretas de ciência. Tendo em conta que o modelo da estrutura interna da Terra é um modelo proposto no currículo de Geologia português, procurou-se descrever e analisar as diferentes fases do ensino dos modelos da estrutura interna da Terra. Com este propósito, foram analisados manuais escolares desde o início do século XX, com base em diferentes dimensões e categorias de análise. Apesar da abordagem da estrutura interna da Terra ter evoluído ao longo das décadas e se justifique algum tipo de desfasamentos entre a produção do conhecimento e a sua inclusão nos manuais escolares, existem alguns lapsos temporais particularmente longos a carecerem de ser interpretados. No início do século XXI, já se verifica a abordagem de aspetos relativos à natureza da ciência e dos modelos nos manuais escolares, embora esta ocorra de forma diferenciada.

Palavras-chave: História da Geologia; Modelos; Modelos Históricos; Modelos da estrutura interna da Terra; Manuais escolares; Natureza da Ciência

II.4.3. Introdução

Os modelos científicos desempenham um papel fundamental, quer na investigação científica, quer no ensino e divulgação das ciências. Na realidade, se os modelos podem ser considerados como ferramentas representacionais primárias (Giere, 2004), no ensino das ciências são fundamentais para os estudantes, contribuindo para a aprendizagem, não só de conteúdos, mas também para a aprendizagem “sobre ciência” e de como se “faz ciência” em contexto real (Justi & Gilbert, 2002). A análise de modelos históricos constitui um exemplo paradigmático na compreensão de como a ciência se processa e se desenvolve, sendo possível que os alunos compreendam uma diversidade de fatores que influenciam o desenvolvimento científico (Buaraphan, 2012; Justi & Gilbert, 2000; Torres et al., 2013). Quanto aos modelos da estrutura interna da Terra, foram várias as propostas que surgiram no decurso dos séculos (Deparis, 2001), estando, em alguns casos, subjacentes concepções filosóficas e religiosas. René Descartes (1596-1650), no século XVII, é considerado o primeiro filósofo a descrever o interior da Terra e a fornecer uma explicação de tipo causal para a respetiva formação, embora com caráter meramente especulativo. Ao longo dos séculos, muitos outros modelos surgiram, sendo os naturalistas influenciados por diversos fatores. No presente, ainda não há consenso relativamente ao modelo do interior da Terra, existindo uma diversidade de modelos para representar o interior do globo terrestre que são objeto de intensos debates no seio da comunidade científica. De facto, tal como refere Deparis (2001, p. 11): “a tarefa está longe de estar terminada, e as profundezas da Terra ainda não revelaram todos os seus segredos”. O modelo da estrutura interna da Terra é um exemplo de um modelo fundamental no ensino das ciências, sendo sugerido no currículo de Geologia, de diversos anos de escolaridade. Atualmente, nos programas de ciências nacionais e internacionais é também recomendado o uso adequado de modelos, assim como o desenvolvimento de concepções adequadas de ciência e da sua natureza. Pelo exposto, considerámos relevante caracterizar a evolução do ensino dos modelos da estrutura interna da Terra, no que concerne aos aspetos de conteúdo e evolução de conhecimento, mas também relativamente a aspetos epistemológicos, nomeadamente ao nível da natureza da ciência e dos modelos.

II.4.4. Metodologia

Com o objetivo de descrever diferentes fases do ensino dos modelos da estrutura interna da Terra em Portugal, foram analisados manuais do início do século XX até à atualidade (tabela II.4.1).

Os 14 manuais escolares, alvo de análise neste estudo, são referentes a diversos anos de escolaridade, sendo o mais antigo de 1917 e o mais recente de 2013. Todos os manuais analisados, teriam obrigatoriamente de integrar o estudo do interior da Terra. A análise de conteúdo focou-se em três dimensões principais: (i) modelos científicos da estrutura interna da Terra; (ii) discrepâncias entre a produção do conhecimento científico e a informação presente nos manuais; (iii) incorporação da natureza da ciência e da natureza dos modelos nos manuais. Relativamente à primeira dimensão de análise, foram também definidas cinco categorias de análise: camadas da Terra; profundidade; métodos; estado físico e dinâmica.

Tabela II.4.1. Manuais analisados neste estudo.

Período	Manual
Manuais anteriores à reforma de Carneiro Pacheco (1936)	- Gonçalves Guimarães, A. J. (1917). <i>Curso de Mineralogia e Geologia</i>. Vol. III. Braga: Livraria Cruz. - Ferraz de Carvalho, A. & Ferreira de Moura, M. M. (1928). <i>Segundo livro de Geologia. Geohistória, com um estudo geológico de Portugal</i>. Coimbra: Moura Marques & Filho. - Ferraz de Carvalho, A. & Ferreira de Moura, M. M. (1928). <i>Primeiro livro de Geologia. Geodinâmica, Geotectónica e Geognosia</i>. Coimbra: Moura Marques & Filho. - Carrington da Costa J. (1932). <i>Compêndio de Geologia para a 7ª classe dos liceus</i>. Porto: Marânus.
Manuais anteriores à reforma de Veiga Simão (1973)	- Cunha, A. G. & Sousa, C. M. (1956). <i>Compêndio de Geologia</i>. Lisboa: Livraria Popular. - Guimarães, N. & Medina, A. (1962). <i>Lições de Geologia para o 7º Ano Liceal</i>. Porto: Porto Editora. - Torre de Assunção, C. F. (1973). <i>Curso de Geologia – Ciclo complementar do ensino secundário liceal</i>. Lisboa: Direcção Geral do Ensino Secundário.
Manuais anteriores à reorganização curricular (2000)	- Baptista, P. & Silva, P. (1988). <i>Geologia: 12º Ano</i>. Vol. I. Lisboa: O Livro. - Silva, P & Baptista, P. (1989). <i>Geologia: 10º Ano: 2º ano do curso complementar</i>. Lisboa: O Livro. - Baptista, P. & Melo, M. C. A. (1992). <i>Ciências da Terra e da Vida 10º Ano</i>. Lisboa: O Livro. - Simões, M. F., Ferreira, M. N. & Silva, C. P. (1994). <i>Ciências naturais 7º Ano</i>. Lisboa: O Livro.
Manuais posteriores à reorganização curricular (2000)	- Dias da Silva, A., Gramaxo, F., Santos, M. E. & Mesquita, A. F. (2006). <i>Terra, Universo de Vida</i>. Porto: Porto Editora. - Guerner Dias, A., Guimarães, P. & Rocha, P. (2009) <i>Biologia e Geologia 10</i>. Porto: Areal Editores. - Motta, L. & Viana, M. A. (2013) <i>Viva a Terra! - Ciências Naturais - 7.º Ano</i>. Porto: Porto Editora.

II.4.5. Resultados

II.4.5.1. Modelos Científicos da Estrutura Interna da Terra

A análise dos modelos da estrutura interna da Terra foi feita de acordo com as cinco categorias de análise definidas. No entanto, neste trabalho apenas serão

indicados alguns dados relevantes resultantes dessa análise. Desta forma, foi possível verificar que os modelos científicos presentes nos manuais escolares sofreram alterações, tendo em conta a evolução do conhecimento científico. No início do século XX, o conhecimento sobre a estrutura interna da Terra era parco e pouco pormenorizado. Em 1917, considerava-se que a Terra era constituída por crusta e núcleo, sendo apresentadas algumas dúvidas relativamente ao estado físico do interior do planeta: *“A opinião geral dos geólogos, dos físicos e dos astrónomos, ainda não há meio século, era que a quase totalidade do globo, esceptuando apenas a parte esterna, numa espessura relativamente fraca, se conserva em estado de fusão ígnea (...) alguns geólogos admitem pelo contrário que o interior da Terra está todo ou quase todo no estado sólido; e a grande maioria (...) mantem-se numa prudente reserva quanto ao estado físico actual.”* (Guimarães, 1917, p. 133). No manual de 1932, de Carrington da Costa, são encontradas as primeiras referências à teoria de Wegener, encontrando-se a Terra dividida em litosfera e endosfera, sendo a endosfera constituída por pirofera e barisfera (figura II.4.1.). Por outro lado, no manual de 1956, o modelo da Terra apresentado tem um aspeto mais rudimentar, sendo constituída por atmosfera, litosfera, hidrosfera, biosfera e endosfera (figura II.4.2.).

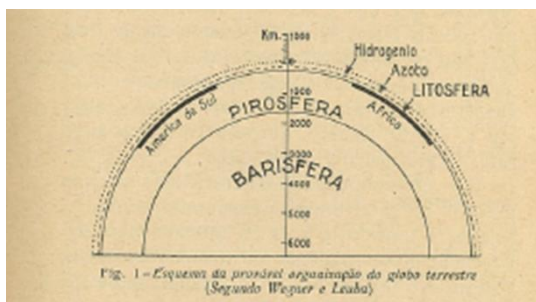


Figura II.4.1. Modelo da Terra.

Extraído de: Carrington da Costa (1932, p. 11).

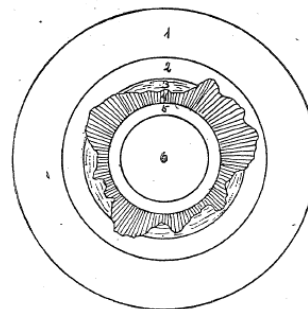


Figura II.4.2. Modelo da Terra.

Extraído de: Cunha & Sousa (1956, p.19).

Já no manual de 1973 encontramos uma diversidade de dados atualizados relativamente ao interior da Terra, quer a nível das suas camadas e respetivas descontinuidades, quer a nível do estado físico dos materiais. Neste manual, o globo terrestre encontra-se constituído por três zonas principais e concêntricas: crosta, manto e núcleo, sendo o núcleo interno considerado sólido e o externo líquido. As primeiras referências à descontinuidade de Mohorovicic são também encontradas neste livro de texto (figura II.4.3). No manual de 1988, por sua vez, são evidenciadas diversas descontinuidades (figura II.4.4), sendo feita referência à astenosfera e seu estado físico. No manual de 1994 já são apresentados dois modelos da estrutura interna da Terra, como se pode observar na figura II.4.5.

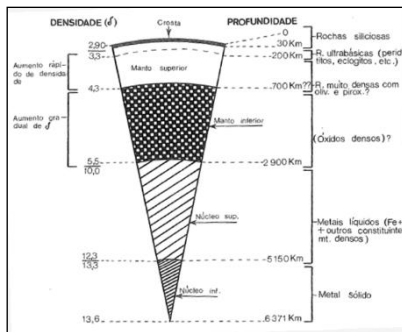


Figura II.4.3. Modelo da Terra.

Extraído de: Assunção (1973, p.32).

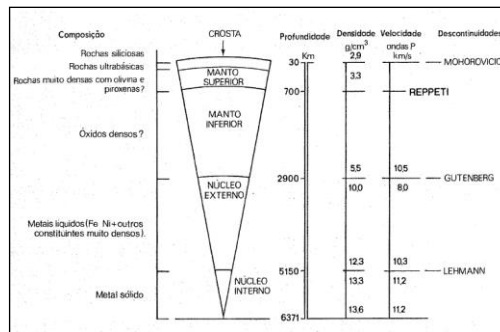


Figura II.4.4. Modelo da Terra.

Extraído de: Baptista & Silva (1988, p. 41)

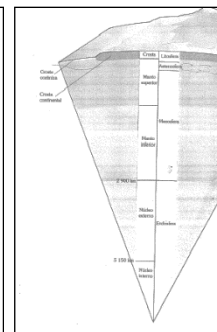


Figura II.4.5. Modelo da Terra.

Extraído de: Simões et al. (1994, p. 10).

II.4.5.2. Discrepâncias entre a produção do conhecimento científico e a informação presente nos manuais

Relativamente a esta dimensão de análise, pretendemos identificar o período que mediou entre a apresentação do modelo e sua aceitação pela comunidade científica, ou parte dela, e a respetiva inserção nos livros de textos. Este desfazamento temporal embora seja sempre expectável poderá adquirir várias dimensões. Relativamente à descontinuidade de Gutenberg o desfazamento é notório, uma vez que esta descontinuidade é sugerida em 1914, sendo apenas referenciada no manual de 1988, ou seja, passados 74 anos. A referência encontrada e relativa à descontinuidade de Mohorovicic também tem lugar 64 anos após a sua proposta. De uma forma geral, verifica-se que os manuais entre 1932 e 1962 são pouco atualizados. Por sua vez, o manual de 1973 já apresenta uma grande atualização de dados. Este facto pode ser interpretado como resultado das políticas que vigoraram durante o período ditatorial, que se traduziram, entre outros aspetos, na entrada em vigor do designado livro único para cada disciplina e ano de escolaridade. A partir de 1973, com a reforma de Veiga Simão começaram a existir os primeiros sinais de mudança que tiveram depois continuidade já no período da democracia.

II.4.5.3. Natureza dos modelos e natureza da ciência

Nesta dimensão de análise pretendeu-se procurar se os manuais apresentavam referências explícitas à natureza da ciência e, em particular, à natureza dos modelos, averiguando-se se era aproveitado o valor da História da Ciência na compreensão desses tópicos. Relativamente à natureza da ciência e à natureza dos modelos, verifica-se que estes tópicos apenas são abordados nos manuais do início do século XXI. Na

realidade, em nenhum dos manuais analisados entre 1917 e 1994 é feita qualquer referência a estes tópicos, surgindo apenas a partir do manual de 2006. Por outro lado, constata-se que nos últimos três manuais analisados (com datas de 2006, 2009 e 2013), a referência à natureza da ciência e natureza dos modelos se processa de forma distinta, sendo a própria História da Ciência abordada de forma diferente. Se por um lado, há manuais que trabalham diversos aspetos da ciência e aspetos e limitações dos modelos, há manuais que apenas lhes fazem breves referências. Da mesma forma, enquanto que há manuais que recorrem à História da Ciência para trabalhar aspetos da natureza da ciência e dos modelos, outros apenas fazem alusão a modelos e episódios históricos. A nosso ver, estes dados revelam que há mudanças recentes que ainda não estão suficientemente consolidadas. Embora a nível das orientações nacionais e internacionais a natureza da ciência e concomitantemente a própria História da Ciência surjam como elementos necessários dos currículos no domínio das ciências experimentais, verificamos que existem desfasamento entre a teoria e a praxis.

II.4.6. Conclusões

Nos manuais escolares analisados, a abordagem da estrutura interna da Terra vai-se modificando, de acordo com a evolução do conhecimento científico, embora se verifique um desfasamento entre a produção do conhecimento científico e a sua inclusão nos manuais escolares. Verifica-se em alguns casos diferenças temporais significativas a nível dos desfasamentos encontrados, que seria interessante aprofundar as causas, no sentido de tentar compreender melhor a diferença encontrada na atualização dos manuais. A partir do início do século XXI verifica-se que diversos aspetos da natureza da ciência e da natureza dos modelos são abordados nos manuais escolares. No entanto, estes aspetos são trabalhados de forma diferente nestes manuais. Se o desenvolvimento de concepções adequadas de ciência e da sua natureza e o uso de modelos e sua compreensão são considerados importantes no ensino das ciências, parece-nos crucial que todos os manuais atuais caminhem nesse sentido, relevando a natureza da ciência, assim como a natureza dos modelos e seu uso. Além disso, sendo a História da Ciência rica em debates científicos e de elevado valor didático na compreensão da natureza da ciência e dos modelos, constatamos que há um desaproveitamento desta em alguns manuais. Sendo assim, os autores consideram também que os manuais atuais deviam explorar a História da Ciência, no sentido de desenvolver as concepções de ciência dos alunos portugueses.

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CHAPTER III

Validation of the instruments and Intervention
programme

III.1. Validation of the instrument to evaluate the views of the nature of science

VIEWS OF NATURE OF SCIENCE: ADAPTATION OF A QUESTIONNAIRE FOR PORTUGUESE PROSPECTIVE SCIENCE TEACHERS (VÍSIONES SOBRE LA NATURALEZA DE LA CIENCIA: ADAPTACIÓN DE UN CUESTIONARIO PARA FUTUROS PROFESORES DE CIENCIAS)

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III.1.1. Abstract

The development of informed views related to the nature of science is currently considered a crucial (but also difficult) aim to achieve in science classes. Accordingly, it is important that teachers themselves have informed views regarding those issues. This study is part of a broader research and intends to provide evidence regarding the validity of an adapted questionnaire designed to assess how Portuguese prospective science teachers understand the nature of science, as well as to present an analysis of their views. We have concluded that the data obtained through questionnaires combined with the data gathered through interviews provide a deep understanding of the views of nature of science held by Portuguese prospective science teachers. Data analysis shows that Portuguese prospective science teachers still hold naïve views concerning the nature of science, thus suggesting the need for improvement.

Keywords: Science Education, Nature of Science, Prospective Science Teachers' views, Questionnaire, Validation.

III.1.2. Introduction

In a world strongly influenced by science, it is important that students understand what science is, what are its strengths and limitations and also how scientists work. In fact, the development of informed views of Nature of Science (NOS) constitutes a central goal for science education at both the international and national level (Abd-El-Khalick, 2006), and it is essential for the development of scientifically literate citizens (Lederman, Bartos & Lederman, 2014). It is currently understood that the development of informed views of NOS (i.e. of views that are consistent with contemporary views of NOS advocated in science education literature which are better described below) is of the utmost importance since it enhances the learning of science content, promotes a better understanding of science, increases interest in science and supports informed decision-making (McComas, Clough & Almazroa, 1998).

Although generally controversial, some science education authors believe that there are some aspects of NOS that are not contentious and that are relevant and accessible for pre-university students (Abd-El-Khalick, Bell & Lederman, 1998; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Scientific knowledge is thus considered to be empirical, subjective, tentative, partly the product of human inference, imagination and creativity and socially and culturally embedded. The distinction between observation and inference and between scientific theories and laws are also considered to be essential for the students' understanding of science (Abd-El-Khalick, 2006; Lederman et al., 2002). Moreover, it is also relevant to note that no research method is applied universally. The development of models and explanations (which are limited by our perceptions and influenced by the scientists' beliefs, imagination, creativity, experiences, training, expectations, and social context) is fundamental to the development of scientific knowledge.

Nonetheless, many studies show that students' understanding (and even teachers) of NOS is not consistent with the views previously mentioned (Bell, Blair, Crawford & Lederman, 2003; Koksal, Cakiroglu & Geban, 2013), and that teachers fail to emphasize NOS aspects in the classroom (McComas et al., 1998). As Abd-El-Khalick et al. (1998) argues, teachers' informed views of NOS are a necessary, but not sufficient, condition to effectively teach NOS. Given the relevance of NOS knowledge in a society deeply influenced by science, we consider that it is equally essential that teachers develop informed views of NOS and that they understand the relevance of teaching NOS.

This study is part of a broader research project whose aim is to improve the perceptions of NOS held by prospective science teachers, emphasising models nature in science and for science teaching. In this study, one questionnaire was adapted and

validated for Portuguese prospective science teachers from the *Views of Nature of Science Questionnaire – Form C (VNOS-C)* (Lederman et al., 2002). To verify the adaptation made, we have examined their views of NOS at the end of the curricular component of their first year as students in biology and geology teaching master's course.

III.1.3. Methodology

III.1.3.1. Participants

Seventeen prospective science teachers, enrolled in the master's course in biology and geology teaching, have voluntarily participated in this study. They had already concluded either a BSc degree in Biology (which includes 50 credits of geology-related subjects) or a BSc in Geology (which includes 50 credits of biology-related subjects) and they will teach biology and geology subjects in middle and high schools (students aged from 12 to 18). At the time of this research they were finishing the curricular component of their master's (which is a required degree to be a professional teacher), which included some scientific (biology and geology) subjects, but essentially educational subjects, such as biology and geology education and educational sciences. Considering this educational background (which implicitly includes epistemological knowledge) and the Portuguese science curriculum (which recommends the development of NOS views), it is desirable that prospective science teachers develop NOS views consistent with the contemporary views advocated in relevant science education literature. Having this in mind it is expected that they develop this view during their classes with their students. The sample included 14 females between the ages of 21 and 48 (average = 24.8 and mode = 22) and 3 males, all aged 25.

III.1.3.2. Data Sources

In order to evaluate the views of NOS held by prospective science teachers, we have developed a questionnaire, as we have mentioned before, that was mainly adapted from the *Views of Nature of Science Questionnaire – Form C (VNOS-C)* (Lederman et al., 2002). All the 10 questions were translated into Portuguese and reviewed by a translator and two experts on science education. Only one question was revised (see Appendix III.1.A, question 7) so as to relate to the respondents' scientific area. The ten open-ended questions aimed to assess the following aspects: the empirical, tentative and subjective nature of scientific knowledge; the relevance of inference, creativity and imagination in

science; its social and cultural embeddedness; the distinction between theories and laws; and the inexistence of a one and only scientific method.

Furthermore, as our intention was to assess the views of prospective science teachers regarding the relevance of history of science and the history of models in science education, question number 2 was added (Appendix III.1.A). One final question was also included, in order to analyse the ways in which the curricular component of the master's degree contributes to framing the views on NOS by prospective science teachers (see Appendix III.1.A, question 12). Follow-up interview scripts were then developed so as to clarify some answers (some examples are provided in Appendix III.1.B).

III.1.3.3. Procedures

One member of the research team has administered the questionnaire, on paper, during a geoscience education class, at the end of the prospective science teachers' curricular semester (their curricular component was almost concluded and they would start their school internship the following year). Although we had not established a time limit, the respondents took approximately forty five minutes to fill in the questionnaire. Afterwards, nine preservice science teachers (52.9%) agreed to answer to the follow-up interviews, in which they were requested to justify their answers to the questionnaire and to explain some unclear answers.

Given its acknowledged validity, we have chosen to adapt the VNOS-C questionnaire in view of the deep and meaningful analysis that it provides (Lederman et al., 2002). However, we have decided to validate this adapted questionnaire in the context in which it is used, considering the specificity of the sample and the inclusion of different questions. As a result, in order to verify if the questionnaire indeed measured what it aimed to measure, we previously analysed the answers so as to verify if respondents addressed the predefined targets regarding different aspects of NOS and to determine its validity (Table III.1.1). Follow-up interviews were then used to get a clearer understanding of the participants' views as well as to verify the researchers' analysis of the answers and establish the reliability of the questionnaire. We compared the NOS profiles generated by the separate analysis of questionnaires and interview scripts, and the discrepancies were analysed. Afterwards, data was analysed in order to reach an understanding of the views of NOS held by prospective science teachers. To guarantee coherence, this final analysis was established by resorting to the same data source, that is, by using the information provided by the questionnaires. The analysis focused on the previously defined target aspects and a comparison with the

contemporary conceptions of NOS was established. The views of NOS held by prospective science teachers were classified as “naïve”, “transitional” and “informed” categories. Informed views match current conceptions whereas naïve views do not. Participants are considered to have transitional views when they show informed views only in a few (not all) questions. The category “without information” is related to those few cases in which participants did not address the aspect under analysis.

III.1.4. Results and discussion

III.1.4.1. Validity and Reliability of the Adapted Questionnaire

Regarding the questionnaires, the respondents did not reveal difficulties in answering the questions and responded to almost all of them (only one respondent did not answer one question).

Table III.1.1. Answers to the questionnaires.

Targeted NOS aspects	Views categories	Without information n (%)	Informed Views n (%)	Transitional views n (%)	Naïve views n (%)
Empirical basis of science		1 (5.9)	4 (23.5)	3 (17.6)	9 (52.9)
Scientific method		12 (70.6)	4 (23.5)	---	1 (5.9)
General structure of experiments		---	5 (29.4)	---	12 (70.6)
Observationally based disciplines		---	6 (35.3)	---	11 (64.7)
Inferential Nature of scientific knowledge		1 (5.9)	13 (76.5)	3 (17.6)	---
Subjectivity in science		---	13 (76.5)	---	4 (23.5)
Creativity and imagination in science		---	12 (70.6)	---	5 (29.4)
Social/cultural influences		---	13 (76.5)	2 (11.8)	2 (11.8)
Tentativeness of scientific knowledge		---	7 (41.2)	---	10 (58.8)
Theories change		3 (17.6)	5 (29.4)	---	9 (52.9)
Scientific theories/laws		---	3 (17.6)	---	14 (82.3)
Scientific theories nature		3 (17.6)	4 (23.5)	2 (11.8)	8 (47.1)
Scientific theories functions		3 (17.6)	9 (52.9)	---	5 (29.4)
History of science and historical models		---	16 (94.1)	---	1 (5.9)

As shown in table III.1.1, the majority of respondents addressed the predefined targeted NOS aspects, except for the item “scientific method”. This difficulty was overcome since this item was specifically focused on the interviews (see table III.1.2). Thus, it was confirmed that questions were understandable and the respondents proved to be capable of presenting a wide range of views (Table III.1.1).

By comparing the NOS profiles generated by the separate analyses of the questionnaires and the transcripts of interviews, a high degree of congruence is achieved, as only a few discrepancies were identified (Table III.1.2).

Table III.1.2. Answers to the interviews and discrepancies between the analysis of questionnaires and interviews.

Targeted NOS aspects	Views categories	Without information n (%)	Informed Views n (%)	Transitional views n (%)	Naïve views n (%)	Discrepancies n (%)
Empirical basis of scientific knowledge		---	2 (22.2)	2 (22.2)	5 (55.6)	2 (22.2)
Scientific method		1 (11.1)	4 (44.4)	---	4 (44.4)	6 (66.7)
General structure of experiments		---	3 (33.3)	---	6 (66.7)	1 (11.1)
Observationally based disciplines		---	2 (22.2)	1 (11.1)	6 (66.7)	1 (11.1)
Inferential Nature of scientific knowledge		---	7 (77.8)	2 (22.2)	---	2 (22.2)
Subjectivity in science		---	7 (77.8)	1 (11.1)	1 (11.1)	2 (22.2)
Creativity and imagination in science		---	7 (77.8)	---	2 (22.2)	3 (33.3)
Social/cultural influences		---	8 (88.9)	---	1 (11.1)	0
Tentativeness of scientific knowledge		---	4 (44.4)	---	5 (55.6)	1 (11.1)
Theories change		---	4 (44.4)	---	5 (55.6)	1 (11.1)
Scientific theories/laws		---	---	1 (11.1)	8 (88.9)	1 (11.1)
Scientific theories nature		1 (11.1)	2 (22.2)	1 (11.1)	5 (55.6)	2 (22.2)
Scientific theories functions		1 (11.1)	3 (33.3)	---	5 (55.6)	2 (22.2)
History of science and historical models		---	8 (88.9)	---	1 (11.1)	2 (22.2)

While the discrepancies were few, it is important to analyse the ones which were identified. A high rate of discrepancies (11 – 10.2%) results from the lack of information, mainly verified in the questionnaires. For example, discrepancies related to the “scientific method” aspect result from the fact that six respondents did not address this aspect in the questionnaire (Table III.1.2). As a consequence, by analysing the interviews, four of these respondents were classified as holding a naïve view and two as holding an informed view regarding the inexistence of a single scientific method.

Also, two of the respondents revealed that they had changed their views:

Both theories and laws may be subject to change. So, maybe I changed my view (...) (Prospective teacher 8 – PT8)

Scientific experiments (...) now I think that it is something that implies the change of a variable. (PT11)

Other discrepancies (13 – 10.3%) result from the fact that more information was given during the interviews, which allowed a deeper and more consistent analysis of the respondents' views. Analysing these discrepancies, we have concluded that the

information given in the interviews was essential to dispel doubts and achieve better conclusions.

III.1.4.2. Views of nature of science

Regarding the prospective science teachers' views of NOS, a few problems were identified, especially related to the empirical basis and the tentativeness of scientific knowledge, the general structure of experiments and observationally based disciplines and the difference between theories and laws.

Empirical Basis of Scientific Knowledge

The majority of respondents did not reveal adequate understandings regarding the empirical basis of scientific knowledge. In fact, 52.9% (Table III.1.1) respondents considered that scientific knowledge is proven true based essentially on experimental evidence:

Science is based on proofs; it is not a simple belief. I think that this is the main difference between science and religion, or art, for example. (...) It is the experiment that allows one to prove or disprove a certain theory or model. (PT4)

Only 6 respondents (35.3% - 4 that were considered to have informed views and 2 transitional views) pointed out that science is a human endeavour to explain the world:

Science is a body of knowledge that allows us (in the best way we can) to explain the world that surrounds us. Science is not static, it is the result of human production; it is subjective and empirical. (PT16)

Scientific Method

Although the majority of the respondents to the questionnaires did not provide information about the (in)existence of a single scientific method, five of them made some references to this aspect, four of which considered that science does not possess a single scientific method:

Scientists do not do science through one single way; there is no single scientific method. (PT11)

On the other hand, one respondent considered that:

Yes. We only develop scientific knowledge if we rely on the scientific method and we perform scientific experiments to prove our theory, in other words, the scientific knowledge. (PT15)

However, after the analysis of the interviews it was possible to verify that a considerable percentage of respondents believed that scientists follow a single method in their research.

General structure of experiments

The description of experiments provided by prospective science teachers was generally unclear and poorly articulated. In fact, only five participants (29.4%) considered that an experiment involves the manipulation of variables:

A scientific experiment must involve manipulation of variables, data analysis, interpretation and conclusions that must be communicated and scientifically discussed with other scientists. (PT1)

It is a procedure organized by scientists where they change some variables in order to deepen the knowledge concerning certain phenomenon. (PT6)

Observationally based disciplines

Eleven (64.7%) respondents considered that experiments are required for developing scientific knowledge. However, only five respondents (29.4%) indicated that experiments involve the manipulation of variables. Two of these believed that experiments are required for developing scientific knowledge:

Yes [it requires scientific experiments], as experiments allow the exploration of facts about nature that would never be unveiled without controlled experiments. (PT6)

On the other hand, the other three referred that experiments are not required for developing scientific knowledge, further giving examples of the relevance of observation:

Scientific knowledge does not necessarily need scientific experiments. Some studies are descriptive or observational. In this context, we may point out relevant scientific contributions, such as those of James Hutton in Geology and Charles Darwin in Biology. (PT1)

Inferential Nature of scientific knowledge

Almost all participants (76.5%) recognized the role for indirect evidence and inference in the construction of scientific knowledge and scientific models:

The model of the interior of the Earth results from inferences that derive from data obtained by indirect methods (...). The definition of species is "created" (artificially) by human beings. (PT1)

This model, as it is indicated by its denomination, is just an approximated explanation model (...) (PT9)

Subjectivity in science

Regarding the subjective nature of scientific knowledge, 76.5% of the respondents considered that scientists interpret the same data (which is scarce) in distinct ways as a result of their own theoretical background and expectations, recognizing the relevance of subjectivity in science:

This is possible as human interpretations depend on the underlying theoretical background. So, two scientists may analyse the same type of data and give more relevance to different data or they may simply construct different explanations that may lead to different conclusions. (PT6)

On the other hand, 17.6% of the respondents failed to recognize the importance of interpretation according to a certain theoretical framework and considered that the dinosaur extinction controversy just results from the scarcity of data. Although it is an important factor, this deficit cannot be considered the only reason for these different interpretations, as they result from the analysis of the same (even scarce) data. However, all these interpretations, without any doubt, result from rigorous processes and from strong, coherent theoretical frameworks, besides being limited by the available data. One respondent (5.9%) surmised that scientists interpret data in different ways but did not provide any explanation for that:

I do not know, but they probably make different inferences, both equally valid. (PT14)

Creativity and imagination in Science

Despite the fact that all respondents believe that creativity and imagination are needed in the development of scientific knowledge, 29,4% of them considered that creativity and imagination are only linked to some stages of the research, such as to the planning stage:

Yes, [imagination and creativity are used] in the planning stage. During the data collection stage scientists must be as thorough as possible. (PT15)

In spite of being more relevant in some stages, as in the data interpretation stage, creativity and imagination are needed in all stages of the research in terms of the invention of explanations. Although creativity and imagination permeate all stages of the research, it does not mean that the need to be rigorous is neglected.

Social and cultural influences

The majority of the participants (76.5%) held informed views regarding social and cultural influences on science, recognizing that scientific activity is embedded in a social and cultural context:

The history of science and historical models allow the understanding of science as mutable and socially dependent (...). I consider that science reflects social and cultural values. Scientific enterprise in a country is greatly influenced by the needs of its society. For example, a country at war will invest more in weapons than in the search for a cure for AIDS. (...) (PT4)

Two participants believe that science is universal and failed to recognize that social factors influence the way scientific research is conducted:

Science is universal. Scientific knowledge that is accepted in one country should be accepted in any other country, as it was subject to many experiments before being accepted. (PT2)

Tentativeness of scientific knowledge

Although all the participants indicated that theories do change, ten respondents (58.8%) seemed to believe that laws are absolute and do not change:

In general terms, a theory is tentative, while a law is definitive. Thermodynamic laws, for example, are laws that no longer change (...). (PT10)

Theories change

Although all respondents contended that theories do change, the majority of them related this change only to technological progress and new information:

Yes, theories do change. They change because technology evolves which in turn allows the accessibility to more information. (PT5)

Difference between scientific theories and laws

Concerning the difference between scientific theories and laws, only three participants (17.6%) held informed views and considered that scientific theories and laws are distinct forms of scientific knowledge:

Yes, there is [a difference between scientific theories and laws]. A law has less coverage than a theory. In general, a theory explains or integrates diverse laws. Furthermore, a law is based on more observations, while a theory constitutes an endeavour to explain these observations. For example,

the law of gravity tells us that two objects attract each other, whereas the theory explains why. (PT3)

The majority of respondents (76.5%) held naïve views concerning this aspect. In fact, one of the respondents expressed a hierarchical relationship between theories and laws while others indicated that theories are more certain than laws. 58.8% of the respondents believed that laws are more certain than theories, and one of them mentioned that theories become laws:

A theory may be reformulated. This theory, when considered to be true, may become a scientific law. A scientific law is considered to be true (...).
(PT13)

The nature of scientific theories

The majority of respondents held naïve views concerning the nature of scientific theories and only six respondents (35.3%) recognized that theories are explanations of phenomena. Moreover, only four out of these six recognized that theories are well-supported systems of explanation:

The scientific theories that we learn are explanations of our reality, of our time (...). A scientific theory is scientifically accepted. (PT1)

Although considering that theories are explanations of our world, the other two did not ascribe them any robustness.

Functions of scientific theories

When asked about the usefulness of learning scientific theories, nine respondents held informed views: 29.4% (n=5) of the respondents recognized that theories provide a theoretical framework that allows the understanding of current knowledge; 11.8% (n=2) considered that scientific theories provide a theoretical framework for future investigations and 11.8% (n=2) recognized that scientific theories have both functions. On the other hand, 29.4% (n=5) of the respondents considered the learning of scientific knowledge only as a contribution to the understanding of how science develops (Table III.1.1).

The history of science and historical models

Regarding the relevance of history of science and historical models in science education, almost all prospective science teachers have indicated that they contribute to the understanding of how scientific knowledge develops:

History of science is important in science teaching for students to understand scientific knowledge development, how this development occurs

and how society influences and is influenced by this process. In other words, it is essential for students to understand the nature of science. (PT3)

However, one respondent only emphasized its contribution to the better understanding of scientific knowledge.

The change of their views about science

Regarding the last question, 64.7% of the respondents indicated that they changed their views about science at the end of the academic year, mainly due to the classes that they had attended. From these, two respondents believed that they only pondered their views, two that they had deepened their views, and five acknowledge that they had changed their views about science, namely regarding the tentative and subjective nature of science and the social and cultural influences.

III.1.5. Conclusions

The results of this study hold a high confidence level on the validity and reliability of the adapted questionnaire to assess the views of NOS by Portuguese prospective science teachers. We have also verified that follow-up interviews were of the utmost importance, as they enable the understanding of views that were not focused on in the questionnaire. Furthermore, as argued by Lederman et al. (2014), the use of follow-up interviews is crucial to get the most valid data possible, as they allow a deeper understanding of the answers given by prospective teachers and a more consistent analysis of the respondents' views.

In this study, we have verified that Portuguese prospective science teachers hold naïve views concerning some NOS aspects, especially related to the following ones: the empirical and tentative nature of scientific knowledge; scientific method and general structure and coverage of experiments; difference between theories and laws. In the same way, in a study conducted by Liu & Lederman (2007) with Taiwanese prospective science teachers, it was also verified that they generally hold naïve views concerning NOS aspects. For example, all of them have naïve views on the relationship between theories and laws and a great majority did not demonstrate adequate understandings about the empirical basis and the tentativeness of scientific knowledge. Moreover, in a study conducted with fifteen Turkish preservice science teacher educators, the majority of the participants revealed inadequate views concerning NOS, being the “scientific method” and “tentative nature of scientific knowledge” the most problematic aspects (Irez, 2006). Likewise, in a study conducted with Portuguese university students it was revealed that they do not held informed views regarding NOS, so the need to improve

NOS instruction in Portuguese educational institutions has been emphasized (Figueiredo & Paixão, 2010). Accordingly, it was also verified, in two pilot studies previously done (Torres & Vasconcelos, 2015; Torres, Moutinho & Vasconcelos, 2015), that Portuguese prospective science teachers, in-service teachers and students hold naïve views concerning some NOS aspects. However, this adapted and validated questionnaire provided an in-depth understanding of the views of NOS by Portuguese prospective science teachers.

Given the relevance of NOS for Science Teaching, we believe that it is crucial to deeply understand and improve the views of NOS by Portuguese science teachers.

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Appendix III.1.A. Adaptation of the “Views of Nature of Science Questionnaire”, Form C (VNOS-C) (Lederman et al., 2002)

Question 1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g. religion, philosophy, or art)?

Question 2. What is the relevance of history of science and historical models for science education?

Question 3. What is an experiment?

Question 4. Does the development of scientific knowledge require experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

Question 5. After scientists have developed a scientific theory (e.g., cell theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:
 - (i) Explain why theories change.
 - (ii) Explain why we bother to learn scientific theories. Defend your answer with examples.

Question 6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example

Question 7. Science textbooks often represent the interior of the Earth as a set of concentric layers with distinct characteristics. How certain are scientists about the structure of the interior of the Earth? What specific evidence, or types of evidence, do you think scientists used to determine how the interior of the Earth looks like?

Question 8. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

Question 9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the Earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

Question 10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
 - If you believe that science is universal, explain why and how. Defend your answer with examples.
-

Question 11. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Question 12. After the classes that you attended during this academic year, do you consider that you have changed your views of the nature of science?

- If so, identify and explain the main changes and the main reasons (and sources) for those changes.
-

Appendix III.1.B. VNOS Interview Protocol

1. Can you read and better explain your answer?
2. What do you mean by (...)?
3. How does your answer to *question a* relates to your answer to *question b*?
4. Have your views changed since you wrote your answer? If so, how?
5. (...)

III.2. Validation of the instrument to evaluate views about models

DEVELOPMENT AND VALIDATION OF AN INSTRUMENT FOR ANALYSING TEACHERS' VIEWS ABOUT MODELS (DESARROLLO Y VALIDACIÓN DE UN INSTRUMENTO PARA ANALIZAR LAS VISIONES DE LOS PROFESORES SOBRE MODELOS)

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Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 14 (1), 181-198.

III.2.1. Abstract

Many studies reveal that models and modelling activities are fundamental in science teaching. However, there are also many studies that show that science teachers do not hold adequate views regarding models in science and for teaching. This study is part of a broader research and intends to present a theoretically grounded instrument (a questionnaire) developed for analysing the teachers' views about models and modelling. The instrument was applied to seventeen prospective science teachers, students of the master in Biology and Geology Teaching, which voluntarily participated in this study. Inter-rater agreement and data from interviews were used in order to validate the instrument. The result of the analysis show that the instrument is able to reveal differences among teachers' views and that it is possible to attain a deep analysis of their views regarding models in science and for teaching through the combined analysis of data (obtained through questionnaires and interviews). Data analysis also reveals that prospective science teachers hold naïve views regarding models and that they do not value all models potentials in science teaching, suggesting the need for improving prospective teachers' views regarding those aspects.

Keywords: Models, Modelling, Prospective Science Teachers' views, Questionnaire, Validation.

III.2.2. Resumen

Diversos estudios ponen de manifiesto que el uso de modelos y el recurso a actividades de modelización son fundamentales en la enseñanza de las ciencias. Sin embargo, también son varios los estudios que demuestran que los profesores de ciencias no revelan visiones adecuadas sobre los modelos en la ciencia y para la enseñanza de las ciencias. Este estudio, parte integrante de un proyecto más amplio, pretende presentar un instrumento (en forma de cuestionario) fundado en bases teóricas sólidas, desarrollado para analizar las visiones de los profesores sobre modelos y modelización. El instrumento se aplicó a diecisiete futuros profesores de ciencias, estudiantes del máster en enseñanza de la Biología y la Geología, quienes participaron de manera voluntaria en este estudio. El acuerdo entre los evaluadores y los datos de las entrevistas se usaron para validar el instrumento. Los resultados de los análisis muestran que el instrumento es capaz de revelar diferencias entre las visiones de los profesores y, que es posible llegar a un análisis profundo acerca de sus visiones sobre modelos en la ciencia y para la enseñanza a través del análisis conjunto de los datos (obtenidos por medio de las respuestas a los cuestionarios y a las entrevistas). El análisis de los datos da a conocer también que los futuros profesores de ciencias tienen visiones ingenuas sobre los modelos y que no valoran todas las potencialidades de los mismos en la enseñanza de las ciencias, sugiriendo la necesidad de mejorar sus visiones sobre estos aspectos.

Palabras claves: Modelos, Modelización, Visiones de futuros profesores de ciencias, Cuestionario, Validación.

III.2.3. Introducción

Aunque los modelos científicos sean muy diversos y presenten diferentes definiciones, su relevancia para el progreso del conocimiento científico es innegable. De hecho, si se pretende que los alumnos desarrollen no solo su conocimiento científico sino también sus capacidades investigativas y la comprensión de cómo la ciencia se procesa, se hace esencial el recurso a los modelos en las clases de ciencias. Sin embargo, para que se usen modelos de forma adecuada en las clases de ciencias, es necesario que los profesores entiendan todas sus potencialidades (Oh y Oh, 2011) y su contribución en el desarrollo cognitivo, epistemológico y en el desarrollo de destrezas científicas de sus alumnos.

A pesar de toda la importancia concedida actualmente a los modelos en la enseñanza de las ciencias, algunos estudios ponen de manifiesto que los alumnos, e incluso los profesores, no revelan un conocimiento adecuado sobre modelos en la ciencia y para la enseñanza de las ciencias (Khan, 2011). En efecto, los profesores no suelen usar modelos y desarrollar actividades de modelización en las clases de ciencias, ni tan poco son conscientes de todo su potencial. De este modo, consideramos relevante mejorar las visiones de los profesores y de los futuros profesores de ciencias sobre modelos para que estén en la capacidad de utilizar todas sus potencialidades.

Este trabajo hace parte de un estudio más amplio que pretende mejorar las visiones de los futuros profesores de ciencias sobre la naturaleza de la ciencia, enfatizando la naturaleza de los modelos en la ciencia y para la enseñanza de las ciencias. De hecho, para que se consiga evaluar el mejoramiento de las visiones de futuros profesores de ciencias de estos aspectos, desarrollamos dos cuestionarios - uno que evalúa las visiones sobre la naturaleza de la ciencia (Torres y Vasconcelos, 2016) y otro las visiones sobre los modelos. Con este trabajo, pretendemos validar el cuestionario sobre modelos y modelización para aplicárselo a futuros profesores portugueses de ciencias, así como examinar sus visiones sobre los modelos en el final de la componente curricular de su máster en Enseñanza de las Ciencias (Biología y Geología).

III.2.4. Marco teórico

A continuación, presentamos los principales conceptos orientadores de este trabajo, o sea, el concepto de *modelo científico* y el concepto de *modelo en la enseñanza de las ciencias*.

III.2.4.1. Los modelos científicos

Los modelos científicos son extremadamente importantes en la actividad científica, siendo considerados las herramientas de representación primarias en las ciencias (Giere, 2004). De hecho, Chamizo (2013) afirma que una de las principales actividades de los científicos es evaluar qué modelos se ajustan mejor a las evidencias disponibles, buscando la explicación más plausible para un cierto fenómeno (Chamizo, 2013; Driver, Newton y Osborne, 2000).

A pesar de las innumerables definiciones de modelos científicos y de la diversidad de tipos de modelos científicos existentes, podemos decir, en términos globales, que un modelo científico es una representación de determinados aspectos del mundo, de acuerdo con un objetivo específico (Chamizo, 2010; Chamizo, 2013; Giere, 2010). Así, el modelo es una representación intencional y simplificada, ya que resulta de la intención, interpretación y conocimiento del científico. Teniendo en consideración la concepción intencional de la representación científica de Giere (2010), se hace evidente que existan modelos múltiples para estudiar diferentes aspectos del mismo sistema, ya que el científico selecciona los aspectos que pretende estudiar. Del mismo modo, también pueden existir diferentes modelos para estudiar el mismo aspecto del mundo, porque los científicos pueden tener ideas diferentes y pueden socorrerse de recursos distintos para construirlos (Oh y Oh, 2011).

Los modelos científicos tienen un papel relevante en la progresión del conocimiento científico, siendo usados en la descripción, explicación y previsión de fenómenos. Estos son también considerados recursos visuales fundamentales, ya que ayudan en la comprensión y en la comunicación del conocimiento (Oh y Oh, 2011).

Sin embargo, los modelos tienen especificidades propias, de acuerdo con el área científica de estudio. Por ejemplo, Sibley (2009) destaca la importancia de los modelos en la Geología para el establecimiento de inferencias sobre eventos pasados. Los modelos y la modelización también son considerados muy importantes en la Biología (Krell y Krüger, 2015), siendo pertinente destacar la relevancia de los organismos modelo en la investigación biomédica y en la investigación biológica básica (Ankeny, 2007; Hubbard, 2007).

III.2.4.2. Los modelos en la enseñanza de las ciencias

Teniendo en consideración la relevancia de los modelos en la actividad científica, nos parece fundamental la inclusión de modelos y de actividades de modelización en las clases de ciencias, de forma a reflexionar sobre la actividad de los científicos. En

realidad, son varios los autores que defienden el uso de modelos y de actividades de modelización en las clases de ciencias. Por ejemplo, Halloun (2007), en un estudio con alumnos de educación secundaria y superior, verificó que la construcción de modelos promueve un mejor desarrollo conceptual; un mejor desempeño en los exámenes; el desarrollo de concepciones adecuadas de la naturaleza de la ciencia; un aprendizaje más equitativo; el desarrollo de competencias de investigación y de estilos de aprendizaje estables. Pujol y Márquez (2011) destacan la relevancia de la construcción de modelos en las clases de ciencias por los alumnos en el desarrollo de procesos de autorregulación, posibilitando el reconocimiento de su aprendizaje, de sus errores y evolución y la capacidad de decidir los pasos a seguir para mejorar su proceso de aprendizaje. Koponen y Tala (2014) también consideran que los modelos son fundamentales en la educación en ciencias, subrayando su relevancia en el desarrollo de visiones adecuadas de ciencia, en el desarrollo de la creatividad y en la construcción del conocimiento científico.

En efecto, los modelos son muy importantes para que los alumnos desarrollen modelos mentales adecuados, ya que las representaciones visuales facilitan la argumentación de los alumnos y el pensamiento con sus representaciones mentales. Además, los modelos permiten que los alumnos desarrollen competencias de investigación y que comprendan aspectos distintos de la naturaleza de la ciencia, incluso la importancia de los modelos en la ciencia (Torres y Vasconcelos, 2015; Torres y Vasconcelos, *in press*). Gilbert y Ireton (2003) refieren que el uso de modelos es también importante para el reconocimiento, que es poco probable que sepamos todo lo que hay que saber sobre el mundo que habitamos.

Dada la relevancia de los modelos en la ciencia y en la enseñanza de las ciencias, Oh y Oh (2011), basados en una revisión teórica de la literatura, resaltan 5 aspectos sobre modelos que los profesores de ciencias deben saber:

- (i) *Significado de modelo* (como representación de un aspecto de la realidad, sirviendo como un mediador conectando una teoría y un fenómeno);
- (ii) *Propósito del modelo* (un modelo científico describe, explica y prevé aspectos de la realidad, siendo importante en la comunicación de ideas científicas a los demás);
- (iii) *Multiplicidad de los modelos* (son necesarios varios modelos para explicar un fenómeno, ya que cada uno de los modelos científicos representa aspectos específicos del mismo. Además, pueden existir modelos múltiples como consecuencia de diferentes ideas de los científicos y de los diferentes recursos usados);

- (iv) *Cambio en los modelos* (los modelos científicos cambian de conformidad con la evolución del conocimiento científico);
- (v) *Uso de los modelos en las clases de ciencias* (los profesores pueden explicar conocimiento complejo con modelos, pero los alumnos también pueden tener un papel activo).

Así, en este trabajo el modelo científico es considerado como una representación simplificada, intencional, provisoria y no exclusiva de la realidad (objeto, proceso o idea), y no como una copia de la misma. Además, el modelo científico es reconocido como fundamental en la construcción del conocimiento científico, permitiendo describir, explicar y prever diferentes aspectos de la realidad.

Respecto a la enseñanza de las ciencias, es importante destacar que los modelos usados en las clases de ciencias son simplificaciones de los modelos científicos, que generalmente son muy complejos. El uso de estas simplificaciones ayuda a los alumnos a desarrollar el conocimiento científico, teniendo como punto de partida su conocimiento (Izquierdo-Aymerich y Adúriz-Bravo, 2003; Justi, 2006). En relación a este tema, Justi (2006) distingue modelos curriculares de modelos para la enseñanza. Mientras que los modelos curriculares son simplificaciones adecuadas de los modelos científicos, los modelos para la enseñanza son representaciones que ayudan a los alumnos a entender algún aspecto particular de un modelo curricular. Del mismo modo, es pertinente referir que la importancia de los modelos en la enseñanza de las ciencias se relaciona no solo con el desarrollo de conocimiento científico de los alumnos, sino también con el desarrollo de capacidades investigativas y de visiones adecuadas sobre la naturaleza de la ciencia. De hecho, es importante que los profesores de ciencias valoren todas estas potencialidades a través del uso y construcción de modelos, sin olvidar las limitaciones inherentes de los modelos. Es igualmente importante que los profesores comprendan que para que los alumnos construyan modelos, son necesarias tres condiciones fundamentales: (i) conocer lo máximo posible sobre ese aspecto del mundo; (ii) seleccionar los aspectos importantes de acuerdo con el propósito; y (iii) tener imaginación y creatividad (Chamizo, 2013).

A pesar de toda la relevancia concedida a los modelos en la enseñanza de las ciencias, Raviolo, Ramírez y López (2010) afirman que los alumnos no revelan visiones adecuadas sobre lo que “son los modelos, sus características, sus funciones y limitaciones” (p. 593). Incluso los profesores presentan visiones limitadas sobre el papel de los modelos en la ciencia y en la enseñanza de las ciencias (Gutierrez y Pintó, 2009; Danusso, Testa y Vicentini, 2010; Khan, 2011; Krell, Upmeier zu Belzen y Krüger, 2012). Además, se verifica que los profesores de ciencias no recurren a la modelización de forma sistemática (Danusso, Testa y Vicentini, 2010; Khan, 2011) y cuando lo hacen, no

aprovechan todas las potencialidades de los modelos, es decir, apenas los utilizan en la comprensión de conceptos científicos (Khan, 2011; Krell y Krüger, 2015; Raviolo et al., 2010). En un estudio con profesores de Biología, Química y Física, Van Driel y Verloop (1999) concluyeron que los profesores tenían un conocimiento limitado e inconsistente sobre modelos. Justi y Gilbert (2002) en un estudio con profesores de ciencias brasileños también indican que los profesores no tenían un conocimiento profundo sobre modelos, valorando el papel de los modelos en el aprendizaje de las ciencias, pero sin valorar su papel en el aprendizaje sobre ciencia, es decir sobre la naturaleza de la ciencia. Estos autores también se refieren a que muchos profesores no prestan atención a las ideas de sus alumnos sobre modelos.

Teniendo en cuenta la relevancia dada actualmente a la comprensión de la naturaleza de la ciencia (que obviamente incluye la naturaleza de los modelos) y a la participación activa de los alumnos en actividades de modelización (permitiendo que estos desarrollen una diversidad de capacidades fundamentales, ya previamente mencionadas), consideramos pertinente que se desarrollen actividades de modelización en las clases de ciencias. De este modo, consideramos fundamental que los profesores de ciencias comprendan qué son los modelos científicos y los modelos para la enseñanza de las ciencias y principalmente que comprendan su importancia en la enseñanza de las ciencias, para usarlos de forma eficaz.

De hecho, este estudio tiene un propósito doble. El principal objetivo de este estudio es validar el cuestionario sobre modelos y modelización para que sea aplicado a futuros profesores portugueses de ciencias. Además, pretendemos obtener algunos indicadores acerca de sus visiones sobre los modelos en el final del componente curricular de su máster en Enseñanza de las Ciencias (Biología y Geología).

III.2.5. Metodología

III.2.5.1. Contexto y muestra

En este trabajo realizamos un cuestionario e hicimos una entrevista a los futuros profesores de ciencias (Biología y Geología) al final de la parte curricular de su máster, en el ámbito de la asignatura Didáctica de la Geología. En ese momento, los estudiantes estaban terminando la parte curricular de su máster y tendrían que realizar su práctica profesional al año siguiente.

Diecisiete futuros profesores de ciencias, estudiantes del máster en enseñanza de la Biología y la Geología, participaron, de manera voluntaria, en este estudio. La muestra del estudio estaba formada por 14 futuros profesores del sexo femenino, con edades

comprendidas entre los 21 y 48 años (media = 24.8 y moda = 22), y 3 del sexo masculino, todos con 25 años. Estos estudiantes tenían un grado en Biología - que incluía un total de 50 ECTS (*European Credits Transfer System* - Sistema Europeo de Transferencia de Créditos) de asignaturas de Geología - o un grado en Geología (que incluía un total de 50 ECTS de asignaturas de Biología) y estaban terminando la parte curricular de su máster en Enseñanza de Biología y Geología. En efecto, después de los acuerdos de Bolonia, para dar clases de Biología y Geología en la educación secundaria obligatoria y en el bachillerato, los estudiantes tienen que tener un grado en Biología (con formación complementaria en Geología) o en Geología (con formación complementaria en Biología) y un máster en Enseñanza de Biología y Geología. Los grados de Biología o Geología se divide en tres cursos académicos distribuidos en seis semestres, mientras que el máster se divide en dos cursos académicos (el primero está enfocado a la parte curricular y el segundo se centra en la práctica profesional en las escuelas).

III.2.5.2. Fuentes de datos

Para evaluar a los futuros profesores de ciencias respecto a sus visiones acerca de modelos en la ciencia y para la enseñanza de las ciencias, así como sus concepciones sobre el uso de los modelos en las clases de ciencias, desarrollamos un cuestionario después de un análisis exhaustivo de artículos científicos relevantes (Justi y Gilbert, 2002, 2003; Jee et al., 2010; Oh y Oh, 2011; Chamizo, 2013). Este cuestionario, formado por preguntas de respuesta abierta, tuvo como base estos artículos y los conceptos que orientan la evolución de este trabajo, descritos anteriormente en el marco teórico. La primera parte del cuestionario (Apéndice III.2.A – desde la pregunta 1 hasta la 8) pretende evaluar las visiones sobre los modelos científicos en la ciencia (su concepto y sus propósitos) y para la enseñanza de las ciencias (su importancia en la enseñanza de las ciencias y sus características). La segunda parte del cuestionario (Apéndice III.2.A – desde la pregunta 9 hasta el final) pretende evaluar las concepciones sobre el uso de modelos en las clases de ciencias y los cuidados a tener en su uso. Se construyeron guías de entrevistas (aplicadas posteriormente a los cuestionarios), solicitando explicaciones y aclaraciones de las respuestas y algunas informaciones adicionales (algunos ejemplos facilitados en Apéndice III.2.B).

III.2.5.3. Procedimientos

Los cuestionarios, en soporte de papel, se administraron por un elemento del equipo de investigación en una clase de la asignatura Didáctica de la Geología, al final de la parte curricular de su máster (los estudiantes realizarían su práctica profesional al año siguiente). Aunque no se haya establecido un límite de tiempo, los estudiantes tardaron cerca de 25 minutos para rellenar el cuestionario. Posteriormente, 9 estudiantes (52.9%) aceptaron participar en las entrevistas, 7 del sexo femenino (con media de edades de 22,1 años) y dos del sexo masculino, los dos con 25 años. En las entrevistas, a los estudiantes, que tenían sus cuestionarios (previamente cumplimentados), se les pidió que leyese sus respuestas y que explicasen, profundizasen y justificasen las respuestas dadas y aclarasen algunas ideas o expresiones que suscitaban dudas.

Las preguntas de los cuestionarios y de las entrevistas fueron seleccionadas de acuerdo a nuestros objetivos y de acuerdo a la revisión de literatura efectuada. Por ejemplo, parte de las preguntas fueron adaptadas de los trabajos de Justi y Gilbert (2002, 2003) y de Danusso, Testa y Vicentini (2010) y otras fueran añadidas por los autores (Tabla III.2.1).

Tabla III.2.1. Fuente de datos para la elaboración del cuestionario.

Cuestión(es)	Fuente de datos
1	Adaptado de Danusso et al. (2010).
2	Adaptado de Danusso et al. (2010) y Justi y Gilbert (2003).
3	Añadida por los autores, basada en el trabajo de Oh y Oh (2011).
4	Añadida por los autores, basada en los trabajos de Oh y Oh (2011) y Justi y Gilbert (2003).
5, 8, 9, 10, 12 e 13	Adaptado de Justi y Gilbert (2002).
6	Añadida por los autores, basada en los trabajos de Justi (2006) y Justi y Gilbert (2002).
7	Añadida por los autores, basada en los trabajos de Chamizo (2013).
11	Añadida por los autores, basada en los trabajos de Justi y Gilbert (2002).
14	Añadida por los autores, para comprender la influencia de las clases en sus visiones sobre modelos.

Aunque muchas preguntas hayan ya sido utilizadas en estos cuestionarios, quisimos validar el cuestionario para el contexto portugués. De hecho, la construcción del cuestionario se basó en un análisis de contenido de publicaciones especializadas (ya mencionadas anteriormente). Además, este fue también validado por dos

especialistas en enseñanza de las ciencias. A tal efecto, los dos especialistas rellenaron el cuestionario, respondiendo a lo que queríamos analizar y conforme a lo que es defendido en los estudios científicos actuales, apoyando así la validez del cuestionario (Lederman, Abd-El-Khalick, Bell y Schwartz, 2002). Los dos especialistas respondieron igualmente en momentos distintos (con un intervalo de tres meses) y respondieron de forma idéntica a los dos cuestionarios (es decir, el análisis de sus respuestas resultó idéntica, revelando visiones idénticas), contribuyendo a garantizar la fiabilidad del cuestionario.

Como los especialistas respondieron a lo que queríamos analizar, de acuerdo con lo defendido actualmente, y las respuestas fueron consistentes a lo largo del tiempo, el cuestionario fue posteriormente aplicado a 16 futuros profesores, como un estudio de seguimiento para garantizar la validez y fiabilidad del instrumento. Así, para comprobar que el cuestionario mide lo que pretendemos, analizamos las respuestas para verificar si los estudiantes responden a los aspectos previamente definidos (tabla III.2.2). El análisis de la primera parte del cuestionario se encuentra en la tabla III.2.3. Con las entrevistas hechas posteriormente, que permiten obtener una comprensión más clara de las visiones de los participantes (acerca de la naturaleza de los modelos científicos y su importancia en la enseñanza de las ciencias), fue posible garantizar la validez y la fiabilidad del cuestionario en el contexto donde es utilizado (Lederman et al., 2002) (a través de la comparación del análisis de las respuestas dadas en la entrevista con el análisis de los investigadores a las respuestas dadas en el cuestionario). Estos análisis se hicieron por separado y después se analizaron las discrepancias (Torres y Vasconcelos, 2016). Esto significa que, después de analizar los datos de los cuestionarios y de las entrevistas de forma independiente, se compararon los resultados obtenidos para las diferentes dimensiones de análisis definidas, analizándose el grado de congruencia. Así es posible reafirmar la fidelidad del cuestionario al comparar el análisis hecho a partir de los cuestionarios y de las transcripciones de las entrevistas y obteniéndose un grado de congruencia elevado. Además, los datos obtenidos a partir de las entrevistas generalmente ayudan a alcanzar el consenso.

A partir de los análisis, surgieron algunos aspectos interesantes en respuestas de algunos estudiantes, por lo que se consideró útil añadir algunas cuestiones sencillas, pero más específicas, para permitir analizar esos aspectos específicos con mayor profundidad. El cuestionario final fue aplicado a uno de los estudiantes que pertenecía al grupo inicial pero no había participado anteriormente. Como las preguntas eran sencillas y se obtuvo fácilmente una comprensión de su visión relativamente a los aspectos en cuestión, concluimos que se podrían añadir estas cuestiones al cuestionario final.

Tabla III.2.2 Aspectos evaluados y sus categorías.

Aspectos evaluados \ Categorías	Visiones informadas	Visiones ingenuas
Concepto de modelo científico	Como una representación de la realidad.	El modelo como una copia de la realidad. El modelo como una herramienta para usar en la escuela.
Propósitos de los modelos científicos	Los modelos son fundamentales para la construcción del conocimiento científico. Sirven para describir, y explicar, pero también para prever.	Los modelos son usados solo para describir o explicar aspectos de la realidad.
Importancia de los modelos en la enseñanza de las ciencias	Además de promover la comprensión del conocimiento científico, los modelos promueven la comprensión de la naturaleza de la ciencia y el desarrollo de capacidades investigativas.	Los modelos son usados en las clases de ciencias solo para promover la comprensión del conocimiento científico.
Diferencias entre modelos científicos y modelos para la enseñanza de las ciencias	Los modelos para la enseñanza de las ciencias son más simples que los modelos científicos.	Los modelos para la enseñanza de las ciencias deben ser iguales a los modelos científicos.

Posteriormente, se analizaron los datos a fin de obtener una comprensión de las visiones de los estudiantes (futuros profesores) sobre modelos. Para esto, usamos esencialmente los datos obtenidos a través de los cuestionarios, para garantizar la consistencia del análisis, ya que sólo algunos estudiantes participaron en las entrevistas. Las visiones de los futuros profesores fueron clasificadas en categorías diferentes: “*visiones ingenuas*”, cuando las visiones de los futuros profesores no corresponden a las visiones actualmente defendidas; “*visiones informadas*”, cuando sus visiones se asemejan a las visiones actualmente defendidas; y “*sin información*”, cuando los estudiantes no mencionaron el aspecto bajo consideración (tabla III.2.2).

El análisis de la segunda parte del cuestionario se desarrolló de forma muy similar a la de la primera. Para los aspectos analizados también se analizaron de un modo separado las respuestas dadas a los cuestionarios y a las entrevistas (siendo las discrepancias posteriormente analizadas). A continuación, analizamos las concepciones de los estudiantes sobre el uso de modelos en las clases de ciencias, recurriendo también a los datos de los cuestionarios. Con este último análisis es posible comprender mejor las visiones de los estudiantes sobre el uso de los modelos en las clases de ciencias, pero también (y principalmente) comprender qué aspectos de los modelos son valorados y qué guiará sus opciones en el uso de modelos en las clases de ciencias.

III.2.6. Resultados

Los estudiantes, futuros profesores de ciencias, no tuvieron dificultades para rellenar el cuestionario, contestando a casi todas las preguntas (solo uno no respondió a una pregunta).

III.2.6.1. Primera parte del cuestionario

En relación a la primera parte del cuestionario y a través del análisis de la tabla III.2.3, se verifica que la mayoría de los estudiantes enfocó los aspectos evaluados, o sea, ha sido posible clasificar sus visiones de acuerdo con las diferentes dimensiones de análisis definidas. Solo tres estudiantes no enfocaron el concepto de modelo científico (sus respuestas fueron tan poco claras, que no ha sido posible clasificar sus visiones a través de sus respuestas en el cuestionario) y solo uno no dio información sobre los propósitos de los modelos científicos. Sin embargo, a través del análisis de las entrevistas, se verifica que los estudiantes enfocaron los aspectos que faltaban, es decir, a través de las respuestas a las entrevistas ha sido posible clasificar sus visiones y clarificar algunos aspectos (Tabla III.2.4). De manera general, las cuestiones fueron comprendidas por los estudiantes y desencadenaron respuestas que traducen diferentes visiones (Tabla III.2.3).

Tabla III.2.3. Análisis de las respuestas dadas a los cuestionarios (primera parte – n=17).

Aspectos evaluados	Categorías	Sin información	Visiones informadas	Visiones ingenuas
		n (%)	n (%)	n (%)
Concepto de modelo científico		3 (17.6)	11 (64.7)	3 (17.6)
Propósitos de los modelos científicos		1 (5.9)	4 (23.5)	12 (70.6)
Importancia de los modelos en la enseñanza de las ciencias		---	6 (35.3)	11 (64.7)
Diferencias entre modelos científicos y modelos para la enseñanza de las ciencias		---	17 (100)	---

Son pocos los resultados discrepantes que se obtienen, comparando los resultados obtenidos a través del análisis de los cuestionarios y a través de las entrevistas (Tabla III.2.4). Además, las tres visiones discrepantes obtenidas en el primer aspecto resultan de falta de información sobre el aspecto evaluado en el cuestionario (categoría sin información). Sin embargo, se verificó que, con las entrevistas, fue posible

evaluar la visión de estos tres estudiantes sobre modelos científicos. De hecho, estas tres visiones discrepantes corresponden a tres estudiantes que en el cuestionario no facilitaron información suficiente para concluir acerca de sus visiones sobre el concepto de modelo científico (fueron evaluadas como “sin información”) y en la entrevista añadieron información, siendo posible concluir acerca sus visiones (las discrepancias en la tabla III.2.4 resultan de resultados distintos a partir del análisis de los cuestionarios y de las entrevistas).

El segundo aspecto evaluado fue el que causó más discrepancias (5). Pero una de ellas también se debe a que un estudiante no enfocó este aspecto en el cuestionario, siendo posible evaluar su visión a través de la entrevista. Las restantes discrepancias (4) están relacionadas con el hecho de que las respuestas en las entrevistas son más amplias (garantizando un análisis más profundo) y también con el cambio de opinión de los estudiantes. Por ejemplo, a este respecto, uno de los estudiantes, al comparar la respuesta dada en el cuestionario con la respuesta dada en la entrevista, reconoce que la ha alterado un poco, añadiendo más información:

“Efectivamente, yo he añadido un dato, porque había contestado en términos de clases y, pues, he añadido...” (Entrevista del respondiente 6 - En6)

Del análisis del tercer aspecto, surgió una discrepancia que se debe también a respuestas con diferentes grados de profundidad. No obstante, se verifica que las respuestas dadas a las entrevistas completan las respuestas dadas a los cuestionarios, permitiendo un análisis conjunto de los datos. De este análisis, resulta que es posible destacar la importancia que las entrevistas tienen como complemento para analizar las visiones de los estudiantes.

Relativamente a las visiones de los estudiantes, la mayoría considera que el modelo es una representación de diferentes aspectos de la realidad:

“Un modelo científico es una representación simplificada de la realidad que tiene como finalidad permitir una mejor comprensión de la misma, probar hipótesis y/o prever acontecimientos”. (Cuestionario del encuestado 3 – Cu3)

Tabla III.2.4. Análisis de las respuestas dadas a las entrevistas y discrepancias obtenidas (primera parte - n=9).

Aspectos evaluados	Categorías	Sin información	Visiones informadas	Visiones ingenuas	Discrepancias
		n (%)	n (%)	n (%)	n (%)
Concepto de modelo científico		---	7 (77.8)	2 (22.2)	3 (33.3)
Propósitos de los modelos científicos		---	5 (55.6)	4 (44.4)	5 (55.6)
Importancia de los modelos en la enseñanza de las ciencias		---	2 (22.2)	7 (77.8)	1 (11.1)
Diferencias entre modelos científicos y modelos para la enseñanza de las ciencias		---	9 (100)	---	0

Sin embargo, 3 de los estudiantes apenas atribuyen importancia a los modelos por su carácter educacional. Así, los modelos son considerados apenas recursos educacionales, no se hace ninguna referencia a su utilidad en la actividad científica:

“Un modelo es una tentativa de explicar un cierto fenómeno. (...) Estos modelos tienen como finalidad explicar la realidad en una manera comprensible al público en general. Ellos se usan para sensibilizar al público en general o a las personas más jóvenes, para intentar que las personas cambien mentalidades o ideas”. (Cu4)

Además, analizando las visiones sobre los propósitos de los modelos científicos, se verifica que la mayoría de los estudiantes destaca apenas su utilidad para describir la realidad:

“Las principales funciones de los modelos científicos son intentar explicar la realidad de una forma más sencilla y fácil de entender, para que la información llegue al público en general.” (Cu4)

Danusso et al. (2010) en un estudio con futuros profesores, también revelan que la mayoría considera que los modelos son utilizados esencialmente para hacer el fenómeno más comprensible. Solo cuatro estudiantes muestran una visión más amplia sobre este aspecto en los cuestionarios, atribuyendo importancia a los modelos para la construcción del conocimiento científico:

“Los modelos científicos son usados para: (i) representar la realidad para facilitar la comprensión de los alumnos; (ii) prever diversos fenómenos – ejemplo: modelos predictivos de la distribución de las especies; (iii) probar hipótesis – modelos matemáticos para probar diferentes escenarios evolutivos.” (Cu3)

Por consiguiente, los estudiantes también revelan una visión limitada sobre la importancia de los modelos en la enseñanza de las ciencias, subrayando apenas su valor en la comprensión de conocimiento científico (en el aprendizaje *de la ciencia*):

“Los modelos pueden ser usados durante las clases, producidos por los profesores o por los alumnos, y son importantes porque pienso que facilitan la comprensión del conocimiento. Sí, yo considero importante [que los alumnos construyan modelos] porque es posible acceder a las concepciones de los alumnos sobre determinado asunto y pienso también que ayuda a la consolidación del mismo.” (Cu5)

Estos resultados se asemejan a los resultados obtenidos por Justi y Gilbert (2002), quienes indican que los modelos son utilizados de forma limitada (casi exclusivamente para el aprendizaje de las ciencias).

Apenas 6 estudiantes demuestran una visión más amplia respecto a la importancia de los modelos en la enseñanza de las ciencias, señalando no sólo su valor en la comprensión de conocimiento científico, sino también su valor en la comprensión de la naturaleza de la ciencia y/o en la promoción del desarrollo de capacidades investigativas:

“[Los modelos] son aplicaciones fundamentales en la enseñanza de las ciencias, porque promueven el razonamiento científico. (...) La concepción del modelo envuelve consolidación del conocimiento conceptual y el entendimiento de la parte procedimental. (Cu1)

“[Los modelos son importantes en la enseñanza de las ciencias] para representar realidades complejas que así se vuelven mejor comprendidas por los alumnos, para probar hipótesis generadas en contexto «inquiry based learning» y para prever acontecimientos, demostrando las aplicaciones de la ciencia para la sociedad. (...) La construcción de modelos es un componente muy importante para el proceso de producción del conocimiento científico.” (Cu3)

Respecto a las diferencias entre modelos científicos y modelos en la enseñanza de las ciencias, y también de acuerdo con Justi y Gilbert (2002), todos los estudiantes consideran que estos deben ser diferentes:

“Los modelos usados en la ciencia son, muchas veces, complejos e implican explicaciones científicas muy elaboradas. Así, los modelos usados en la enseñanza no deben ser muy diferentes de aquellos usados en la ciencia, pero deben tener en cuenta algunas simplificaciones necesarias para que sea posible su aplicación en la escuela.” (Cu13)

Durante el análisis de los cuestionarios surgieron algunos aspectos sobre los modelos que consideramos importante analizar (presentes en un número reducido de las respuestas). Por ejemplo, solo el estudiante 1 se refirió al carácter provisional de los modelos científicos:

“Un modelo científico se fundamenta en una teoría o ley (...). De manera característica podrá ser provisorio.” (Cu1)

De este modo, consideramos pertinente plantear cuestiones más específicas y añadimos algunas cuestiones al cuestionario inicial (preguntas 3, 4 y 7 del cuestionario final – apéndice III.2.A) y a la guía base de la entrevista (preguntas 7, 8 y 9 de la guía final – apéndice III.2.B). Las preguntas de las entrevistas se refieren a dos aspectos de los modelos que no aparecen mencionados en los cuestionarios. De este modo, se pretende que los estudiantes hagan referencia a lo que es representado por un modelo y a la multiplicidad de los modelos de forma indirecta. Las preguntas en la entrevista servirán esencialmente para profundizar las visiones de los estudiantes y, en caso de que los estudiantes no hagan referencia a esos aspectos, para evaluar su visión acerca de ellos.

Solo uno de los estudiantes contestó a todas esas preguntas, porque fue posible su participación en el estudio en una fase posterior (durante su práctica profesional en la escuela). Con el análisis conjunto de las respuestas dadas a las nuevas preguntas del cuestionario y de la entrevista fácilmente se obtuvo una comprensión de su visión relativamente a lo que puede ser representado por un modelo, al carácter múltiple y provisional de los modelos, su relación con las teorías y a las capacidades que los alumnos necesitan para producir modelos.

III.2.6.2. Segunda parte del cuestionario

En la segunda parte del cuestionario evaluamos las concepciones de los estudiantes sobre el uso de modelos en las clases de ciencias. Se verificó que, en general, los estudiantes enfocaron los aspectos pretendidos, dando sus opiniones sobre el uso de modelos en las clases de ciencias y el uso que puede conllevar más dificultades. Con relación a estos dos aspectos, fue posible analizar la visión de todos los estudiantes, siendo pocos los resultados discrepantes (apenas 1 en el análisis del uso de modelos en las clases de ciencias y 3 en el análisis del uso que puede conllevar más dificultades), al comparar los resultados obtenidos a través del análisis de los cuestionarios y a través de las entrevistas.

Del mismo modo, todos los estudiantes presentaron sus concepciones sobre los cuidados a tener con el uso de modelos y sobre las características de un buen modelo

para la enseñanza de las ciencias. Con el análisis de los datos de las entrevistas, fue posible completar el análisis de los datos de los encuestados. Además, la segunda parte del cuestionario, es también importante porque permite que los estudiantes, cuando justifiquen sus opciones, revelen sus opiniones sobre modelos. Por ejemplo, se verificó que cuando se les preguntaba sobre el modo de usar modelos en las clases, estos no valoraran la importancia de los modelos en la comprensión de la naturaleza de la ciencia y en la promoción del desarrollo de capacidades investigativas (ver abajo).

En relación al modo de usar modelos en las clases, se observa que los estudiantes consideran que es importante no solo mostrar los modelos a los alumnos sino también darles la oportunidad a los alumnos de construir modelos. Solo un estudiante opta, en el cuestionario, apenas por una de las opciones (dar la oportunidad a los alumnos de construir modelos). Sin embargo, en la entrevista, él señala que las dos son importantes, enfatizando la construcción de los modelos por los alumnos:

“Pienso que la parte más interesante es darles a los alumnos la oportunidad de construir modelos. Después de eso, podemos proponer a los alumnos que critiquen sus modelos y los modelos de sus colegas. (...) No obstante, pienso que también es interesante presentar a los alumnos modelos ya hechos para que los alumnos critiquen, prueben y manipulen el modelo.” (En9)

De hecho, con el análisis de la entrevista fue posible comprender mejor la visión de este estudiante, verificándose, una vez más, que los datos resultantes del análisis de la entrevista completan los datos obtenidos a través del análisis del cuestionario. Además, las entrevistas promueven más y mejores justificaciones de las opciones de los estudiantes.

En relación a las justificaciones del modo de usar modelos en las clases se verifica que las principales se relacionan con el tiempo, el equilibrio y el desarrollo de conocimiento conceptual. De nuevo se observa que los estudiantes no valoran la importancia de los modelos en la comprensión de la naturaleza de la ciencia y en la promoción del desarrollo de capacidades investigativas:

“Es bueno presentar mi modelo para ayudar a los alumnos a comprender la materia. Por otra parte, es importante que ellos construyan sus modelos para ayudar a consolidar la información.” (Cu5)

La mayoría de los estudiantes considera que la producción de los modelos por parte de sus alumnos conlleva más dificultades (tabla III.2.5):

“Pienso que construir el modelo es más difícil porque es una tarea más compleja. Para comprender un modelo es solo necesario comprenderlo. Por

otra parte, es necesario construirlo y comprenderlo bien para producirlo bien.” (Cu5)

Tabla III.2.5. Concepciones sobre el uso de modelos en las clases de ciencias (Dificultades).

	Fuentes de datos	Cuestionario	Entrevista	Discrepancias
		n (%)	n (%)	n (%)
Concepciones				
Más Dificultoso	Comprensión de un modelo	2 (11.8)	2 (22.2)	3 (33.3)
	Producción de su modelo	10 (58.8)	5 (55.6)	
	Ambas opciones	5 (29.4)	2 (22.2)	

En relación a este tema y a las discrepancias resultantes del análisis de las respuestas dadas a los cuestionarios y a las entrevistas (tabla III.2.5), se observa que los propios estudiantes admiten haber cambiado sus visiones, siendo posible comprender las discrepancias y analizar las respuestas:

Quizá alteré mi respuesta. Comprender un modelo a veces es más difícil que construirlo. (...) Eso puede ser mucho más difícil, comprender algo que alguien ha hecho. (...) Sí [mi visión] ha cambiado. (En11)

Sobre los cuidados a tener en cuenta en el uso de modelos en las clases de ciencias, solo 3 estudiantes mencionaron la importancia de alertar a los alumnos de la naturaleza y de las limitaciones de los modelos:

Es importante que los alumnos comprendan que un modelo es una representación simplificada de la realidad y las ventajas y limitaciones asociadas a ese proceso de simplificación. (Cu3)

En realidad, la mayoría de los estudiantes solo mencionó el cuidado de evitar el surgimiento de concepciones alternativas.

Relativamente a las características de un buen modelo, las destacadas por los estudiantes son: el rigor; la claridad; la simplicidad y la pertinencia:

Un buen modelo debe ser simple, para ser comprendido por el mayor número de alumnos posible. Debe ser simple, pero no debe tener errores científicos, ni tampoco estar construido de forma que generar confusiones. (Cu5)

Son pocos los estudiantes (17.6%) que indican que un buen modelo debe ser manipulable por los alumnos. Además, solo un estudiante justifica esta opción, indicando la importancia de los modelos en el desarrollo de capacidades investigativas.

De la misma forma que ocurrió en la primera parte del cuestionario, consideramos adecuado plantear una cuestión más específica sobre el modo más ventajoso de usar modelos en las clases de ciencias. De hecho, añadimos la cuestión 11 del cuestionario final (apéndice III.2.A), ya que solo 2 estudiantes hicieron referencia a este aspecto al rellenar el cuestionario inicial:

“Los dos modos, dependiendo del objetivo y producto final pretendido (...) Sin embargo, pienso que es más ventajoso que los alumnos produzcan los modelos. (Cu16)

De manera similar a lo que ocurrió con la primera parte del cuestionario, solo un estudiante contestó a esa pregunta. Con el análisis conjunto de la respuesta dada a la pregunta 11 y la pregunta correspondiente en la entrevista, fue posible comprender de forma sencilla su visión relativamente a la opción que consideraba más ventajosa:

“La opción más ventajosa es la producción del modelo. El proceso de pensar en los materiales y en las diferentes maneras de representar permite a los alumnos comprender sus dificultades y como superarlas.” (Cu17)

“Yo pienso que es más ventajoso que el alumno construya su modelo, aunque sea más difícil. Pero el grado de dificultad permite que el alumno aprenda y evolucione más.” (En17)

La última pregunta del cuestionario se añadió al final de todo este proceso y, de forma similar a la última pregunta del cuestionario sobre la naturaleza de la ciencia, pretende analizar posibles cambios de las visiones de los estudiantes y sus causas.

III.2.7. Conclusiones y recomendaciones didácticas

Los resultados obtenidos soportan un elevado nivel de confianza en la validez y fiabilidad del cuestionario para analizar las visiones de los futuros profesores de ciencias portugueses acerca de la naturaleza de los modelos científicos y su importancia en la enseñanza de las ciencias y acerca del uso de los modelos en las clases de ciencias. Sin embargo, las entrevistas se revelan cruciales ya que permiten obtener datos más completos, detallados y robustos, siendo importante aplicarlas siempre que sea posible. Como señala Lederman et al. (2014), el uso de entrevistas es fundamental para obtener los datos más válidos posible, ya que permiten una comprensión más profunda y un análisis más consistente de los datos. Sin querer restarle valor a los resultados

obtenidos a través del cuestionario, la triangulación de métodos y técnicas, como refieren Bickman y Rog (1998) permite aumentar la validez y compensar la fiabilidad de los resultados de la investigación.

A pesar de que la mayoría de los estudiantes considere que un modelo científico es una representación de diferentes aspectos de la realidad, verificamos que algunos estudiantes presentan visiones poco informadas sobre su definición y, en especial, sobre los propósitos de los modelos científicos en la actividad científica. Del mismo modo, los estudiantes revelan también visiones ingenuas sobre los propósitos de los modelos en la enseñanza de las ciencias, enfatizando solamente su contribución en la comprensión del conocimiento conceptual.

Aunque la mayoría de los estudiantes reconozca que es importante que los alumnos construyan modelos, se verifica, una vez más, que no valoran su relevancia en el desarrollo de visiones adecuadas acerca de la naturaleza de la ciencia y en la promoción del desarrollo de capacidades investigativas. Además, son pocos los estudiantes que subrayaron la importancia de advertirles a los alumnos de la naturaleza y limitaciones de los modelos.

Estos resultados están en la misma línea de los resultados obtenidos en un estudio piloto realizado anteriormente (Torres y Vasconcelos, 2015), aunque los datos obtenidos con este cuestionario y entrevistas sean mucho más detallados, proporcionando más informaciones sobre las visiones, las dificultades y las perspectivas del uso de modelos en las clases de ciencias, lo que recalca la importancia de este cuestionario y de esta entrevista.

Por todo lo recogido anteriormente, reiteramos una vez más que la falta de conocimientos sobre modelos en la ciencia y para la enseñanza de las ciencias es problemática, siendo fundamental mejorar las visiones de los futuros profesores. De este modo, los profesores deberán entender qué son modelos científicos y modelos para la enseñanza de las ciencias, pero también sus potencialidades en las clases de ciencias, no sólo en la comprensión del conocimiento científico, sino en la promoción de conocimientos sobre la naturaleza de la ciencia y de capacidades investigativas. Por último, es crucial que los profesores cambien actitudes y usen los modelos de forma eficaz en las clases de ciencias, de acuerdo con las perspectivas actuales de la Educación en Ciencias.

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Apéndice III.2.A “Cuestionario Modelos”

Cuestión 1. ¿En su opinión, qué es un modelo científico?

Cuestión 2. ¿Cuáles son las funciones principales de los modelos científicos? ¿En qué circunstancias se utilizan?

Cuestión 3. ¿Qué relación considera que debe existir entre un modelo científico y una teoría científica? Justifique su respuesta.

Cuestión 4. ¿Considera que los modelos científicos cambian con el tiempo? Defienda su respuesta con ejemplos.

Cuestión 5. Desde su punto de vista, ¿cómo se pueden usar modelos en la enseñanza de las ciencias? ¿Cuál es la importancia de los modelos en la enseñanza de las ciencias?

Cuestión 6. ¿Considera importante que los alumnos produzcan modelos? ¿Por qué?

Cuestión 7. ¿Qué necesitan los alumnos para construir modelos?

Cuestión 8. Desde su punto de vista, ¿los modelos usados en la enseñanza de las ciencias pueden/deben ser diferentes de los modelos usados en la ciencia? ¿Por qué? ¿Cuáles deben ser las principales diferencias?

Cuestión 9. ¿Cómo piensa usar los modelos en sus clases de ciencias? ¿Mostrando sus modelos a los alumnos o dando a oportunidad a los alumnos de construir modelos? Justifique su respuesta.

Cuestión 10. ¿Qué considera que presenta más dificultades para los alumnos: la comprensión de un modelo (presentado por su profesor, existente en el libro de texto,...) o la producción de su modelo? ¿Por qué?

Cuestión 11. En su opinión, ¿cuál es la opción más ventajosa para un alumno: la comprensión de un modelo suministrado o la producción de su modelo? ¿Por qué?

Cuestión 12. En la producción de modelos para la enseñanza, ¿cuáles son los aspectos que se deben tener en cuenta? ¿Cuáles son los cuidados a tener cuando se usan modelos en las clases?

Cuestión 13. En su criterio, ¿qué características debe tener un buen modelo para la enseñanza de las ciencias? ¿Por qué?

Cuestión 14. Después de las clases de este año escolar, ¿considera haber alterado sus visiones sobre modelos científicos y su uso en las clases de ciencias? Si es así, indique los principales cambios y las principales fuentes responsables del cambio.

Apéndice III.2.B. “Guía de Entrevista Modelos”

1. ¿Puede leer y explicar mejor su respuesta?
 2. ¿Quiere añadir algo más a su respuesta?
 3. ¿Qué quiere decir con (...)?
 4. ¿Cómo se relaciona su respuesta en A con lo que ha dicho en su respuesta B?
 5. ¿Ha cambiado su visión desde que escribió su respuesta? ¿Cómo?
 6. De las opciones disponibles, ¿qué opción seleccionaría para definir modelo científico?
 7. ¿Qué puede ser representado como un modelo?
 8. ¿Pueden existir diferentes modelos para representar diferentes aspectos del mismo sistema representado?
 9. ¿Pueden existir múltiples modelos para estudiar el mismo aspecto del mundo?
 10. (...)
-

III.3. Description of the Intervention Programme

INTERVENTION PROGRAMME - SCIENTIFIC MODELS, MODELLING AND NATURE OF SCIENCE IN SCIENCE TEACHING

Joana Torres & Clara Vasconcelos

Adapted from Models in Geoscience classes: How can teachers use them? In Vasconcelos, C. (Ed.). Geoscience Education: Indoor and Outdoor. p. 25-41. Springer: Switzerland. (2016). ISBN: 978-3-319-43318-9 and from *Aplicação de um programa de intervenção em história da ciência dirigido a estudantes do mestrado em ensino da biologia e da geologia*. In C. R. Gomes, A. Rola & I. Abrantes (Eds.), E-book do colóquio II - História das Ciências para o Ensino – Atas do Colóquio II, 105-125. Coimbra: Universidade de Coimbra. Faculdade de Ciências e Tecnologia. Departamento de Ciências da Terra (2014).

III.3.1. Introduction

Bearing in mind the need for students to develop not only scientific knowledge, but also epistemological knowledge, and inquiry competencies, and the lack of knowledge revealed by both teachers and students concerning NOS and models, we believe that science teachers (namely prospective science teachers) must develop their knowledge concerning NOS and models.

In fact, it is of the utmost importance that teachers fully understand the nature of science, the nature of models and their full potential in order to conduct effective NOS instruction and modelling activities in their science classes (Krell, Upmeier zu Belzen, & Krüger, 2014; Mendonça, & Justi, 2011; Moutinho, Moura, & Vasconcelos, 2014).

In this regard, Oh and Oh (2011), based on a literature review, presented five subtopics about models that should be known by science teachers: (i) meanings of a model; (ii) purposes of modelling; (iii) multiplicity of scientific models; (iv) change in scientific models; (v) uses of models in the sciences classrooms. Bearing in mind these topics and considering the three major aims proposed by Justi and Gilbert (2002-2003)

of models and modelling in science education (to learn: *of* science; *to do* science; and *about* science), we developed and applied an intervention programme to prospective science (biology and geology) teachers.

III.3.2. Intervention programme – scientific models, modelling and nature of science in science teaching

In this section we present a set of activities designed to improve prospective (and even in-service) science teachers' views regarding models in science and for teaching. These activities were used with prospective science teachers in Portugal, which greatly improved their views regarding models.

The intervention programme was developed in five classes, of five hours each, which were organized according to the objectives presented in the table III.3.1.

Afterwards, we are going to describe some of the activities which may be used in the training of science teachers. These activities were designed for them to understand the role of scientific models in scientific research, as well as the relevance of models and modelling in science teaching.

III.3.2.1. Class 1 - Scientific models and the development of scientific knowledge

In the first intervention, we started with a problematic scenario that included a concept cartoon, where it is discussed the existence of multiple models to represent the Earth's interior, and some titles of relevant articles. After posing and discussing some questions, prospective science teachers were asked to collaboratively respond to some questions, based on the analysis of some papers, like those of Oh and Oh (2011), Chamizo (2013) and Giere (2010).

Those questions, which were mainly related to the understanding of scientific models and their role in science, were provided below:

- (i) What are scientific models? Please, provide some examples.
- (ii) What can be represented by models?
- (iii) "Abstraction is considered to be a powerful tool in the process of knowledge acquisition". Explain how a model may be considered an abstraction tool (aimed for knowledge acquisition and for the understanding of reality).
- (iv) Please comment on this statement: "Models are copies of the reality".
- (v) Please comment on this statement: "A model is an abstract tool to analyse reality designed from the observation of that reality".

Table III.3.1. Main objectives of each class of the intervention programme.

Class	Main Objectives
1. Scientific models and the development of scientific knowledge	i. To understand what scientific models are and with which purpose they are used in science; ii. To realize the relevance of modelling in science, namely in geology. <i>(learning about science)</i>
2. Models and modelling in science teaching	iii. To understand the importance of models and modelling activities as contributors to the development of accurate mental models, and to the understanding of scientific activity and of the nature of science. <i>(learning of science; of how to do science and about science)</i>
3. Historical models and nature of science in science teaching	iv. To recognize the relevance of resorting to historical models in order to promote the understanding of different aspects of nature of science; v. To reflect on how to teach nature of science aspects and on the importance for students to develop accurate views of nature of science. <i>(learning about science and of science)</i>
4. Models, modelling, analogies and nature of science	vi. To understand the advantages and precautions to take when using models and analogies in science classes; vii. To analyse how textbooks and the science (biology and geology) standard documents cover nature of science, models and modelling activities. <i>(learning of science; of how to do science and about science)</i>
5. Models, modelling, analogies and nature of science – lesson planning	viii. To apply all the concepts developed in the construction of didactic materials and lessons plans and to justify their options. <i>(learning of science; of how to do science and about science)</i>

(vi) What types of models may exist?

(vii) What is the relationship between models and theories.

(viii) What are the purposes of using scientific models in science?

- (ix) Oh and Oh (2011) pointed out five relevant subtopics about models that should be known by science teachers. Please specify the subtopics and briefly describe them.
- (x) In science education research, the use of methodologies that are in line with inquiry based-learning approaches are currently advocated. In this way, why do you consider that resorting to modelling is important in science teaching?
- (xi) Oh and Oh (2011) stated that using models in geology teaching is extremely important. Can you please explain why?

After discussing the answers to all these questions, a PowerPoint presentation was analysed in order to prompt the understanding of scientific models contributions in the development of scientific areas, such as physics, chemistry, biology and geology. As this intervention programme was specifically designed for prospective geology and biology teachers, more emphasis was given to geology and biology models.

Concerning biological models, different types of models were discussed and the relevance of model organisms in the development of biological knowledge was highlighted. In geology, through an analysis of a historical perspective regarding the use of models, the purposes, potentials, and limitations of models in geological research were analysed and debated (please see biological models and geoscientific models section of the introduction of this thesis).

At the end of this class, a final worksheet was given for prospective science teachers to apply their knowledge by analysing different models and by classifying them according to a specific typology of models.

III.3.2.2. Class 2 - Models and modelling in science teaching

In this class it was intended that prospective science teachers understand the role of models for teaching, by discussing some theoretical aspects but also by developing modelling activities.

With the intent to address the three main aims suggested by Justi and Gilbert (2002-2003) of models and modelling in science education, we started this lesson by deepening the understanding of the role of models in the understanding of science. To that end, prospective science teachers were encouraged to represent their own mental model about Earth's structure models through a drawing, its explanation and a concept map. By starting with this activity and by focusing some studies concerning Johnson-Laird' mental models theories, the intention was to clarify mental model concept and the

relevance of using models in order to support the construction of accurate mental models.

Afterwards, prospective science teachers experienced different modelling activities in a way that allowed them to better understand the role of models in the learning of science, of how *to do* science and *about* science. The activities started with a problematic situation concerning spatial planning and landslides. Thus, in order to seek for some solutions, prospective science teachers developed some modelling activities (with physical but also with digital models) where they analysed several factors that influence the stability of a slope and where they analysed the effectiveness of different mitigation measures for landslides (Figure III.3.1).

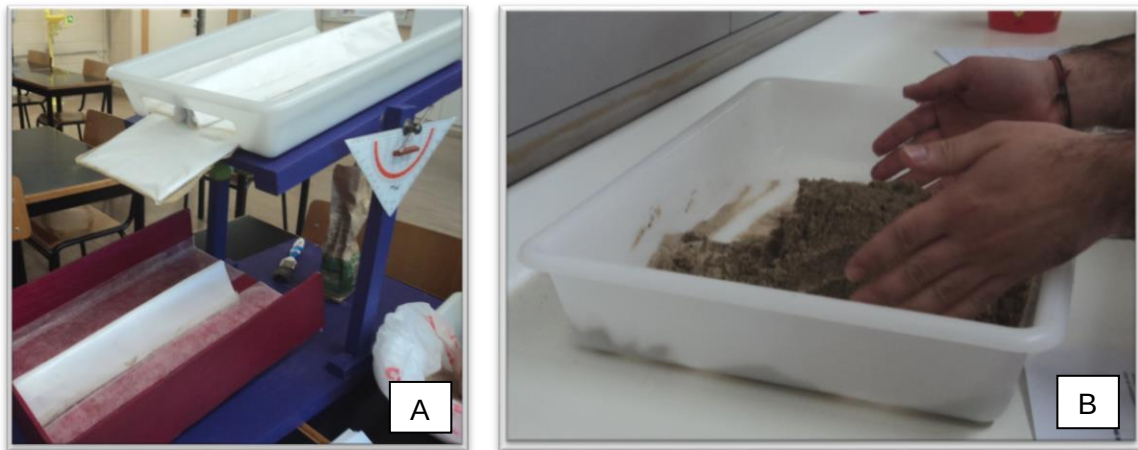


Figure III.3.1. Modelling activities. (A. Factors that interfere with slope stability; B. Influence of water in slope stability).

In these activities, prospective science teachers developed their conceptual knowledge regarding landslides (understanding *of* science), but they also developed their inquiry skills (the understanding of how *to do* science). Specifically, they were instigated to observe, to measure, to formulate hypotheses, to predict, to analyse data, to reason and to formulate conclusions, as those activities were planned and guided taken those intentions into account and as they also filled in two Gowin's Vees. With these activities, prospective science teachers could also implicitly develop their views about NOS and about the nature of models.

Furthermore, at the end of those modelling activities, prospective science teachers were asked about the activities they conducted and about models in science. With the intention of explicitly develop prospective science teachers' knowledge *about* science, they were asked to discuss and answer to some questions, such as:

- (i) In your opinion, what is a model in science?

- (ii) For what purposes are models used in science? For what purpose have you used models in these activities?
- (iii) How close should a model be to its target?
- (iv) What is important to include in a scientific model?
- (v) Is it possible that scientists have more than one model to represent the same target?
- (vi) Is there any circumstance that requires the change of a scientific model?
- (vii) Why do you consider it relevant to use models and modelling activities in science classes?

After all these modelling activities, a final discussion was held regarding all the advantages of models and modelling in science classes.

III.3.2.3. Class 3 - Historical models and nature of science in science teaching

The third class was mainly designed for prospective science teachers to recognize the relevance of historical models as contributors to the understanding of the nature of science aspects, as well as to discuss and deepen their knowledge regarding those NOS aspects.

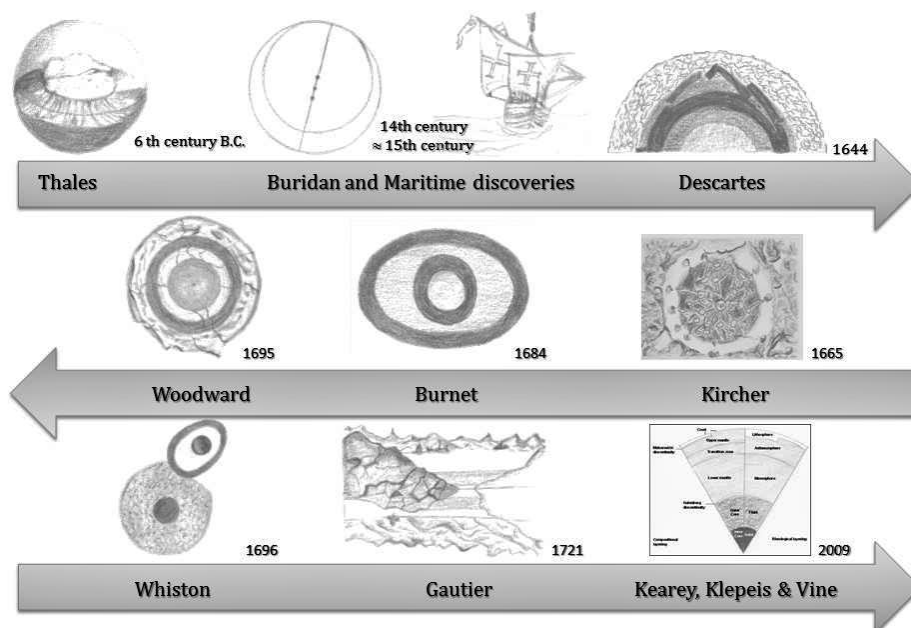


Figure III.3.2. Historical evolution of Earth's structure models.

Credits: Marta Queiroz, 2016

Thus, using the historical evolution of Earth's structure models as a starting point for the discussion, prospective science teachers were asked to analyse three main documents about the historical evolution of Earth's structure models from the 6th century B.C. to the 21st century (Figure III.3.2) and to discuss different aspects of science.

The first document entitled "Historical models of Earth's internal structure – The first models" makes a brief and quick description of some models from the 6th century B.C. until 1665, with Kircher's model. With this document, it was intended that prospective science teachers discuss different aspects that influenced knowledge development, as well as some aspects related to models nature and function. After the analysis of the text, prospective science teachers were asked to reflect and respond to some questions, such as:

- (i) According to document one, which factors have influenced the development of knowledge about the structure of the Earth?
- (ii) Although being created from a sun, what is the main difference between the model of Descartes and the model of Kircher? Which factors may constrain that distinction?
- (iii) What are the main functions of the models of Descartes and Kircher?
- (iv) Deparis (2001) mentioned that history is rich in speculations, sometimes audacious, about Earth's depths. Why did he use the expression "speculations"? Could "speculations" be replaced by another expression?
 - a. What are the conditions to construct models?

Moreover, some complementary activities were also conducted, in order to better distinguish observations from inferences, relying, for example, on the inferences that Cadell made based on his experimental models (Figure III.3.3.).

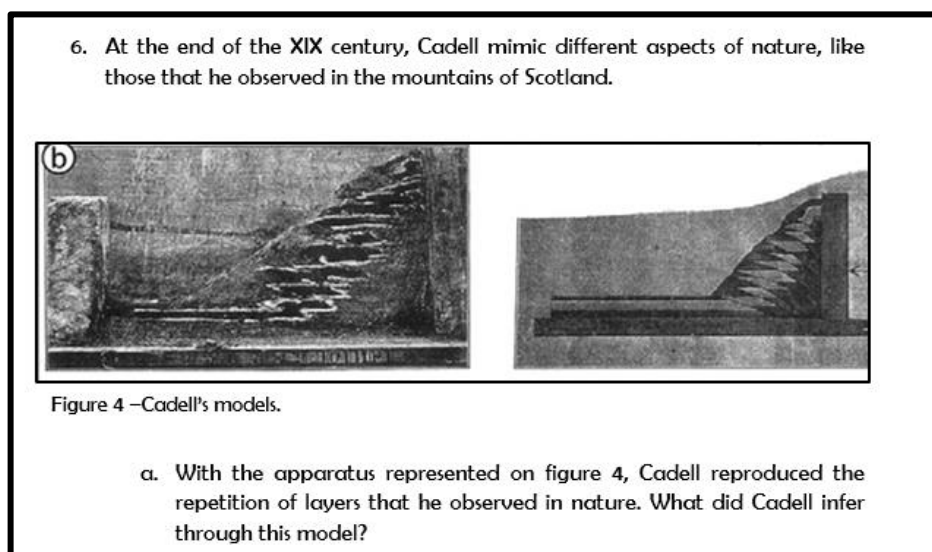


Figure III.3.3. Example of a question of the complementary activities.

Regarding the second document, entitled “Historical models of Earth’s internal structure – How to explain the Deluge?”, the influence of several aspects in scientific knowledge development, specifically religion was emphasized. To illustrate the influence of religion on science, the models that explain both the interior of the Earth and the deluge were presented (Figures III.3.4, III.3.5 and III.3.6).

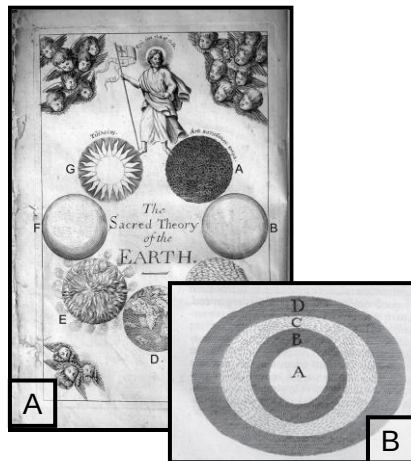


Figure III.3.4. Thomas Burnet's model.
A) Frontispiece of *Theory of the Earth* (1684); B) The interior of the Earth before the deluge.

Retrieved from: Magruder (2006, p. 248 e 246).

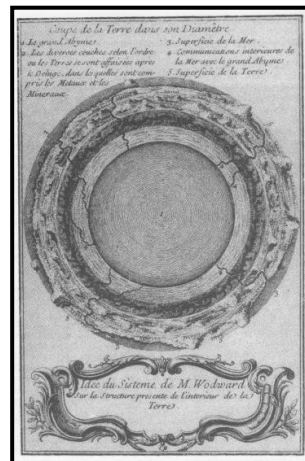


Figure III.3.5. Woodward's model of the interior of the Earth.

Retrieved from: Deparis & Legros (2000, p.144).

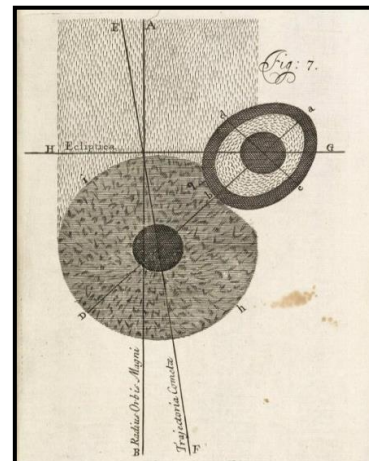


Figure III.3.6. Whiston's model.
Retrieved from: goo.gl/9I2cQs.

Some questions were asked in order to prompt the reflection and debate, such as:

- (i) In document two, it is well illustrated the influence of one factor in the development of scientific knowledge about the structure of the Earth. Can you please identify it?
- (ii) What other factors do you think interfere in the development of scientific knowledge?
- (iii) Woodward became interested in the study of plants and minerals, giving special attention to fossils. For him, fossils were remains of animals and plants which are related to specific rock formations. According to this information and to the text, do you consider that scientists knowledge influence their interpretation of data and their conclusions (about Earth's structure model)?
- (iv) Mention some examples where experiences and previous ideas influence scientists' interpretation and conclusions.

At the end of the analysis of this document, some complementary activities, which included analysis of images, the viewing of a documentary and discussion of some paradigmatic examples, were conducted concerning the subjectivity in science.

With the third document “Historical models of Earth’s internal structure – From amazing to current models”, some characteristics of scientific knowledge were discussed, like its dynamism, subjectivity, tentativeness, empirical character and the inexistence of a single scientific method. Some of the questions that were discussed were presented below:

- (i) Bearing in mind the examples given, how do you characterize the development of scientific knowledge?
- (ii) What are the contributions of analysing models in science teaching?
- (iii) How certain are scientists concerning Earth’s structure model? What evidence do you think scientists used to develop Earth’s structure model?
- (iv) How can we distinguish science from other disciplines?

Some other complementary activities were also developed. Discussed were many aspects like the difference between theories and laws and the relevance of imagination and creativity in science.

In the fifth and last complementary activity, some fundamental characteristics of science were discussed, by adapting an activity developed by Lederman & Abd-El-Khalick (1998) – figure III.3.7. It was highlighted that science is characterised by a search of patterns, that were based on evidences, but that also result from inferences and from scientists’ imagination and creativity.

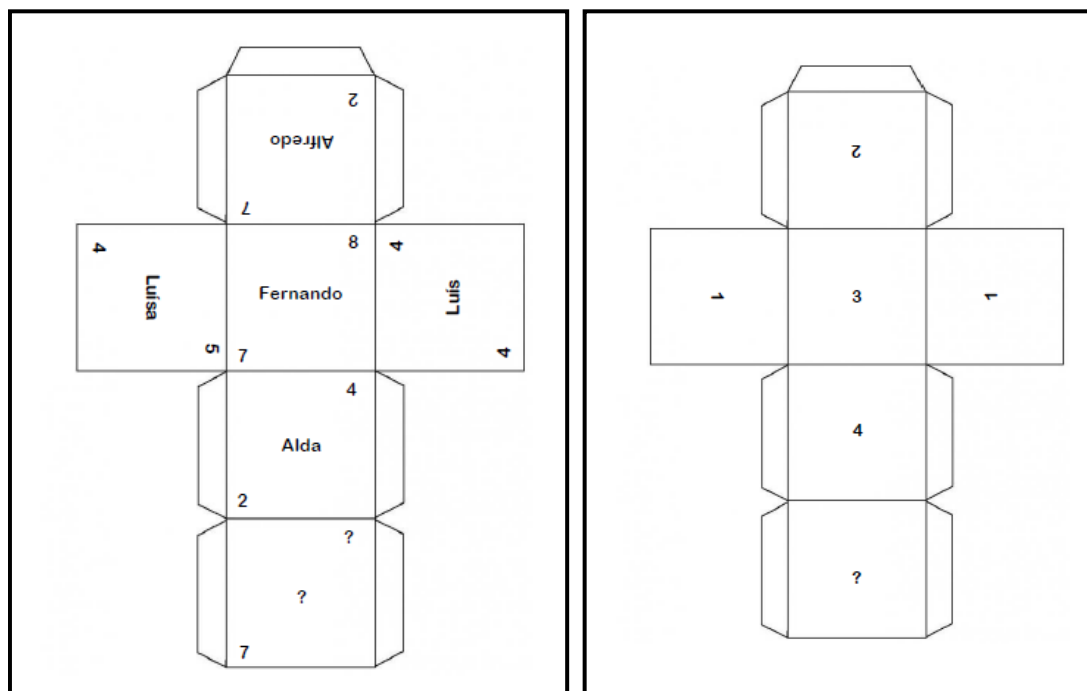


Figure III.3.7. Mysterious cubes adapted from Lederman & Abd-El-Khalick (1998).

At the end of this class, a discussion was held on the relevance of teaching NOS aspects and also the importance of its teaching in an explicit, embedded and reflective way.

III.3.2.4. Class 4 - Models, modelling, analogies and nature of science

Our intention in the fourth intervention was to have prospective science teachers reflect and critically analyse how textbooks and the science standard documents convey the nature of science, models. and modelling activities, as well the advantages and precautions to take when using models and analogies in science classes.

As such, prospective science teachers analysed Biology and Geology curricula of the 10th and 11th grade (secondary school), in order to examine the suggestions and recommendations provided concerning models and NOS.

Afterwards, an activity that relies on an analogical comparison was analysed by prospective science teachers in a way that prompted the discussion concerning the use of analogies and models in science classroom, emphasizing positive and negative aspects of their use, the characteristics of good analogies and models, as well as the precautions to take when using them.

With the final activity of this class it was intended that prospective science teachers critically analysed and compare different textbooks, concerning models and NOS. All the analysed sections of the textbooks were related to the theme Earth's structure models. Questions like "Which textbook takes into consideration the mental models of students?" and "Which textbook gives more relevance to the nature of models and to NOS aspects?" were used to guide prospective science teachers' analysis.

III.3.2.5. Class 5 - Models, modelling, analogies and nature of science – lesson planning

In the final intervention, prospective science teachers were asked to present and discuss their final work. This consisted of a lesson plan and associated activities, which were related to a geological theme. The lesson plan must include a modelling activity and must contribute to the development of conceptual knowledge, to the development of inquiry skills and also to the understanding of the nature of models and of the nature of science.

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CHAPTER IV

Main Results

IV.1. Prospective science teachers' views of the nature of science after the intervention programme

PROSPECTIVE SCIENCE TEACHERS' VIEWS OF NATURE OF SCIENCE: DATA FROM AN INTERVENTION PROGRAMME

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IV.1.1. Abstract

The development of accurate views of nature of science is considered to be a crucial aim for science education. This study assesses Portuguese prospective science teachers' views of the nature of science before and after an intervention programme that took place in the first year of their master. Nine prospective science teachers that will teach biology and geology in middle and high schools voluntarily participated in this study. Pre and post questionnaires and interviews were administered and analysed. By the end of the intervention programme they were asked to construct a lesson plan which was also analysed. Results show that prospective science teachers greatly improved their views of NOS. However, some of them still struggled with some aspects, which stresses the need to better understand the factors that influence science teachers' views of NOS. Although they have recognized that they have improved their views of NOS and that they have better understood the relevance of NOS instruction in science classes, more research is needed to understand the factors that mediate teachers' views into their instructional practice.

Keywords: nature of science, models, science teachers' views, intervention programme, science education.

IV.1.2. Introduction

The development of students' informed views of nature of science (NOS) is internationally considered to be a crucial goal for science education (Abd-El-Khalick, 2006; Deng, Chen, Tsai, & Chai, 2011; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). There are many reasons that justify the inclusion of NOS instruction in science classes. For example, NOS knowledge is considered to be an important component in developing students' science literacy (*Lederman, Bartos & Lederman, 2014; McComas, Clough, & Almzroa, 1998; Moutinho, Torres, Fernandes & Vasconcelos, 2015*) and some studies also reveal that a better knowledge of NOS is positively related to conceptual learning in science (Bell, 2006; Cheng & Lin, 2015; Deng et al., 2011, McComas et al., 1998). Moreover, the knowledge of NOS is related to the enhancement of informed decision-making (Khishfe, 2012; Koksai, Cakiroglu & Geban, 2013) and contributes to the understanding of how science operates and to the promotion of interest in science (McComas et al., 1998).

Despite the relevance that is attributed to NOS in science education, it is generally shown that students (Bell, Blair, Crawford & Lederman, 2003; Koksai et al., 2013, Lederman, 2007) and even teachers (Bell, Mulvey, & Maeng, 2016; Lederman, 2007; Wahbeh & Abd-El-Khalick, 2014) do not hold informed views of NOS. Furthermore, Abd-El-Khalick et al. (1998) also concluded that even when teachers reveal adequate understandings of some aspects of NOS, they gave little relevance to its teaching. In fact, "teachers do not regard NOS as an instructional outcome of equal status with that of 'traditional' subject matter outcomes" (Lederman, 2007, p. 869).

Although there is no direct translation between teachers' views of NOS and their instructional practice, improving teachers' views of NOS is fundamental, as it is not a sufficient, but a necessary, condition to instruct NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Matkins, & Gansneder, 2011). Having the aforementioned aspects in mind, we consider it fundamental to deepen prospective science teachers' views of NOS. However, it is also our aim to make them aware of the relevance of NOS and of how to teach NOS in science classes, in an attempt to contribute to an explicit-reflective approach of NOS.

Starting with teachers' views, the main purpose of this study was to analyse how an intervention programme may influence prospective teachers' views concerning NOS.

IV.1.3. Theoretical Background

Despite the wide consensus on the relevance of NOS instruction in science classes, there remains a lack of complete agreement regarding the definition of NOS (Abd-El-Khalick et al., 1998) and the aspects of NOS that should be focused in classes (Acevedo-Díaz & García-Carmona, 2016). On the other hand, many authors, like Abd-El-Khalick (2006) and Lederman et al. (2002), believe that there is a general agreement regarding aspects of NOS that are not controversial and that are accessible and fundamental for secondary students. In our present work we have adopted this consensus view concerning the nature of science, given its widespread acceptance and given the fact that we believe that it is an appropriate starting point for students and for science teachers in developing an authentic picture of science (Torres & Vasconcelos, 2015). As a result, scientific knowledge is considered to be empirical (i.e. based on and/or derived from observations of the natural world that depend on our perceptions and instrumentations), tentative (i.e. scientific knowledge changes based on new information or perspectives) and subjective (i.e. it depends on the particular scientist's background, aims and experiences). The distinction between observation and inferences is also considered to be an important aspect of NOS to be taught, as both inferences and observations are fundamental in scientific knowledge construction, as well as the distinction between theories and laws. Furthermore, scientific knowledge is considered to be influenced by the creativity and imagination of scientists, and to be both influenced by and an influence on our society and culture. The understanding that no single scientific method is applied universally is also considered to be relevant (Abd-El-Khalick, 2006; Lederman et al., 2002).

Although NOS instruction remains a challenging undertaking, an explicit and reflective NOS instruction is assumed to be the best way to teach NOS endeavour (Mesci, & Schwartz, 2016). Moreover, the use of history of science is helpful for students to better understand NOS, making it possible to prompt an explicit and reflective NOS instruction (Torres & Vasconcelos, 2015; Acevedo-Díaz, García-Carmona, & Aragón, 2016; Pavez, Vergara, Santibañez, & Cofré, 2016). History of science may be used in many different ways and by resorting to different activities and strategies (Pavez et al., 2016). In our study we mainly rely on historical models, as well as historical episodes and complementary activities, to teach NOS to Portuguese prospective science teachers.

As claimed by Herman & Clough (2016), science teachers must have a strong knowledge regarding science, as well as regarding NOS. However, many studies show that science teachers do not hold accurate views of NOS (Bell et al., 2016; Lederman,

2007; Pavez et al., 2016; Wahbeh & Abd-El-Khalick, 2014). For example, in studies conducted in Portugal, it was found that secondary science students and both in-service and preservice science students hold uniformed views regarding some NOS aspects (Torres & Vasconcelos, 2015; Torres, Moutinho, & Vasconcelos, 2015). Accordingly, we consider it fundamental to develop science teachers' views as a primary step in promoting an efficient NOS instruction.

IV.1.4. Research questions

The purpose of this study was to examine how prospective science teachers improve their views of NOS after attending the intervention programme. Below, we present the research questions that guided our study:

- (i) How do prospective science teachers change their views of specific aspects of NOS?
- (ii) How do prospective science teachers plan to teach NOS aspects in science classes?

IV.1.5. Methods

This study is part of a broader research project which mainly aims to improve prospective science teachers' views of NOS and models (so as to contribute to an efficient and explicit NOS instruction, as well as an appropriate and extensive use of models in their future teaching practices) and to understand the factors that mediate the translation of teachers' views into their practices in classes.

Bearing in mind the former aim, we developed and applied an intervention programme entitled "Scientific models, modelling and nature of science in science teaching", which will be described below. The major aim of this study was to evaluate how this intervention programme influenced prospective teachers' views concerning NOS, by analysing their answers to the questionnaires and interviews that were administered before and after the intervention programme and by analysing their lesson plans that were constructed individually at the end of the intervention programme - a deep analysis of prospective science teachers' knowledge about models was carried out in another study (Torres & Vasconcelos, in press). This study relied on a qualitative approach and data was analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package.

IV.1.5.1. Participants

The targeted participants consisted of nine prospective science teachers enrolled in the Master's in Biology and Geology Teaching of a public university in the north of Portugal, a degree which will enable them to teach biology and geology subjects in middle and high schools. All of them already hold a bachelor's degree, either in biology or geology, or even in both biology and geology. In fact, in order to enrol in the aforementioned master's program, students must complete at least 50 ECTS-credits (European Credit Transfer and Accumulation System) related to geology subjects along with their BSc degree in biology or at least 50 ECTS-related to biology subjects along with their BSc degree in geology. In the first year of their master's study, the students attend classes of educational subjects, namely biology and geology education and also of scientific (biology and geology) subjects. The second year of the program is devoted to internship in schools, and prospective science teachers only attend a few classes in the university.

All of the prospective science teachers voluntarily participated in this study and are designated by fictional names: Maria, Vera, Andreia, Bárbara, Sofia, Francisco, Carolina, Inês and Rita. Our sample comprises eight females and one male, with ages ranging from 21 to 38 (average = 23.89 and mode = 21).

IV.1.5.2. Procedures

With the aim of improving prospective science teachers' views of NOS and models, we prepared and implemented an intervention programme. The intervention programme was organized in five classes, of five hours each (Torres & Vasconcelos, in press). In the first class, the main intention was for prospective science teachers to understand what scientific models are and with which purpose they are used in science, emphasizing their relevance in science. In the second class, a modelling activity was conducted for prospective science teachers to better understand the importance of models and modelling activities as contributors to the development of accurate mental models, and to the understanding of scientific activity and of the nature of science. In the third class, in which historical models were referred to, the aim was to have prospective science teachers improve their views regarding NOS and recognize the relevance of using historical models in order to promote the understanding of different aspects of NOS. An additional aim was for the teachers to reflect on how to teach NOS aspects and on the importance for students to develop accurate views of NOS. After the teachers had completed these three classes, the intention was for them to critically analyse and discuss the advantages of using models and analogies in science classes, as well as the

precautions to take when using them. A further topic of conversation was how textbooks and the science (biology and geology) standard documents cover NOS aspects, models and modeling activities. In the end, prospective science teachers were asked to construct one lesson plan and associated didactic materials in order to apply all the concepts that were developed during the intervention programme. (They were free to choose a scientific theme, but they have to teach NOS and use models.) The intervention programme was conducted by the first author of this paper, in the subject of geoscience education, which took place in the first year of their master's programme. NOS aspects were taught explicitly and activities were designed in order to promote reflection and debate.

Before and after the intervention programme, questionnaires and interviews were administered to the prospective science teachers. Their views of NOS were analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package, regarding specific NOS aspects, which were previously defined (see table IV.1.1). Their views were compared with the contemporary conceptions of NOS (which were described in the theoretical background) and classified as “naïve”, “transitional” and “informed” categories. Informed views of NOS match current conceptions of NOS aspects, while naïve views do not. Transitional views were those that reflect emerging conceptions of some NOS aspects, for example, when participants show informed views only in a few (not all) questions regarding each NOS aspect (they simultaneously show arguments that were aligned, and others that were not aligned, with currently accepted conceptions). The category “without information” is related to those few cases in which participants did not address the aspect under analysis (table IV.1.1).

The lesson plans constructed in the end of the intervention programme were also analysed according to a previously validated grid.

Table IV.1.1. Prospective teachers' views of nature of science, before (Pre) and after (Post) the intervention programme.

Targeted NOS aspects	Views categories	Pre				Pos			
		Without information n (%)	Informed Views n (%)	Transitional views n (%)	Naïve views n (%)	Without information n (%)	Informed Views n (%)	Transitional views n (%)	Naïve views n (%)
Empirical basis of science		---	1 (11.1)	4 (44.4)	4 (44.4)	---	9 (100.0)	---	---
Scientific method		---	6 (66.7)	2 (22.2)	1 (11.1)	---	9 (100.0)	---	---
General structure of experiments		---	1 (11.1)	2 (22.2)	6 (66.7)	---	7 (77.8)	1 (11.1)	1 (11.1)
Observationally based disciplines		---	2 (22.2)	---	7 (77.8)	---	9 (100.0)	---	---
Inferential Nature of scientific knowledge		---	3 (33.3)	4 (44.4)	2 (22.2)	---	6 (66.7)	3 (33.3)	---
Subjectivity in science		---	6 (66.7)	1 (11.1)	2 (22.2)	---	8 (88.9)	1 (11.1)	---
Creativity and imagination in science		---	4 (44.4)	---	5 (55.6)	---	9 (100.0)	---	---
Social/cultural influences		---	6 (66.7)	---	3 (33.3)	---	9 (100.0)	---	---
Tentativeness of scientific knowledge		---	2 (22.2)	---	7 (77.8)	---	7 (77.8)	---	2 (22.2)
Theories change		---	1 (11.1)	---	8 (88.9)	---	6 (66.7)	---	3 (33.3)
Scientific theories/laws		---	---	---	9 (100.0)	---	4 (44.4)	4 (44.4)	1 (11.1)
Scientific theories nature		2 (22.2)	2 (22.2)	1 (11.1)	4 (44.4)	---	8 (88.9)	---	1 (11.1)
Scientific theories functions		---	6 (66.7)	---	3 (33.3)	1 (11.1)	8 (88.9)	---	---
History of science and historical models		---	7 (77.8)	2 (22.2)	---	---	9 (100.0)	---	---

IV.1.5.3. Instruments

In order to evaluate how the intervention programme influenced prospective teachers' views of NOS, a questionnaire and an interview (appendixes IV.1.A and IV.1.B) were administered before and after the intervention programme. The questionnaire was adapted from the *Views of Nature of Science Questionnaire – Form C (VNOS-C)* (Lederman et al., 2002). Despite its acknowledged validity, we validated this adapted questionnaire for Portuguese prospective science teachers in a previous study, considering the specificity of the sample and the inclusion of different questions (more details of this process are presented in *Torres & Vasconcelos, 2016*). Interviews were always conducted after filling out the questionnaire. In the interviews, respondents were asked to better explain and justify certain answers and also to clarify some unclear responses. The grid to evaluate the lesson plans was mainly used to analyse which NOS aspects were intended to be focused and how these NOS aspects were intended to be taught, as well as the intention of using models and the purposes that justify their uses.

IV.1.6. Results and discussion

IV.1.6.1. NOS views

As shown in table IV.1.1, prospective science teachers greatly improved their views of NOS after attending the intervention programme. In fact, before the intervention programme several problems were identified, especially related to the empirical, tentative and inferential nature of scientific knowledge, the general structure of experiments and observationally-based disciplines and to the difference between theories and laws and theories change. The following section will present prospective teachers' views of each NOS aspect evaluated, either before or after the intervention programme.

Empirical Basis of Scientific Knowledge

Before the intervention programme, only one respondent (11.1%) possessed an informed view concerning the empirical basis of scientific knowledge. In fact, 44.4% of the respondents believed that science is based on facts and concrete things, emphasising the need for experiments in the development of scientific knowledge. The other 44.4% presented a transitional view, i.e., they simultaneously presented arguments

that were aligned and others that were not aligned with the currently accepted conception of the empirical basis of scientific knowledge. In this regard, Vera stated:

In my opinion, the development of scientific knowledge requires experiments, as theoretical scientific knowledge must be tested through experiments in order to prove or disprove the theory.

(Pre_Questionnaire_PreQ)

I think that imagination is important, as if we just stick to data, we are not able to make new interpretations and we are not able to discover the key point. With imagination we can make inferences, beyond what is there, that may be even more important.” **(Pre_Interview_Prel)**

After the intervention programme, all prospective teachers held informed views of the empirical nature of scientific knowledge. In fact, they recognized that experiments are not always needed in the development of scientific knowledge and that science is the result of a human endeavour to explain the world (table IV.1.2).

Scientific Method

When asked about the existence of a single scientific method, the majority of respondents (6 – 66.7% - before the intervention programme and 9 – 100.0% - after the intervention programme) recognized that there are different ways of doing science. Despite the number of informed answers given before the intervention programme, it was verified that prospective science teachers improved their views concerning the (in)existence of a single scientific method.

General structure of experiments

Before the intervention programme, the majority of prospective science teachers revealed some difficulties in describing an experiment. In fact, only one respondent presented an informed view concerning the general structure and aim of an experiment. However, after the intervention programme, the majority of prospective science teachers (77.8%) recognized the manipulative nature and aim of experiments.

For example, Inês stated:

An experiment consists of a manipulation of variables of an object, phenomena or process that occurs in the real world and I think that we may verify the causes and effects, the object of the study may acquire different behaviours under different situations. **(PosI)**

Table IV.1.2. Prospective teachers' views of nature of science, before (Pre) and after (Post) the intervention programme

NOS aspects	Examples	
	Pre	Pos
Empirical basis of science	Science is based on facts and concrete things, while other disciplines are influenced by individuals (...).	Science differs from other disciplines because, although it is based on interpretations, scientific disciplines try to explain phenomena and processes of nature.
	Scientific knowledge requires experiments. We need to conduct experiments for the development of scientific knowledge.	Q_Francisco (Informed) No, the development of scientific knowledge is not based solely on experiments.
		I (interview)_Francisco (Informed)
	In science there is no single scientific method and there is always some subjectivity of the scientist.	No [I do not think that scientists use a specific method when they do science]. As science is subjective, I think that there isn't a general guide that should be followed by all scientists (...) there are different ways to reach the same conclusion
Scientific method		Q_Sofia (Informed)
	I think that there is no single scientific method; I think that there are many methods to achieve something.	I_Sofia (Informed)
	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 (Uninformed)
	An experiment is a practical activity performed to prove or disprove a scientific theory.	[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.
General structure of experiments	Yes, I believe that there is no need to manipulate variables in an experiment.	Q_Vera (Uninformed)
	An observation may constitute an experiment.	

	<i>I_Vera (Uninformed)</i>	<i>Q_Inês (Informed)</i>
	The development of scientific knowledge, depending on the topic, doesn't always rely on experiments; that is, there is scientific knowledge which was only based on observation (and with no need to rely on experiments).	Not always. Because there are scientists that develop theories based only on observations.
Observationally based disciplines	<i>Q_Maria (Informed)</i> In my opinion, the development of scientific knowledge requires experiments, as theoretical scientific knowledge must be proven through experiments in order to prove or disprove a theory. Theories are only scientifically valid after being tested with experiments. <i>Q_Vera (Uninformed)</i> With the increase of technology that allows the exploration of remote places of the Earth, I think that it is possible to do research about the different layers of the Earth's interior. <i>Q_Inês (Uninformed)</i> (...) Through the data that they collect in the field, when they go to the sites, they remove samples and, according to those samples, the composition of those samples, I think that they try to elaborate the structure of the interior of the Earth. <i>I_Inês (Uninformed)</i> Scientists are not completely certain about the Earth's interior, as they do not use direct data; they use inferred data (for example, data from seismic waves propagation). (...) Scientists are certain concerning species definition (...). <i>Q_Vera(Transitional)</i> 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	<i>Q_Maria (Informed)</i> No, I don't think so [that the development of scientific knowledge requires experiments] (...) knowledge can be developed through direct observations, it doesn't need experiments. (...) Yes, my view has changed a little [since I responded to the first questionnaire] <i>I_Vera (Informed)</i> I have said that scientists are not absolutely certain about the Earth's internal structure, as the data that they use to construct the models (that are currently accepted) result from inferences and not from direct observations. As such, it might be influenced by whom is doing the inferring from the data. Also, scientists are not totally certain about the concept of species. (...) My view has changed as in the former questionnaire I said that they were certain regarding species definition. <i>I_Vera (Informed)</i> 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
Inferential Nature of scientific knowledge		
Subjectivity in science		

	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>I_Carolina (Uninformed)</i>	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>I_Rita (Informed)</i>
Creativity and imagination in science	In my opinion, scientists use imagination and creativity in two stages. In the planning stage, as the selection of the theme is crucial, that should bring something new to science. After data collection, imagination is important, because there is a need to make inferences from the data obtained.	<i>Q_Vera (Uninformed)</i>	Yes, scientists use imagination and creativity, especially when they formulate questions and also after data collection. To formulate questions, scientists must imagine or expect possible results and in the end they have to explain the results obtained. (...) [Imagination and creativity] are mainly used on these stages, but scientists use imagination and creativity in all stages of their investigations.	
	Scientists use their imagination and creativity after data collection, as they try to make sense of the data collected.	<i>Q_Bárbara (Uninformed)</i>		<i>I_Bárbara (Informed)</i>
	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.		Yes, I consider that science reflects social and cultural values. As I have mentioned before, the environment where scientist live may influence its knowledge concerning a certain aspect.	<i>I_Francisco (Informed)</i>
Social/cultural influences	I consider that science reflects social and cultural values, as we are influenced by those values. (...) We are all influenced, depending on the region. For example, I behave in a different way from a person from Afghanistan; our points of view are completely different. And yes, science will be influenced by my educational background, by my empirical experience; all of this will influence me as a scientist... I think so.	<i>Q_Francisco (Uninformed)</i>	Yes, science reflects social and cultural values as we are integrated in a society and culture. We belong to that society and culture, as our personality is built in that environment. This will influence our interpretation of and even our questioning towards reality.	
		<i>I_Maria (Informed)</i>		<i>I_Sofia (Informed)</i>
Tentativeness of scientific	Scientific theories change over the course of time (...). A scientific law is		I believe that scientific theories change and may be reformulated.	

knowledge	established as a universal truth and it is something that is accepted by the entire scientific community, such as the law of gravity. On the other hand, a theory tries to explain something without been recognized a truth, like, for example, the theory of evolution. Q_Vera (Uninformed) 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 (Informed) 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 (...)
Theories change	These changes may occur, for example, because technology has advanced and now there are new means that demonstrate that the former conception was not the correct one. Q_Vera (Uninformed) 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 (Informed) (...) and theories explain those scientific laws, they are not hypotheses. I_Bárbara (Informed) Theories are suppositions, probable ideas. Laws are theories that
Scientific theories/laws	A theory is something that may undergo changes, while a law is something concrete and immutable. Q_Francisco (Uninformed) I think that a law is something that is proven; a theory is something that we suppose. (...) I think that a theory may evolve into a law. Q_Andreia (Uninformed) A scientific theory may be what is proposed as an explanation for certain phenomena, structures and actions. (...) Accepted theories represent what is known at the moment and give us a well-founded explanation of what exists. Q_Carolina (Informed)
Scientific theories nature	

Scientific theories functions	Theories may change because they are not facts. So, they are hypotheses that may prove to be erroneous. (...) Theories are suppositions (hypotheses) of what happens. We bother to learn scientific theories because we are very curious and we wonder ourselves about the world. It is important to learn scientific theories not only to understand the world but also because a theoretical framework is always needed in order to conduct research projects.	are scientifically accepted by the scientific community. For example, the theory of plate tectonics, that tries to explain the movement of the tectonic plates. Because it is important to reach more completed theories, based on theories that are not completely correct.	Q_Andreia (Uninformed) Q_Francisco (Informed)
	Q_Andreia (Uninformed) Q_Bárbara (Uninformed)		
	Q_Sofia (Uninformed)		
	I_Andreia (Informed)		
History of science and historical models	History of Science is important [in science education], as it is possible to verify that science is not dogmatic and that current scientific knowledge is achieved through the contributions of several scientists of the past. Yes, historical models are also important [in science education] as they facilitate the learning and the transmission of content knowledge. Just saying that "the nucleus of the cell contains this and that" is very different from explaining it with a model that students may observe.	Both history of science and historical models are very important [in science education] as they explain how science changes over the course of time; they demonstrate scientists' ideologies and beliefs in the past. (...) In this way, students will understand that science is not a dogma and it depends on cultural, economic, technological and social aspects of that time. Employing content related to history of science and historical models in science education allows students to develop an in-depth view about science, its evolution, its characteristics and its nature. To understand the history and evolution of science is essential to understand what we known and how we achieve that knowledge. To understand that several contexts have influenced science, it helps us to understand how science is constructed.	Q_Maria (Informed) Q_Vera (Informed) Q_Rita (Informed)
	I_Maria I_Maria (Transitional)		

Observationally based disciplines

Concerning the relevance of observationally based disciplines in science, only two prospective science teachers held an informed view prior to the intervention programme (for example Maria – see table IV.1.2). However, after the intervention programme all respondents understood the relevance of observation in science and that experiments are not always required to develop scientific claims.

Inferential Nature of scientific knowledge

Only three (33.3%) prospective science teachers had a full understanding of the inferential nature of scientific knowledge before the intervention programme. Two of them presented naïve views and four (44.4) transitional views, as they recognized the inferential nature of scientific knowledge only in some situations. In this regard, Andreia stated:

Scientists are not totally certain, as the information that they obtain from the interior of the Earth does not come from direct observation, but from indirect data (...) Scientists are certain concerning species definition, as they have conducted experiments that enable scientists to analyse singularities of each organism and group them in distinct species (PreQ)

After the intervention programme, the majority of respondents (66.7%) recognized that indirect evidence is used to determine structures and models, such as the Earth's interior model. They further indicated that species is a construct (which is not certain) that helps scientists to organize, classify and establish relationships between organisms. For example, Vera stated:

I think that the concept of species emerges from the need to group organisms, due to the variety of organisms that exist, it is more related to the need scientists have to group organisms in order to facilitate their work. (PosI)

Subjectivity in science

In spite of the verified improvement of prospective science teachers' understanding regarding subjectivity in science, the majority of them presented informed views either before or after the intervention programme (table IV.1.1), recognizing the influence of scientists' knowledge, background, expectations and opinions in science. In this way, they believed that subjectivity may explain the dinosaur extinction controversy and thus why different conclusions are possible. However, before the intervention programme, 2

respondents surmised that this controversy results simply from the scarcity of data and did not give any relevance to subjectivity in science.

Creativity and imagination in Science

Although all prospective science teachers had previously recognized that creativity and imagination are relevant to the development of scientific knowledge, the majority of them (55.6%) believed that creativity and imagination are linked only to certain stages of the research, namely the planning stage and the stage after data collection (see table IV.1.2). After the intervention programme, all prospective science teachers held informed views concerning creativity and imagination in science, highlighting their use in every stage of the research:

Creativity and imagination are very important in scientific research. For example, when constructing a model (...) **(PosQ_Francisco)**

[Scientists] use imagination and creativity, as they are human beings. Imagination and creativity are used in all stages of the research, such as the formulation of questions, the formulation of hypotheses, the experiment (that can be performed in very different ways), the formulation of conclusions and of a final theory (...). **(PosI_Rita)**

Moreover, it is emphasised that science and imagination are fundamental in science as they

"(...) allow the evolution and enables the progress (...) [scientists] are creating something, therefore they need creativity and imagination" **(PosI_Sofia)**

Social and cultural influences

The majority of respondents (66.7% before the intervention programme and 100.0 after it) held informed views concerning social and cultural influences on science, as they recognized the influence of social and cultural aspects on science development.

Tentativeness of scientific knowledge

Despite the fact that all prospective science teachers assumed that theories change, the majority of them (77.8%) held the naïve view that laws are more certain than theories, suggesting a certain lack of knowledge concerning the tentativeness of scientific knowledge. Furthermore, five prospective science teachers (55.6%) mentioned that laws are absolute and do not change.

After the intervention programme, the majority of prospective science teachers improved their views concerning the tentativeness of scientific knowledge. In fact, only two prospective science teachers persisted with the view that laws are more certain than theories. For example, Andreia still mentioned:

Yes, I said that theories are assumptions, probable ideas and that laws are theories that are scientifically accepted (...) theories can still be tested, laws are typically proven. (PosI)

Theories change

When analysing why theories change, we also verified that prospective science teachers improve their views, as only one prospective teacher presented informed views prior to the intervention programme. In fact, they mainly mentioned that theories change due to technological advances and new knowledge (table IV.1.2). On the other hand, after the intervention programme, the majority of respondents held informed views, recognising the role of different interpretations and perspectives in the development of scientific knowledge.

Difference between scientific theories and laws

Prior to the intervention programme, all prospective science teachers presented naïve views regarding the difference between scientific theories and laws. Indeed, seven respondents (77.8%) indicated that laws are more certain than theories and two of them also added that theories evolve into laws, as they become proven (see examples of table IV.1.2). It was verified that prospective teachers improve their views, as after the intervention programme, four respondents (44.4%) possessed informed views and four others transitional views. For example, Vera recognized that “a scientific law constitutes a generalization of patterns that are observed in nature, while a scientific theory provides explanations for those laws (PosQ)”. On the other hand, she also believed that laws are more certain than theories, which revealed a transitional view.

The nature of scientific theories

Only two prospective science teachers held informed views concerning the nature of scientific theory prior to the intervention programme. It is important to emphasize that at this stage of the study prospective science teachers undervalued scientific theories, considering them flawed and less important than laws. In this respect, Vera said:

A theory tries to explain something without being recognized as a truth, like, for example, the theory of evolution. (PreQ)

After the intervention programme, the bulk of respondents (88.9%) held an informed view, recognising that theories are explanations that have scientific value:

A scientific theory must be approved by the scientific community to be recognized as a scientific theory. (...) scientific theories are explanations which were validated by the scientific community (PosQ, Vera)

Functions of scientific theories

Concerning the function of scientific theories, the majority of prospective science teachers held informed views both before and after the intervention programme. However, before the intervention programme three respondents had some difficulties in justifying the usefulness of scientific theories. After the intervention programme, eight respondents (88.9%) possessed informed views concerning the usefulness of learning scientific theories: 66.7% (n=6) believed that theories provide a theoretical framework that allows for the understanding of current knowledge; 11.1% (n=1) recognized that scientific theories provide a theoretical framework for future investigations and 11.1% (n=1) stated that scientific theories have both functions.

The history of science and historical models

When asked about the relevance of history of science and historical models for science education, the majority of prospective science teachers also presented informed views both before and after the intervention programme. However, we can verify that after the intervention programme they exhibited a better understanding of their relevance for science education, as they improved their views related to historical models. In fact, both Maria and Inês did not understand the full potential of historical models in science education, as their relevance was restricted to the fact that they were visual aids in the learning process.

The change of their views about science

The results related to the last question of the questionnaire (that was only applied after the intervention programme) were already discussed in a previous work (Torres, Amador, & Vasconcelos, 2016) and are briefly discussed in this paper. In this regard, all respondents recognized that they had changed their views of NOS and had particularized some changes concerning specific NOS aspects. Three respondents

(33.3%) expressed that they had come to a better understanding of the fact that experiments are not always required in the development of scientific knowledge:

I have learned that science involves much more than conducting experiments. (PosQ_Andreia)

Moreover, two respondents (22.2%) emphasised that they had improved their views concerning the difference between theories and laws and two others their views related to social and cultural influences on science:

The main change was related to the influence of socioeconomic context in scientific enterprise. In the beginning, I thought that there was no relationship, now I recognize it (PosQ_Vera)

Another important achievement was the recognition that they had arrived at a better understanding of the relevance of NOS instruction in science classes (44.4%, n=4), which we considered of the utmost importance, considering the nonlinear translation of NOS views to classroom practice. Furthermore, three respondents (33.3%) also revealed that they better understood the relevance of using history of science in their classes.

Concerning the sources (or reasons) responsible for the changes that have occurred, all respondents mentioned the classes of the intervention programme and three (33.3) the reading of certain documents, such as scientific papers.

IV.1.6.2. Models views

Although models are considered to be an important aspect of science, we decided to analyse in depth prospective science teachers' knowledge about models in another study (Torres & Vasconcelos, in press). Globally, we concluded that the prospective science teachers who attended the intervention programme improved their views regarding models in science (both the concept and purposes of scientific models) and for teaching science (as they greatly amplified their views regarding the relevance of models in science teaching).

IV.1.6.3. Lessons Plans

Lessons plans constructed by prospective science teachers were mainly analysed regarding the intention of instructing NOS and the use of models. Although all prospective science teachers included NOS aspects in their lessons plans, there are some differences concerning the number of aspects incorporated in each lesson plan. For example, Inês made only references to the tentativeness of scientific knowledge,

while Rita focused on six distinct aspects. The majority of prospective science teachers (n=8 – 88.9%) focused on the tentativeness of scientific knowledge, while none of them focused on the difference between theories and laws (see table IV.1.3). In fact, the difference between scientific theories and laws was the aspect that revealed the fewest informed views before and even after the intervention programme (see table IV.1.1), which may explain why this aspect was not focused on in any lesson plan. Both social and cultural influences on science and the relevance of models in scientific knowledge development were included in the lesson plans of four prospective teachers.

Table IV.1.3. Number of teachers that included each NOS aspect in their lesson plan.

NOS aspects	Number of teachers that included each NOS aspect
Tentativeness of scientific knowledge	8 (88.9)
Empirical basis of science	2 (22.2)
Subjectivity in science	3 (33.3)
Creativity and imagination in science	2 (22.2)
Social/cultural influences	4 (44.4)
Observation and inferences in science	2 (22.2)
Inexistence of a single scientific method	1 (11.1)
Scientific theories/laws	0
Scientific model meaning	2 (22.2)
Scientific models characteristics	2 (22.2)
Relevance of scientific models	4 (44.4)

In the same way, all prospective teachers developed lessons plans that required the use of models. All of them intended to use models to promote the development of conceptual knowledge, eight (88.9%) to promote the development of inquiry skills and only two (22.2%) to promote the development of views of NOS. The analysis of the lessons plans also showed the intention of teaching NOS in an embedded (100%) and explicit (66.7%) way.

IV.1.7. Conclusions

Before the intervention programme, results showed that prospective science teachers hold naïve or transitional views regarding most of the NOS aspects evaluated. However, after the intervention programme the majority of them presented informed views

concerning almost all aspects of NOS. These results are consistent with findings obtained by Mesci & Schwartz (2016) and Herman & Clough (2016). However, the prospective science teachers still struggled with some NOS aspects, for example the difference between theories and laws. In the study conducted by Mesci & Schwartz (2016) this aspect was also one that caused difficulties and the most problematic to be changed.

It is important to emphasize that prospective science teachers themselves recognized that they have changed their views and that they have come to a better understanding of the relevance of NOS instruction in science classes, which may contribute to the translation of their views to their instructional practices.

Although all of them had planned to teach NOS in their lessons plans, prospective science teachers revealed different types of awareness regarding NOS instruction. Also, the NOS aspect that was least understood was not focused by any of them in their lesson plans, a fact which highlights the need to both better develop the less understood aspects and investigate further the factors that may influence science teachers' views of NOS. Although the majority of prospective science teachers have recognized the full potential of models in science teaching, only two students planned to use them to teach NOS aspects.

Despite these positive results, it is crucial to analyse the factors that influence the translation of their views to their classroom practices. As a result, we will observe their classes during their internship to better understand the factors that intervene in efficient NOS instruction.

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Appendix IV.1.A. Adaptation of the “Views of Nature of Science Questionnaire”, Form C (VNOS-C) (Lederman et al., 2002)

Question 1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g. religion, philosophy, or art)?

Question 2. What is the relevance of history of science and historical models for science education?

Question 3. What is an experiment?

Question 4. Does the development of scientific knowledge require experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

Question 5. After scientists have developed a scientific theory (e.g., cell theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:
 - (iii) Explain why theories change.
 - (iv) Explain why we bother to learn scientific theories. Defend your answer with examples.

Question 6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example

Question 7. Science textbooks often represent the interior of the Earth as a set of concentric layers with distinct characteristics. How certain are scientists about the structure of the interior of the Earth? What specific evidence, or types of evidence, do you think scientists used to determine how the interior of the Earth looks like?

Question 8. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

Question 9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the Earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

Question 10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
 - If you believe that science is universal, explain why and how. Defend your answer with examples.
-

Question 11. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Question 12. Reflecting upon the classes you have attended this academic year, do you feel as though you have changed your views of the nature of science?

- If yes, identify and explain the main changes and the most important reasons for, and sources of, those changes.
-

Appendix IV.1.B. VNOS Interview Protocol

1. Can you read and better explain your answer?
2. What do you mean by (...)?
3. How does your answer to *question a* relates to your answer to *question b*?
4. Can you provide some examples that better illustrate your answer?
5. Have your views changed since you responded to the first questionnaire? If so, how?
6. (...)

IV.2. Prospective science teachers' views of models after the intervention programme

MODELS IN SCIENCE AND FOR TEACHING SCIENCE: DATA FROM AN INTERVENTION PROGRAMME

Joana Torres & Clara Vasconcelos

International Journal of Learning and Teaching, (to be published in 2016).

IV.2.1. Abstract

Currently, implementing models and modelling activities in science teaching is considered to be essential. Apart from being crucial as an auxiliary aid to the construction of scientific knowledge, they also play a major contribution in the development of adequate views of nature of science and models, as well as in the development of scientific inquiry competencies. However, many studies disclose that science teachers do not rely on models in their classes very often, thus revealing some lack of knowledge regarding them. With the intention of improving prospective science teachers' views of the nature of science, emphasising the nature of models, as well as their role in science and for teaching science, an intervention programme was conducted and evaluated. Nine prospective science teachers voluntarily attended the intervention programme and responded to previously validated questionnaires and interviews about models before and after it. Data was analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package. In general terms, prospective science teachers improve their views regarding models in science and for teaching. Nevertheless, the observation of their classes will be an invaluable asset for future research.

Keywords: Intervention programme, modelling, models, prospective teachers' views, science teaching.

IV.2.2. Introduction

Scientific models are considered to be crucial in scientific enterprise, being considered “not only products of science but also tools and processes of science” (Cheng & Lin, 2015, p.2454). In fact, scientific models play a fundamental role in scientific knowledge construction and development, as they are used to describe, explain and to predict natural phenomena, as well as to communicate scientific ideas to others (Oh & Oh, 2011).

In spite of the existence of diverse definitions and different types of scientific models, they may be defined, in general terms, as simplified representations of a target, which are built according to a particular portion of that target and with specific purposes (Chamizo, 2013; Giere, 2010; Torres & Vasconcelos, 2015).

Given the relevance of scientific models in science, models and modelling activities are currently considered to be fundamental in science teaching. As Justi and Gilbert (2002-2003) state, models and modelling activities should promote the learning of science, of *how to do* science and *about* science.

In fact, models and modelling may help students to develop mental models that are in accordance with the major models that are the products of science. Moreover, students may develop inquiry skills and understand how scientists work by creating, testing and revising their own models (Namdar & Shen, 2015; Vasconcelos, Moura, Torres, Moutinho, & Lima, 2015) and may also develop a better understanding of the nature of models and the nature of science. In fact, as models and modelling are considered to be an important aspect of science, the understanding of the nature of models will contribute to the understanding of the nature of science and, consequently, to a better conceptual learning in science (Cheng & Lin, 2015).

There are many studies that reveal the positive effects of employing models in science teaching. Halloun (2007) claims that students achieve, for example, better conceptual understanding of scientific knowledge; better performance in the exams; better views about the nature of science and acquire better learning styles when using models in science classes. Furthermore, this author states that students develop stable inquiry skills, tools and learning styles that may be used in other situations and courses.

Haugwitz and Sandmann (2010) claim that the use of models in science classes simplifies the learning process and promotes better conceptual understanding, while prompting the interest of the students. Moutinho, Moura & Vasconcelos (2014) emphasize the relevance of modelling activities in the restructuration of students' mental models. In this regard, Gilbert and Ireton (2003) also add that the reliance on multiple models contributes to a richer mental model construction.

In spite of the relevance that it is attributed to models and modelling in science education, some studies reveal that science teachers' understanding of models and modelling is limited and that they do not use models very often in science classes (Khan, 2011; Krell & Krüger, 2016). In a study conducted in Portugal, it was demonstrated that science teachers and high school students do not possess a consistent definition of models and that models are only used in science classes as contributors to the learning of science (Torres, Moutinho, & Vasconcelos, 2015).

Some inconsistencies regarding the definition of models were also found in a study conducted with prospective science teachers in Portugal (Torres & Vasconcelos, 2015). Moreover, an analysis of the syllabus of geology and biology education subjects of seven Portuguese universities showed that prospective teachers do not deeply deal with models in their initial training. In fact, it was demonstrated that little relevance was attributed to models and modelling activities in their training (Torres & Vasconcelos, 2014).

In view of this, we consider it fundamental that prospective teachers (and even in-service teachers) improve their views of models in science and for teaching and that they recognize their full potential when used in science classes. In fact, it is crucial that teachers understand how important it is to engage students in modelling activities that reflect scientists' activities and that prompt the development of scientific knowledge, inquiry skills and accurate views of the nature of science. In this regard, Oh and Oh (2011), after a literature review, suggested five subtopics that science teachers should know about models: (i) meanings of a model; (ii) purposes of modelling; (iii) multiplicity of scientific models; (iv) change in scientific models; (v) uses of models in the sciences classrooms.

Having the above mentioned aspects in mind, we planned an intervention programme, which primarily aims to improve science teachers' views of nature of science, emphasising the nature of models, as well as their role in science and for teaching science. The intervention programme was organized in five classes, of five hours each.

Starting with activities that intended to promote a better understanding of what scientific models are and with which purposes they are used, a set of modelling activities was developed. These activities were designed in order to foster a better understanding of the importance of models and modelling activities in the development of accurate mental models, and in the understanding of scientific activity and of the nature of science.

Some activities with historical models were also developed, mainly for teachers to recognize their relevance in the understanding of certain aspects of the nature of science. Furthermore, we engaged teachers in a critical analysis of Portuguese science

textbooks and science standard documents and in some discussions concerning the advantages and precautions to take when using models and analogies in science classes.

It was expected that, at the end of the intervention programme, teachers be prepared to present a lesson plan that must include a modelling activity and must contribute to the development of conceptual knowledge and inquiry skills, as well as to the understanding of the nature of models and of the nature of science.

In this study we started to work with prospective science teachers that will teach biology and geology subjects in middle and high schools. Thus, we will analyse how the intervention programme influenced their views about models, by comparing the views they held before and after it.

IV.2.3. Methods

The study presented in this article is part of a broader research which aims to deepen prospective science teachers' views of the nature of science (emphasising the nature of models, as well as their role in science and for teaching science), and to understand the factors that mediate the translation of teachers' views into their practices in classes. Concerning the former aim, an intervention programme was prepared and applied to prospective teachers (which was briefly described in the introduction). With this study we mainly intended to evaluate how this intervention programme influenced prospective teachers' views concerning models in science and for teaching science.

Nine prospective science teachers voluntarily attended the intervention programme and responded to a questionnaire and interview before and after the intervention programme. The questionnaire was validated in a previous study and comprises fourteen open-ended questions which mainly evaluate prospective teachers' views regarding models in science and for teaching science, as well as their conceptions concerning the use of models in science classes (Appendix IV.2.A).

In the interviews, prospective science teachers were asked to better explain and clarify their answers and to add some needed information (some examples of questions are provided in Appendix IV.2.B). The interviews were audiotaped and transcribed and the data (obtained through questionnaires and interviews) was analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package.

These prospective science teachers will teach biology and geology subjects in middle and high schools and are designated, in this study, by fictional names: Maria, Vera, Andreia, Bárbara, Sofia, Francisco, Carolina, Inês and Rita (8 females and 1 male). This sample comprises prospective teachers between the ages of 21 and 38 (average =

23.89 and mode = 21). When they participated in the intervention programme, they had already concluded either a BSc degree in Biology, or a BSc in Geology, or a BSc in Biology and Geology and were enrolled in the master's course in biology and geology teaching.

IV.2.4. Results and discussion

With this study, it was verified that after attending the intervention programme, prospective science teachers improved their views about models in science and for teaching science. As shown in table IV.2.1, prospective teachers greatly developed their views regarding scientific model concept and purposes.

Before the intervention programme, prospective teachers had presented confusing definitions of models, viewing them as tools to use only in school or as copies of reality. After the intervention programme, all of them had recognized models to be representations of some aspects of reality, as well as their relevance in scientific development. For example, Vera stated:

"Yes, I change a lot my view concerning model definition. In the first questionnaire, I just pointed out that scientific models mirrored an event. Now I understand that a model is not a mirror, i.e., it is not a copy of reality, it is influenced by other things".

Furthermore, the vast majority of prospective science teachers (88.9%) also improved their views regarding the purposes of scientific models. In fact, before the intervention programme, all prospective teachers had mentioned that models were solely used to describe or explain certain aspects of reality.

After the intervention programme, eight prospective teachers pointed out the relevance of models in scientific knowledge development, either by describing, by explaining or by predicting some phenomenon or aspect of reality. Concerning this change of perception, Francisco stated:

"Yes [I change my view about the purposes of scientific models]. I had only associated scientific models with classes. Now I understand that scientific models are used in science".

Table IV.2.1. Prospective teachers' views about models in science, before (Pre) and after (Post) the intervention programme.

Views Analysed aspects	Uninformed		Informed	
	Pre	Post	Pre	Post
Scientific model concept	Example <i>In my opinion, a scientific model is a set of ideas, theories and methods to follow towards a problem to solve.</i> Q_Sofia (Q – questionnaire' answer)		A model is an approximated representation of a real thing. Q_Francisco	A scientific model is a demonstration of a phenomenon. It intends to represent certain phenomena of reality that we are trying to explain. I_Sofia (I – interview' answer)
	(%) 6 (66.7)	---	3 (33.3)	9 (100)
Scientific model purposes	Example <i>The main purpose is to explain the reality in a simple manner, in a way that everyone understands it. Models are used in the classroom or in the training context. A teaching or learning context may be completed with scientific models.</i> Q_Rita <i>Models are used as an orientation to a better understanding and learning.</i> Q_Sofia	<i>Trying to explain phenomena of reality, trying to represent them.</i> I_Sofia		<i>Scientific models are used to explain and represent ideas or phenomena. In science they are also used to predict. (...) Models are very important in geology, as it is a science that deals with aspects that are not directly observed.</i> QI_Rita (QI – questionnaire and interview' answer)
	(%) 9 (100)	1 (11.1)	---	8 (88.9)
What can be represented by a scientific model	Example <i>A scientific theory, I think that it is a theory, I think so.</i> I_Sofia <i>Theories.</i> I_Bárbara		<i>A geological mechanism, geological phenomena (...) [a model] may represent the DNA molecule. It may represent many objects of analysis for a certain scientific area.</i> I_Inês	<i>A phenomenon of reality, a process of reality.</i> I_Sofia <i>Many things. Phenomena, events, (...) systems, like the endocrine system (...).</i> I_Bárbara
	(%) 2 (22.2)	---	7 (77.8)	9 (100)
Relationship between scientific model and theory	Example <i>A scientific model is almost the practical demonstration of a scientific theory. When we construct a scientific model it is to support a scientific theory. (...) To construct a model, we must have a theory beforehand.</i> QI_Bárbara	<i>The scientific model may try to demonstrate a process, a phenomenon, structure that it is integrated in the scientific theory.</i> Q_Carolina	<i>(...) 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> I_Rita	<i>A scientific model establishes a bidirectional relationship with a scientific theory. A model may function as the basis to the elaboration of a theory or to support or to prove it. (...) through scientific models we may construct theories or through theories we may construct scientific models.</i> QI_Bárbara
	(%) 8 (88.9)	5 (55.6)	1 (11.1)	4 (44.4)

Change in scientific models	Example	Yes [models may change] if the scientific theory, which is related with model construction, also changes. Q_Maria		Yes because science is tentative. If there are new discoveries, they will contribute to the change of scientific models, for them to correctly represent the target. Q_Maria
	(%)	---	---	9 (100)
Multiplicity of scientific models	Example	Yes, multiple models may exist to study the same target and different aspects of the same target. I_Bárbara		Yes, multiple models may exist to study the same target and different aspects of the same target. With different materials, for example. I_Bárbara
	(%)	2 (22.2)	---	7 (77.8)

Moreover, after the intervention programme, all of the prospective teachers possessed informed views concerning what may be represented by scientific models, the multiplicity of scientific models and their change over the course of time (Table IV.2.1). The majority of prospective teachers only failed to improve their view concerning “the relationship between scientific model and theory” aspect. In fact, after the intervention programme, only four prospective teachers expressed a belief that scientific models establish a bidirectional relationship with a scientific theory.

The majority of prospective science teachers also improved their views concerning the relevance of models in science teaching. In fact, only two prospective science teachers continued with the limited view that models are just used to prompt a better understanding of scientific knowledge. The other prospective science teachers understood that models may be used to prompt not only the understanding of scientific knowledge, but also the understanding of the nature of science and the development of inquiry skills (Table IV.2.2).

Furthermore, after the intervention programme, the majority of prospective teachers recognized that apart from scientific knowledge, there are other important conditions (needs) for students to develop models, such as imagination and creativity, as well as the ability to select, choose and integrate a set of items, depending on a particular goal. All of them also recognised that models in science teaching are usually different from models in science, as models in science teaching must be adapted according to the level of students and to the science teaching objectives, which are certainly different from those of models in science (Table IV.2.2).

Table IV.2.2. Prospective teachers' views about models for teaching, before (Pre) and after (Post) the intervention programme.

Analysed aspects	Views	Uninformed		Informed	
		Pre	Post	Pre	Post
Models contribution in science teaching		Models may help students in the understanding of how certain things happen, certain natural phenomena. (...) I_Andreia	Models may have an important role in science teaching. (...) They may be a useful tool to prompt students' learning. (...) With models, knowledge becomes more significant for students. Models also allow the visualization of events that are difficult to understand. Q_Vera	Models are very important for students to visualize what happens in reality and, sometimes, what is difficult to teach. When building models, students develop their critical thinking, their capability of constructing them (...). They may also understand how the construction of models happens from theories. Q_Rita	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
	Example	In science teaching, models are used to reify some subjects that are difficult to understand. The construction of models requires theoretical knowledge, prompting the learning of concepts. Q_Vera			Models allow students to reflect scientists' activity. In classes, models allow students to better understand that activity and to better understand reality. I_Andreia
	F (%)	7 (77.8)	2 (22.2)	2 (22.2)	7 (77.8)
Favourable conditions for students to develop models		For students to construct models they should be completely informed concerning the theoretical content in which a scientific model is based. Q_Sofia	I think that students need a theoretical contextualization (...) I think that the first step is the understanding of what they are going to represent. I_Sofia	Creativity, for example. Also the understanding of what they are going to do. Also, a little bit of teacher's orientation is also very important. I_Maria	Students must know what they want to represent, which variable they are going to represent, they must gather information. Of course, to construct they must have the information for doing so. (...) They also need creativity and imagination. I_Maria
	Example				
	F (%)	7 (77.8)	1 (11.1)	2 (22.2)	8 (88.9)
Differences between models in science teaching and models in science		I think that from a model that is used in science, we can use it in science teaching. They must be equal (...) I_Andreia		They must be different, as they should be adapted to the school grade in which they are used. By using a scientific model, students may not understand and tend to lose interest. Q_Carolina	The models that are used in teaching must be adapted to the school grade in which they are used and they must be, in general terms, simpler and clearer. They must be related with the theme. Q_Andreia
	Example				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
	F (%)	3 (33.3)	---	6 (66.7)	9 (100)

The second part of the questionnaire was more focused on prospective teachers' views about the use of models in science teaching and the precautions to take when using them. Regarding prospective teachers' views about the use of models in science teaching, all of them indicated that they consider it important to present models, as well as to ask students to construct models, either before or after the intervention programme.

When it comes to the difficulty of constructing or understanding (previously constructed) models, the majority of prospective science teachers (66.7% before the intervention programme and 55.6% after the intervention programme) considered that the construction of models entails more difficulties. Only one prospective teacher (after the intervention programme) mentioned that the understanding of a previously constructed model involves more difficulties, while 3 prospective teachers (before and after) considered that both options entail difficulties.

When asked about the most advantageous option, the majority of prospective teachers (55.6% before the intervention programme and 66.7% after the intervention programme) chose the construction of models. We may say that the results are similar before and after the intervention programme. However, we observed that after the intervention programme prospective teachers gave more emphasis to important aspects when justifying their options, such as the development of creativity and inquiry skills, the understanding of scientists' activity, and the understanding of the role and limitations of models in science. For example, Bárbara stated:

"It is more advantageous that students construct models. In spite of being a challenge to overcome, the construction of models provides students with new abilities to work or to do future research (...) Also, students may reflect the role of scientists, in order to understand how scientific knowledge evolves and also to understand the role of models, or to understand the reality, or to predict (...)"

Concerning the characteristics of good models, prospective teachers mainly stated that models in science teaching should be clear, simple, rigorous, pertinent and adapted to the level of students of the class in which they are used (Table IV.2.3).

Table IV.2.3. Characteristics of good models in science teaching.

Main characteristics	Frequency (%)	
	Pre	Post
Clear	7 (77.8)	8 (88.9)
Simple	7 (77.8)	7 (77.8)
Rigorous	6 (66.7)	7 (77.8)
Pertinent	7 (77.8)	4 (44.4)
Adapted to the level of students	5 (55.6)	6 (66.7)
Attractive/ motivator	7 (77.8)	1 (11.1)

As shown in table IV.2.3, there are no substantial differences in the main characteristics mentioned before and after the intervention programme. Also, in these two moments the majority of prospective teachers emphasized the need for models to be clear in order to avoid the development of misconceptions. Nonetheless, it is important to highlight that after the intervention programme, five prospective teachers

also added the relevance of warning students of what models are, their limitations and how they are used in science:

We should indicate that models are not copies of reality, they may not be correct, as the theoretical framework that originated them may also not be correct (...). What we observe may not correspond to reality (...) – Vera (after the intervention programme)

When developing modelling activities, we should explain what modelling is and students should reflect and understand for what purposes models are used (...) - Rita (after the intervention programme)

Moreover, prospective science teachers also displayed a greater awareness, after the intervention programme, for the importance of students to have an active role when using models.

Additionally, they specifically mentioned that they change their views about models, especially their views concerning the definition of models and their contribution to science teaching.

IV.2.5. Conclusions

With these results, we may conclude that the prospective science teachers who attended the intervention programme improved their views regarding models in science and for teaching science. In fact, they greatly developed their views regarding the concept (definition) and purposes of scientific models and greatly widened their views regarding the relevance of models in science teaching. We also demonstrated that when justifying their options concerning the use of models in science classes, they expressed a greater awareness of both the potential and nature of models.

These results are rather exciting, as they may contribute to the effective use of models in science classes in the future, in a way that enables students to develop not only conceptual knowledge, but processual and epistemological knowledge as well.

However, we considered it of the utmost importance to observe the forthcoming classes of these prospective students, in order to understand the challenges they will inevitably face when implementing modelling activities in their classes.

Given the satisfactory results obtained in this study and considering the lack of knowledge that in-service teachers revealed in several other studies, we also think that it is important to broaden the scope of this type of intervention to include them as well, in order to contribute to the effective implementation of modelling activities in science classes.

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Appendix IV.2.A. Questionnaire about models

Question 1.	In your opinion, what is a scientific model?
Question 2.	What are the main purposes of scientific models? In what circumstances are they used?
Question 3.	What is the relationship established between scientific models and theories? Justify your answer.
Question 4.	Do you believe that scientific models change over the course of time? Justify your answer with examples.
Question 5.	In your opinion, how can models be used in science teaching? What is the relevance of using models in science teaching?
Question 6.	Do you consider it important that students build models? Why?
Question 7.	What do students need to construct models?
Question 8.	In your opinion, may (or should) models that are used in science teaching be different from models that are used in science? Why? What may be the main differences?
Question 9.	How are you thinking of using models in science classes? By presenting your models to students or by giving them the opportunity to construct models? Justify your answer.
Question 10.	What do you consider to be more difficult for students: the understanding of a model (either presented by the teacher or one encountered in a textbook, ...) or the constructing of a model? Why?
Question 11.	In your opinion, which is the most advantageous situation for students: the understanding of a presented model or the constructing of a model? Why?
Question 12.	When constructing models for science teaching, what aspects should we take into consideration? What precautions should we take when using models in classes?
Question 13.	In your opinion, what are the characteristics of a good model in science teaching? Why?
Question 14.	After the classes that you attended during this academic year, do you feel that you have changed your views about scientific models and regarding the use of models in science classes? If so, identify and explain the main changes and the main reasons (and sources) for those changes.

Appendix IV.2.B. General interview script about models

Question 1.	Can you read and better explain your answer?
Question 2.	Do you want to add something more to your answer?
Question 3.	What do you mean by (...)?
Question 4.	How does your answer to <i>question a</i> relate to your answer to <i>question b</i> ?
Question 5.	Have your views changed since you wrote your answer? If so, how?
Question 6.	From those options, which one do you chose to define scientific model?
Question 7.	What can be represented by a scientific model?
Question 8.	Can different models exist to represent different aspects of the same target?
Question 9.	Can different models exist to represent the same target?
Question 10.	(...)

IV.3. Concepções desenvolvidas e alteradas após o Programa de Intervenção – Pequenos questionários

ANÁLISE DOS PEQUENOS QUESTIONÁRIOS APLICADOS

Joana Torres & Clara Vasconcelos

Adaptado de Aplicação de um programa de intervenção em história da ciência dirigido a estudantes do mestrado em ensino da biologia e da geologia. In C. R. Gomes, A. Rola & I. Abrantes (Eds.), E-book do colóquio II - História das Ciências para o Ensino – Atas do Colóquio II, 105-125. Coimbra: Universidade de Coimbra. Faculdade de Ciências e Tecnologia. Departamento de Ciências da Terra (2014).

IV.3.1. Introdução e Descrição do Estudo

Com o objetivo de melhorar as concepções dos professores em formação inicial acerca da natureza da ciência e do uso de modelos foi aplicado um programa de intervenção (PI). Este PI, para além de ser desenvolvido com o intuito de melhorar as concepções dos professores, pretende também ter um papel promotor de diversas práticas letivas, nomeadamente da dinamização de atividades que espelhem a atividade dos cientistas, promovendo o desenvolvimento de conhecimento científico, competências de investigação e de visões adequadas sobre a natureza da ciência.

Como já descrito anteriormente, este PI foi aplicado a 9 estudantes (8 elementos do género feminino e 1 do género masculino) do mestrado em ensino da Biologia e da Geologia no 3º ciclo do ensino básico e no ensino secundário, de uma universidade pública do Norte de Portugal. O PI decorreu no âmbito da unidade curricular de Didática da Geologia II, no segundo semestre do ano letivo 2013/2014.

Após cada uma das quatro primeiras intervenções do PI, foi solicitado aos estudantes que preenchessem um pequeno questionário, previamente validado, no sentido de as avaliar. Neste estudo, apresentamos os resultados que resultam das respostas às seguintes questões: (i) Indica, de forma completa, quais as principais

concepções que desenvolveste nesta aula; e (ii) Consideras que, com esta aula, alteraste as tuas concepções? Quais as concepções alteradas?

As respostas dos estudantes foram alvo de uma análise de conteúdo, recorrendo-se ao programa NVivo 10.

IV.3.2. Resultados e Discussão

Nesta secção são apresentados os resultados das respostas dadas a cada uma das questões do pequeno questionário aplicado, por intervenção.

IV.3.2.1. Intervenção 1

Relativamente à primeira questão da primeira intervenção, verifica-se que todos os estudantes consideram ter desenvolvido as suas concepções relativamente aos modelos científicos e às suas características, apresentando como exemplo o facto de os modelos poderem representar uma diversidade de alvos (Tabela IV.3.1).

Tabela IV.3.1. Principais respostas dadas à questão 1 (intervenção 1).

Q1 - Quais as principais concepções que desenvolveste nesta aula?	
Concepções	%
Os modelos científicos e as suas características	100
Modelos como representações de diversos alvos	66.7
Importância dos modelos no Ensino das Ciências	66.7

Como exemplo, um dos estudantes refere:

«A principal concepção desenvolvida nesta aula foi a noção de “modelo” e “modelo científico”. O desenvolvimento destas noções foi também acompanhado por esclarecimentos relativos às principais características dos mesmos.» (E2)

Foi também salientada, por 66.7% dos estudantes, a importância dos modelos no ensino das ciências:

“Além do seu uso ser essencial na ciência, estes podem ainda ser um importante auxílio na sala de aula, para professores e alunos.” (E3)

Tabela IV.3.2. Principais respostas dadas à questão 2 (intervenção 1).

Q2 - Quais as concepções alteradas?	
Concepções	%
Diversidade de modelos	83.3
Definição de modelos	50.0
Necessidade da abstração na construção de modelos	33.3

No que concerne às concepções alteradas (Tabela IV.3.2), grande parte dos estudantes (83.3%) considera ter modificado as suas concepções relativamente à diversidade de modelos e 50% dos estudantes considera ter alterado a definição de modelos que possuía:

“Por exemplo, fiquei a conhecer os vários tipos de modelos (...)” (E9)

“Esta aula levou-me a alterar as concepções relativamente aos modelos científicos, uma vez que alterei a concepção dos tipos de modelos, do que é um modelo científico (...)” (E8)

Uma das concepções alteradas referidas por 33.3% dos estudantes prende-se com a necessidade da abstração na construção de modelos. Como exemplo, um dos estudantes refere:

“Também em relação à necessidade de abstração para construção de modelos, nunca tinha pensado nisso.” (E3)

IV.3.2.2. Intervenção 2

No que diz respeito à primeira questão da segunda intervenção, 77.8% dos estudantes refere ter desenvolvido a sua definição de modelo mental e suas características, mencionando, por exemplo, que os modelos mentais são idiossincráticos (Tabela IV.3.3):

“Aprendi que os modelos mentais diferem de indivíduo para indivíduo. Este é um facto a ter em conta com os alunos no processo de ensino e de aprendizagem.” (E7)

Foi também mencionado, por 44.4% dos estudantes, a aplicabilidade dos modelos nas aulas de ciências. Como exemplo, um dos estudantes refere:

“(...) fiquei completamente esclarecida quanto à definição de modelos, sua contextualização histórica e, nomeadamente, a sua aplicação em termos didáticos na sala de aula no ensino das ciências.” (E6)

Tabela IV.3.3. Principais respostas dadas à questão 1 (intervenção 2).

Q1 - Quais as principais concepções que desenvolveu nesta aula?	
Concepções	%
Definição de modelos mentais e suas características	77.8
Os modelos mentais são idiossincráticos	33.3
Aplicabilidade dos modelos nas aulas de ciências	44.4
Definição de modelos conceituais	33.3

Quanto às concepções alteradas na segunda intervenção (Tabela IV.3.4), os estudantes referem, essencialmente, a relevância dos modelos e das atividades de modelação nas aulas de ciências:

“Após a realização da atividade prática sobre a estabilidade de uma vertente, ao longo da execução da mesma verifiquei que a aplicação de modelos didáticos no âmbito da sala de aula é muito importante. Isto deve-se ao facto de esta aplicabilidade proporcionar uma melhor compreensão e contacto com o fenómeno em estudo, como também a partilha e discussão de conhecimento entre os elementos constituintes da turma.”
(E7)

“Esta aula possibilitou uma assimilação mais prática das concepções alteradas na aula anterior quanto à importância dos modelos e das atividades de modelação no ensino das ciências.” (E8)

Tabela IV.3.4. Principais respostas dadas à questão 2 (intervenção 2).

Q2 - Quais as concepções alteradas?	
Concepções	%
Relevância dos modelos e das atividades de modelação nas aulas de ciências	33.3

IV.3.2.3. Intervenção 3

Relativamente à primeira questão (Tabela IV.3.5), grande parte dos estudantes (75%) considera ter desenvolvido as suas concepções relativamente à NdC, nomeadamente as relativas aos seus componentes (62,5%) e ao seu ensino (50%). Quanto aos

componentes da NdC, dois alunos (25%) destacam ainda a clarificação da distinção entre teoria e lei.

Por exemplo, um dos estudantes refere o seguinte:

“As principais concepções desenvolvidas na aula foram a definição de natureza da ciência; quais os componentes da natureza da ciência; e de que forma a natureza da ciência poderá ser levada para as salas de aula.”
(E2)

62,5% dos estudantes considera ainda ter desenvolvido as suas concepções relativamente aos modelos históricos, nomeadamente ao nível da sua importância e do seu contributo na compreensão da NdC. O estudante 8 refere:

“As principais concepções que desenvolvi na aula foram: qual o contributo dos modelos históricos na compreensão da natureza da ciência; quais os componentes da Natureza da Ciência e como abordar a natureza da ciência em sala de aula.” (E8)

“Compreendi a importância de revelar a história da ciência e o avanço da ciência ao longo dos tempos aos alunos, bem como defender estes mesmos fatores recorrendo a modelos históricos. Como a ciência evolui os modelos também evoluem e é importante divulgar isso.” (E1)

Tabela IV.3.5. Principais respostas dadas à questão 1 (intervenção 3).

Q1 – Quais as principais concepções que desenvolveste nesta aula?	
Concepções	%
Natureza da Ciência	75,0
Componentes da Natureza da Ciência	62,5
Ensino da Natureza da Ciência	50,0
Modelos históricos	62,5

É ainda referido que esta aula permitiu o desenvolvimento de concepções acerca da construção do conhecimento científico (37,5%) e acerca da importância da história da ciência no ensino das ciências (25%).

No que concerne à questão 2, grande parte dos estudantes (75%) considera ter alterado algumas das suas concepções relativas à temática em estudo e um não o refere de forma explícita. Apenas um aluno considera não ter alterado as suas concepções:

“De certa forma, a aula não alterou muito as minhas concepções sobre a temática (...).” (E5)

A maioria dos alunos (87,5%) refere ter alterado as suas concepções relativamente à importância dos modelos históricos no ensino das ciências, nomeadamente ao nível da abordagem de aspetos da NdC (Tabela IV.3.6).

Tabela IV.3.6. Principais respostas dadas à questão 2 (intervenção 3).

Q2 – Quais as concepções alteradas?	
Concepções	%
Importância dos modelos históricos no Ensino das Ciências	87,5
Possibilidade de abordar aspetos da natureza da ciência em sala de aula	50,0
Importância da natureza da ciência no Ensino das Ciências	50,0

Como exemplo, um dos estudantes refere:

“Sem dúvida! Sempre achei que demonstrar a história da modelação só servia para criar concepções erróneas aos alunos. No entanto, compreendi que não só ajuda a compreenderem a evolução da ciência ao longo dos tempos, como demonstra a influência que a sociedade da época tem nessa mesma evolução.” (E1)

Metade dos estudantes refere também ter alterado as suas concepções relativamente à importância da NdC no ensino das ciências:

“A aula permitiu-me uma compreensão mais profunda acerca da natureza da ciência e história da ciência, essencialmente na aplicação dos mesmos no ensino das ciências. (...)” (E3)

“Sim, de certa forma esta aula serviu para atribuir uma importância maior ao papel que os modelos históricos têm no ensino das ciências. O mesmo aconteceu para a importância do conhecimento da natureza da ciência, que, também após a aula, me fez atribuir uma importância maior.” (E6)

De uma forma geral, verifica-se que os estudantes compreenderam melhor a importância dos modelos históricos e da NdC no ensino das ciências.

IV.3.2.4. Intervenção 4

No que concerne à questão 1 da intervenção 4, grande parte dos estudantes (66.7%) considera ter desenvolvido o conceito de analogias, destacando as suas

potencialidades e precauções necessárias aquando da sua aplicação em sala de aula (Tabela IV.3.7).

Neste sentido é referido:

“Compreendi a importância das analogias como forma de explicitação.” (E1)

“Entendi que as analogias não podem ser escolhidas ao acaso, devem ser adequadas ao nível do aluno e devem permitir estabelecer fáceis relações entre a realidade e a variável que esta analogia manipula.” (E1)

Foi também destacada a importância da análise de manuais relativamente à natureza da ciência, modelos e modelação:

“Ao longo desta aula, aprendi a analisar e procurar evidências nos manuais escolares de ciências naturais, de Biologia e Geologia acerca da natureza/história da ciência, em conformidade com a sua referência nos programas, e metas curriculares.” (E4)

Tabela IV.3.7. Principais respostas dadas à questão 1 (intervenção 4).

Q1 - Quais as principais concepções que desenvolveste nesta aula?	
Concepções	%
Conceito de analogias	66.7
Potencialidades das analogias	55.6
Precauções necessárias na sua aplicação em sala de aula	44.4
Análise de manuais relativamente à natureza da ciência, modelos e modelação.	44.4

Relativamente às principais concepções alteradas na intervenção 4, foi referido, por 44.4% dos estudantes, as precauções necessárias para assegurar o uso correto de analogias nas aulas de ciências (Tabela IV.3.8):

“A única concepção alterada foi a de que o uso da analogia deve ser muito ponderado uma vez que poderá desencadear efeitos inversos aos pretendidos.” (E2)

Tabela IV.3.8. Principais respostas dadas à questão 2 (intervenção 4).

Q2 - Quais as concepções alteradas?	
Concepções	%
Precauções necessárias para assegurar o uso correto de analogias nas aulas de ciências	44.4
A relevância dos modelos e do seu uso na compreensão da natureza da ciência	22.2

Foi também salientada a relevância dos modelos e do seu uso na compreensão da natureza da ciência, por 22.2% dos estudantes:

“Antes desta aula não daria a mínima importância à natureza da ciência. Agora compreendo que mesmo durante a apresentação dos modelos devo esclarecer a história que tem por trás. Desta forma é possível fazê-los compreender quão mutável é a ciência e os modelos que a explicam.” (E1)

IV.3.3. Conclusão

De acordo com os resultados obtidos, é possível verificar que os estudantes consideraram ter melhorado e alterado as suas concepções relativamente aos modelos e à natureza da ciência, de acordo com os objetivos inicialmente estabelecidos. Revelam também possuir uma melhor compreensão da importância dos modelos históricos e da natureza da ciência no ensino das Ciências.

Estes resultados constituem um bom indicador acerca da eficácia do PI, revelando que estes estudantes não só melhoraram as suas concepções, mas também que compreenderam a relevância da natureza da ciência e das atividades de modelação nas aulas de ciências.

De forma a alcançar resultados mais consistentes, irá ainda ser efetuado um estudo mais aprofundado acerca da alteração das concepções destes estudantes, através da comparação das respostas dadas a questionários e entrevistas aplicados anteriormente e posteriormente ao PI.

Apesar das melhorias mencionadas pelos estudantes, consideramos fundamental acompanhá-los no seu estágio profissionalizante, de modo a compreender os fatores que medeiam a transposição didática e de procurar colmatar algumas lacunas referidas na literatura da especialidade relativamente a esta questão.

IV.4. Prospective science teachers' opinions regarding their change of views concerning nature of science and models

ANALYSIS OF PROSPECTIVE SCIENCE TEACHERS' ANSWERS TO THE LAST QUESTIONS OF THE FINAL QUESTIONNAIRES - THEIR OPINIONS CONCERNING THEIR CHANGE OF VIEWS

Adapted from Torres, J., Amador, F. & Vasconcelos, C. (2016). Developing prospective science teachers' views of nature of science: The scientific models. In J. Lavonen, K. Juuti, J. Lampiselkä, A. Uitto & K. Hahl (Eds.), Electronic Proceedings of the ESERA 2015 Conference. Science Education research: Engaging learners for a sustainable future, Part 6 (co-ed. M. Izquierdo & V. Vesterinen), (pp. 820-827). Helsinki, Finland: University of Helsinki (2016) and from Torres, J., & Vasconcelos, C. (2016). Models in Geoscience classes: How can teachers use them? In Vasconcelos, C. (Ed.). Geoscience Education: Indoor and Outdoor. p. 25-41. Springer: Switzerland.

IV.4.1. General Introduction and Study Description

Nature of Science (NOS) is currently considered a prerequisite to scientific literacy and, therefore, a fundamental issue in science teaching. As scientific knowledge partially results from inference and scientists' creativity, many scientific concepts are functional theoretical models rather than faithful copies of reality (Lederman, Antink, & Bartos, 2014). Thus, the development of models and explanations (which are limited by several factors) are fundamental to the development of scientific knowledge.

Given the relevance of scientific models in scientific enterprise, it is currently advocated that scientific models and modelling play a crucial role to the elucidation of a reliable picture of science (Koponen, 2007), being fundamental in science education. In fact, Justi & Gilbert (2002-2003) argued that models and modelling have a central role in science education to the: (i) learning of science, as students learn significant scientific

and historical models; (ii) learning *about* science, as students may develop an adequate view of the nature of models, as well as of the nature of science, and be able to appreciate the role of models in the accreditation and dissemination of the products of scientific enquiry; and (iii) learning *of how to do* science, as students may build and evaluate their models.

However, and despite all the benefits of models and of developing NOS knowledge in science classes, many studies reveal that students do not possess an adequate view of these aspects (Bell, 2006; Park, 2013). Although this fact may result from several factors, it is undeniable the influence that teachers have on students' educational experience (McComas et al., 1998). In fact, studies unveil that teachers generally do not give too much attention to the design and development of learning activities that prompt a suitable construction of their students' NOS conceptions (Abd-El-Khalick et al., 1998) and that they also do not usually engage students in model-based teaching activities (Khan, 2011).

For all the above mentioned, it becomes crucial that teachers develop an adequate knowledge of NOS, models and modelling, as well as an understanding of their relevance in science teaching, in order to effectively teach science. If it is intended that science classroom activities reflect scientists activities, we consider fundamental to resort to modelling activities that will also contribute to NOS understanding.

With this research, we intend to develop prospective science teachers' views regarding NOS, models and modelling in order to promote an efficient and explicit NOS instruction, as well as an appropriate use of models in their future teaching practices. Also, we intend to better understand the factors that influence the translation of teachers' conceptions into their teaching practices.

This study is part of this research project and relates to the implementation of the intervention programme to the main sample of our research (students that were enrolled in the master in Biology and Geology Teaching in Middle and Secondary Schools in 2013/2014 and 2014/2015 academic years). This intervention programme was implemented during 2013/2014 academic year and aimed to improve prospective science teachers' conceptions regarding NOS and scientific models and also their conscious awareness for the inclusion of these issues in their teaching practices.

Questionnaires and semi-structured interviews were administered before and after the implementation of the intervention programme in order to evaluate the evolution of prospective science teachers' conceptions regarding NOS and scientific models. In this study, we mainly analysed teachers' opinions regarding their change of views concerning NOS and models.

IV.4.2. Results

IV.4.2.1. General Preliminary Results

Regarding Portuguese science teachers and high school students' knowledge, we verified that, although teachers achieve better results, both hold intermediate views regarding NOS and scientific models. Moreover, teachers only used models in science classes mostly as an auxiliary resource to the understanding of phenomena or scientific processes (Torres, Moutinho & Vasconcelos, 2015).

Portuguese prospective science teachers also possess, in general terms, intermediate views of NOS. Regarding scientific models, some inconsistencies were found in relation to models' definition and some naïve views were revealed concerning models' nature (Torres & Vasconcelos, 2015).

With the analysis of the syllabus of Biology and Geology Education we verified that it is not given too much attention to models and modelling activities in Biology and Geology teachers training. Also, we concluded that little relevance is attributed to history of science, to models and to modelling as contributors to NOS understanding (Torres & Vasconcelos, 2014a).

The majority of prospective science teachers that were enrolled in the intervention programme recognized that they have changed and developed some concepts regarding NOS, models, historical models and their use in science classes, when responding to the short questionnaires - that were administered at the end of each class of the intervention programme (Torres & Vasconcelos, 2014b) - and to the questionnaires (A and B) and correspondent interviews - that were administered at the end of the intervention programme. The results concerning their change of views which were obtained through these final questionnaires and interviews were better described in the next section.

IV.4.2.2. Analysis of prospective science teachers' opinions regarding their change of views concerning NOS and models

In this section, we are going to present the results concerning the analysis of prospective science teachers' answers to the last questions of the final questionnaires (A and B) and to the correspondent questions of the interviews. They were related to their opinions concerning their change of views concerning NOS and models:

- 1) Question 12 of the questionnaire A (that evaluates NOS views) - *After the classes that you attended during this academic year, do you consider that you have*

changed your views of the nature of science? If so, identify and explain the main changes and the main reasons (and sources) for those changes.

- 2) Question 14 of the questionnaire B (that evaluates models views) - *After the classes that you attended during this academic year, do you consider that you have changed your views about scientific models and regarding the use of models in science classes? If so, identify and explain the main changes and the main reasons (and sources) for those changes.*

In the interviews, we simply asked to better explain the answers given in the questionnaires and to add some information if needed. Table IV.4.1 shows that all prospective science teachers considered that they have changed their views of NOS. Some prospective teachers specifically highlighted some views that they have changed concerning particular NOS aspects. For example, three of them (33.3%) considered that they have better understood the fact that experiments are not always required for developing scientific knowledge:

I have learned that science involves much more than conducting experiments.

(Questionnaire of prospective teacher 3 - **Q_PT3**).

Two of them (22.2%) underlined their better understanding concerning the difference between theories and laws:

The most evident change about science was the difference between scientific theories and laws.

(**Q_PT6**)

Likewise, other two (22.2%) emphasized the influence of context in science:
(...)[the main changes] in NOS views are related to how science is influenced by culture.

(**Q_PT1**)

Moreover, four prospective science teachers (44.4%) considered that they have better understood the relevance of NOS instruction in science classes and three (33.3%) the relevance of resorting to history of science.

When it comes to the sources (or reasons) for the changes that have occurred, all prospective science teachers indicated the classes of the intervention programme and some (3- 33.3%) the reading of some documents, namely scientific papers:

The sources responsible for the changes were the classes of the intervention programme, the papers that I have read and textbooks.

(**Q_PT9**)

Table IV.4.1. Changes identified by prospective science teachers, when responding to question 12 of the questionnaire A (that evaluates NOS views) and corresponding questions of the interviews.

Identified changes	F (%)	Examples
Views about science and its nature	9 (100)	<i>Yes, I changed my views about science.</i> (Questionnaire of prospective teacher 6 - Q_PT6) <i>In the questionnaire I referred that I greatly changed my views about science.</i> (Interview of prospective teacher 7 – I_PT7)
Relevance of NOS instruction in science classes	4 (44.4)	<i>Yes, as I deepened my knowledge about scientific knowledge. I essentially realized the relevance of NOS instruction in science teaching. These were the changes that have occurred.</i> (Q_PT9)
Relevance of resorting to history of science in science classes	3 (33.3)	<i>I was not aware of the relevance of NOS and history of science for students. I thought that the use of historical models in science teaching could promote the development of misconceptions ... Now I understand that through historical models students may better understand the provisional nature of scientific knowledge. (...) It is important that students understand that what they learn may be subject to change, according to scientific knowledge evolution.</i> (I_PT7)

With regard to models, all respondents also considered that they have changed their views about them. The main changes identified by these prospective science teachers are presented in table IV.4.2.

The majority of respondents considered that they have changed their views concerning models definition and models values in science classes.

With regard to the sources (or reasons) for the changes that have occurred, all prospective science teachers mentioned the classes of the intervention programme and some (4 - 44.4%) the reading of some documents. One respondent also indicated her active participation in the construction of a model as a relevant reason for the changes that have occurred:

Learning activities in the classes of the intervention programme; reading of scientific papers and literature review.

(Q_PT9)

Yes, it was the classes of the intervention programme. My active participation in the model construction was also important.

(I_PT1)

Table IV.4.2. Changes identified by prospective science teachers, when responding to question 14 of the questionnaire B (that evaluates models views) and corresponding questions of the interviews.

Identified changes	F (%)	Examples
Scientific model definition	6 (66.7)	<i>The main changes are related with model definition and with their different uses in science classes.</i> (Questionnaire of prospective teacher 2 - Q_PT2)
		<i>The concept of model was greatly developed; it was something that changed a lot.</i> (Interview of prospective teacher 2 – I_PT2)
		<i>I definitively changed my views about scientific models. (...)</i> (Q_PT6)
Understanding of models values in science classes	6 (66.7)	<i>The main changes are related with model definition and with their different uses in science classes.</i> (Q_PT2)
		<i>I did not know the real and wide advantages of using models in science classes. Now I understand their usefulness in students' active learning.</i> (Q_PT9)
		<i>I think that using models is extremely important. It is also extremely important to be aware of misconceptions that might arise [when using models].</i> (I_PT1)
Cautions to take when using models in science classes	3 (33.3)	<i>I have better learned models definition; what we should avoid when building models (...).</i> (Q_PT3)
		<i>I understood the relevance of pointing out models and scientific knowledge mutability in modelling activities.</i> (Q_PT7)

IV.4.3. Conclusions

With the results obtained, we verified that there is a generalised lack of knowledge regarding NOS and models among high school science students and teachers (in-service and prospective science teachers). Furthermore, it is important to highlight the limited value attributed to models in science classes, only as auxiliary resources to the understanding of phenomena or of scientific processes.

Also, from the analysis of the syllabus of Biology and Geology Education of different universities of the country, we may also conclude that little relevance is attributed to history of science, to models and to modelling as contributors to the understanding of NOS.

These preliminary results warn for the need to improve initial and continuous science teachers training concerning those aspects. The prospective science teachers that attended our intervention programme considered that they have changed their views of NOS and about models, as well as concerning the relevance of NOS and models in science education. In this way, and given the relevance of models and modelling in science classes, we consider it to be fundamental to implement these kinds of activities in initial and even in continuous teacher training, if we expect to have an effective use of models and modelling in our science classrooms.

However, more information is needed in order to analyse the evolution of prospective science teachers' views regarding NOS and models and also to understand the factors that mediate its translation into classroom practice.

The forthcoming analysis of the results that were obtained through the observation of the classes of some of the prospective science teachers that were enrolled in the intervention programme and through the final interviews will be of the utmost importance. They will be an invaluable asset for us to better understand how different factors may influence teachers' classroom practice regarding NOS and models.

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IV.5. Prospective science teachers' perceptions concerning the use of models and the teaching of NOS in their science classes during their internship

IS IT THAT SIMPLE TO IMPLEMENT MODELS AND NATURE OF SCIENCE IN GEOSCIENCE CLASSES?

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16th International Multidisciplinary Scientific GeoConferences (SGEM 2016) Conference Proceedings (to be published in 2016).

IV.5.1. Abstract

Employing models in science teaching is considered to be fundamental for an authentic learning of science. In fact, the use of models in science classes may help students in the development of a better understanding of scientific content, of inquiry skills and also in the understanding of the nature of models and of the nature of science. Also, the analysis of historical models may also play a major contribution to the understanding of scientific knowledge construction and development. Moreover, in geoscience education models acquire an even greater relevance, as geology deals with processes and forces that cannot be directly perceived, and students may develop important geological reasoning skills. Nonetheless, some studies reveal that science teachers do not possess accurate views regarding models and the nature of science. It is also shown that teachers do not use models very often in their classes and that they do not implement activities which foster students' views of the nature of science. As a result, we considered important to develop science teachers' views of the nature of science and regarding models, in a way that may contribute to the improvement of their teaching. This study is part of a broader research which aims to improve prospective science teachers' views of the nature of science and models, so as to promote an efficient and explicit instruction

of the nature of science, as well as an appropriate use of models in their future teaching practices. Ultimately, it was intended to better understand the factors that influence the translation of teachers' conceptions into their teaching practices. Having this in mind, we planned and implemented an intervention programme to prospective science teachers and we evaluated their views (by means of questionnaires and interviews). Afterwards, we observe their classes in their internship and conducted more interviews. Nine Portuguese prospective science teachers, that will teach geology and biology in middle and secondary schools, voluntarily participated in this research (nine in the first part and six of them in the second part). This study is integrated in the second part of the research and it is focused in the last interviews, which were analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package. The most relevant results are presented and discussed, revealing the main perceptions of prospective science teachers when implementing modelling activities and when teaching NOS during their internship and the reasons that justify their options. The difficulties they faced were also discussed, such as those that arise from the discrepancy between prospective science teachers' practices and the practices that students are familiar with.

Keywords: geoscience education, nature of science, models, modelling, teachers training

IV.5.2. Introduction

Scientific models are considered to be representations of a target, which are built according to a particular portion of that target and with specific purposes [1]. Being not only products of science, but also tools and processes of science [2], they are fundamental to scientific knowledge construction and development.

In this way, models are fundamental for an authentic learning of science, being important not only to prompt the learning of scientific knowledge, but also the development of inquiry skills and of views of nature of science (NOS) [3, 4]. In fact, there are many studies that reveal the undeniable positive effects of implementing models in science teaching [5, 6]. For example, in geoscience classes models acquire a crucial role, as it allows students to observe what is impossible to observe in real time [4] and it also promotes skills that are fundamental to geological reasoning. Also, the understanding of what a models is, its characteristics and limitations allows students to develop critical thinking and reasoning, as well as to better understand science.

In general terms, NOS describes what science is, how science operates and how scientists work. Therefore, the development of accurate views of NOS is considered to

be a major aim for science education [7], being several the references to the positive effects of including NOS instruction in science classes [8].

Although there are some controversies concerning specific issues of NOS, in this study we adopted the consensus view advocated by many authors, such as Lederman and collaborators [7]. In view of this, scientific knowledge is considered to be tentative; empirically based; subjective; the product of human inference, creativity and imagination; and socially and culturally embedded. Moreover, to understand science it is also important to understand the difference between scientific theories and laws and between observation and inference and that there is no unique scientific method.

Despite the positive effects of implementing models and NOS instruction in science classes that are described in the literature, many studies reveal that even teachers do not hold accurate views regarding models [9] and NOS [10]. Moreover, teachers do not teach NOS and do not use models very often, and when they do so they do not take into account the full potential of those [8, 9]. In a study conducted in Portugal, some inconsistencies were also founded regarding prospective science teachers' views of NOS and models [4].

Having this in mind, we considered fundamental to deepen science teachers' views of NOS and models, in order to contribute to the improvement of NOS instruction and the use of models in science classes.

IV.5.3. Methods

This study is part of a broader research that aims to improve prospective science teachers' views of NOS and models and ultimately to analyse the factors that mediate the translation of their views into their practices in classes. Concerning this latter aim, with this study we intended to analyse prospective science teachers' experiences when implementing modelling activities and when teaching NOS during their internship, the reasons that justify their options and the main difficulties that they face.

After the implementation of an intervention programme that aimed to improve prospective science teachers' views of NOS (emphasising the nature of models, as well as their role in science and for teaching science), we observed their classes during their internship. Afterwards, we elaborated, validated and administered a semi-structured interview that was organized in different dimensions of analysis: main objectives of classes; general view of science education; analysis of particular activities; use of models in classes; nature of science instruction and other activities. All interviews were conducted by the first researcher of this paper and took an average of 34 minutes.

Interviews were audiotaped and transcribed and the data was analysed with the help of the Q.S.R. NVivo 10 qualitative data analysis package.

Six prospective science teachers that will teach biology and geology subjects in middle and high schools and that have previously attended the intervention programme voluntarily participated in this study. The sample included 5 females with ages between 21 and 38 (average = 25.6) and 1 male, aged 24. In this study, these prospective science teachers are designated by fictional names: Maria, Sofia, Francisco, Carolina, Inês and Rita.

IV.5.4. Results

In this section we are going to present the main results concerning prospective science teachers' perceptions concerning the use of models and the teaching of NOS in their science classes during their internship. Additionally, we are going to analyse the impact of extracurricular modelling activities organized by the prospective science teachers.

IV.5.4.1. Models

When asked about the relevance of using models in science classes, all prospective science teachers recognized that models are very important, mainly because they facilitate understanding:

"Yes, [models are important] because through models we can explain things. With models, students are able to understand several things or to relate concepts or aspects (...). It is much easier to use models, than reading a book or showing an image" Rita

Also, it was mentioned that models promote the development of inquiry skills and of conceptual knowledge, direct students' learning, motivate students and make them more responsible.

Regarding the objectives of using models in science classes, all prospective science teachers mentioned that models may be used in science classes as contributors to the development of conceptual knowledge. In this regard, Carolina mentioned:

"[With that physical model], I intended that they understand the factors that prompt landslides; that they understand what originated what they observe in the field."

Moreover, five of them (83.3%) referred that models facilitate understanding, four of them (66.7%) mentioned that they promote the development of inquiry skills and three (50%) underlined that models make lessons more appealing and motivating. Two

respondents (33.3%) also indicated that models are also used for students to apply knowledge, to be active and to develop views of NOS.

In spite of the relevance attributed to models, one respondent (16.7%) did not use them in classes, demonstrating some lack of reflexion concerning her options, as she mentioned that she did not remember to use models in her classes:

"I do not know why [I didn't use models], maybe I did not remember. I am even in favour of using models (...)." Sofia

Of the five prospective teachers that use models in their classes, only one of them use models in a transmissive way, i.e., the teacher just show how the model works. On the other hand, two of them planned models activities, where students had a central role and the other two planned different modelling activities, where the students or the teacher have the central role, but always ensuring that students played an active role (Figure IV.5.1). The main reasons that justify teachers' central role are: time constraints (33,3%, n=2) and to ensure that the activity will work as planned (33,3%, n=2).

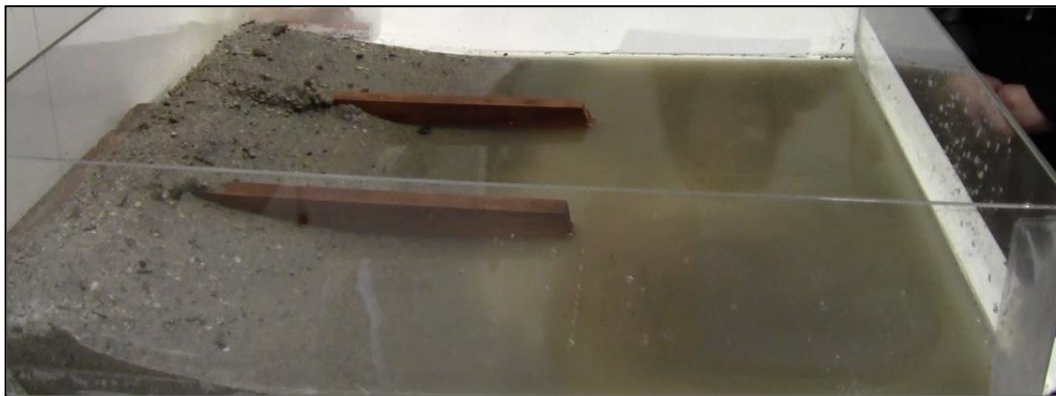


Figure IV.5.1. Example of a model (coastline erosion) – students played an active role.

Although one prospective science teacher (16.7%) did not use models in her classes, all of them believed that they feel confident to implement models. However, some difficulties faced by four of them (66.7%) were described (Sofia did not use models and Maria stated that she didn't experienced difficulties). Two prospective science teachers (33.3%) mentioned that modelling activities requires more preparation. On this subject, Rita stated:

"Yes, there are some potential pitfalls and it is obvious that is it more difficult to work with models than simply read a text. It is easier to read a text. Students may always ask things that we were not expecting, which is good, but we have to find out how to cope with it."

Additionally, it was also mentioned by two prospective teachers (33.3%) that they had to ensure that the activity worked as planned and that reached all students:

"Difficulties... I wanted that all understand what we are doing (...) The biggest difficulty when using models was to assure that all students understand the objective of the activity." **Rita**

When it comes to students' reactions, all prospective science teachers that implement models in classes believed that students liked those classes. Also, four of them referred that students are also interested and three that they better understand the concepts. For example, Inês stated:

I think that they like it. They usually say that they like practical activities, that they better understand the content. I think that all went well, they were all interested.

Concerning scientific models understanding, only one respondent considered that students do not understand what a scientific model is and its characteristics. In fact, the other four considered that students understand it, as they explain it to students and also promoted the debate. Only one respondent advocated that they understand it in an implicit way:

I think that they understand what a scientific model is, although I did not mentioned anything about that. In fact, students constructed models. As a result, they understand that they represent something (...). **Inês**

Furthermore, all respondents believed that it is fundamental to discuss characteristics and limitations of models with students, namely the fact that a model is a simplified representation of the reality (50% - n=3). Also, some precautions to have when using models were referred, such as to guarantee models' clarity, in order to convey correct ideas (50% - n=3).

All respondents mentioned that they intend to use models in their future classes, as a way to improve and facilitate learning.

IV.5.4.2. Nature of science

In the same way, all prospective science teachers believed that it is important to teach NOS, in order to teach what science is and its characteristics and to make classes more interesting. Yet, Sofia advocated that NOS instruction do not attract students. Nevertheless, she was the only prospective science teacher that did not enact NOS instruction. She referred that she didn't teach NOS because she was more concerned with content and also due to the theme and to personal choices. Moreover, when asked about her option of not making any reference to knowledge construction issues and some history of science aspects that were mentioned in the textbook, she said:

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

On the other hand, the other five (83.3%) argued that they teach NOS in their classes, namely its tentative (83.3%) and inferential nature (33.3%), the cultural and social influences on science (33.3%) and the relevance of imagination and of models in science (16.7%).

Three prospective teachers only mentioned certain NOS aspects during their classes, while the other two promoted the debate to discuss NOS aspects. History of science and models are considered to be helpful to teach NOS.

I promoted debates [to discuss NOS aspects]. Then by using models, I also talked about nature of science. Why are we using models?... And in science, how does it work? **Rita**

Although the bulk of respondents indicated that they felt confident to teach NOS (83.3%, n=5), two of them recognized that it entails some difficulties and one believed that he did not feel confident due to the lack of experience.

When asked about the difficulties faced when teaching NOS, only three mentioned some (Sofia did not teach NOS and Inês and Maria stated that they didn't experienced difficulties), such as: students' characteristics (mentioned by two respondents - 33.3%); the time constraints (by one respondent-16.7%) and the difficulty of the subject and the fact that the students are unfamiliar with NOS instruction (by one respondent-16.7%):

*I think that students understand some NOS aspects, but to be honest, I think that they have a lot of difficulties in understanding it, in thinking about that because we (prospective teachers) teach NOS, but they are not used to learn NOS aspects. (...) In fact, I think that they like to learn NOS aspects, but it is not commonly teach in schools. **Rita***

When asked about their options of not deepen NOS instruction in some crucial occasions (identified in the observation of the classes), time constraints and the thematic were the reasons mentioned by three respondents. Also, students' characteristics and the fact of giving more relevance to conceptual knowledge were referred by two prospective science teachers:

*The main factor was the time. I would like to do much more things. However it was almost impossible with the time that we have. **Francisco***

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

Concerning students' reaction to NOS instruction, all prospective teachers that teach NOS aspects believed that students understood some of them. Also, three of them

indicated that students liked to learn it and only one mentioned that students were not enthusiastic:

I think that they responded well to NOS instruction, but they did not care about that. They responded well, they understand, but they do not think a lot about that. Carolina

Finally, all the respondents also revealed that they intend to teach NOS in their future classes.

IV.5.4.3. Other activities in school

Concerning extracurricular activities, all prospective science teachers developed activities with models. For example, Francisco and Sofia (that worked together in the same school) organize the existing models of the school and build new models of cells, in order to improve school materials, as a way to promote students' knowledge improvement (Figure IV.5.2 – a, b). Inês and Maria (that worked together in another school) also participated in the organization of activities directed to the whole school community, by using geological models. With them, they intended to promote a better view about science. Students actively participated in those activities. Rita and Carolina (that worked together in another school) also organized a modelling activity, in which students must construct the DNA molecule (Figure IV.5.2 – c, d). In this case, students also participated in an enthusiastic way and, among other things, understand the structure of the DNA molecule.



Figure IV.5.2. Models constructed by prospective teachers (a, b) and by students (c, d).

IV.5.5. Conclusions

All prospective science teachers that participated in this study believed that it is important to implement models in science classes. Although it is attributed more relevance to models to the understanding of conceptual knowledge, some prospective science teachers also mentioned their importance to the development of inquiry skills and of views of NOS (either in classes or in extracurricular activities). Therefore, they showed a greater awareness of the full potential of models in science teaching. Despite some difficulties mentioned by the prospective science teachers, all of them assumed to feel confident to implement models in science classes, revealing their interest to use models in their future practices.

In the same way, all prospective science teachers believed that it is important to teach NOS in science classes. Despite the recognized difficulty of teaching NOS, the majority of prospective teachers felt confident to do that. However some limitations to teach NOS are mentioned, such as: time constraints, students' characteristics, the theme and the overvaluation of teaching content knowledge. For example, Carolina stated that she didn't deepen the debate concerning NOS aspects because students were not critical. However, we considered that these kinds of activities are fundamental precisely to develop, among other things, students' critical thinking and reasoning, which means that prospective science teachers must be persistent, must be innovative and must reflect a lot and in a critical way about their practice.

For example, Sofia demonstrated some lack of reflexion concerning her options, as we discussed above. Also, she referred that she didn't teach NOS because she agreed with her school supervisor to focus only in conceptual knowledge. We believed that in this stage prospective science teachers must strive to teach in line with science education guidelines and must be innovative, being also stimulated by their school supervisors to do so.

Prospective science teachers also indicated that students were surprised with both the instruction of NOS and the use of models in science classes, revealing that they are not familiar with those kinds of practices. Indeed, Rita also warned for the need of continuous training on NOS instruction for teachers, as "we teach in line with what we learn, students like that (...) but then in-service teachers do not talk about that [NOS]". Thus, we considered to be fundamental to narrow the gap between the main practices in schools and the current achievements in science education, by promoting continuous training for in-service teachers, especially those that orientate the prospective science teachers.

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IV.6.Final Results

MODELS AND NATURE OF SCIENCE: WHAT MEDIATES ITS IMPLEMENTATION IN PORTUGUESE SCIENCE CLASSES?

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IV.6.1. Abstract

Currently, it is considered of the utmost importance to improve students' views of 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. Aiming 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 was collected relying to a diversity of data sources: (i) questionnaires and interviews (applied to prospective science teachers before and after the intervention programme); (ii) prospective science teachers' lesson plans and portfolios; (iii) videotape and observations of classroom instruction; (iv) and final interviews applied both to prospective science teachers and their school supervisors. Although prospective science teachers greatly improved their views regarding NOS and models, they taught NOS and used models in very different ways. Some factors that mediate the translation of teachers' views and some educational implications were discussed.

Keywords: models, nature of science, prospective teachers, intervention programme, science education

IV.6.2. Introduction

Improving students' views of the nature of science (NOS) is currently considered one of the principal goals of science education. In fact, although results are rather inconclusive and there are still many questions to be answered (Kampourakis, 2016; Lederman, 2007), students having accurate views of NOS is considered to be integral for students to be literate about science; 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 (Kampourakis, 2016; Lederman, 2007; McComas, Clough & Almazroa, 1998).

However, many studies indicate that students do not possess accurate views of the NOS (Bell, Blair, Crawford & Lederman, 2003; Kampourakis, 2016; Lederman, 2007). Given the relevance which is attributed to teachers' influence on classroom learning, researchers naturally focused their attention to teachers' views and practices about NOS (Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci, & Köseoğlu, 2016). Indeed, many studies indicated that even science teachers do not hold accurate views of NOS (Bell, Mulvey, & Maeng, 2016; Lederman, 2007) and do not really emphasize NOS teaching (Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 2007). For example, in a study conducted by Capps & Crawford (2013) with twenty-six well-qualified and highly motivated teachers from the United States it was revealed that teachers hold limited views concerning NOS and that they do not commonly teach NOS in their classes.

Taking into account the relevance of scientific models in scientific enterprise (Schwartz & Lederman, 2005), it seems obvious that the understanding of models also contributes to a better understanding of NOS (Cheng & Lin, 2015). As such, models are crucial in science classes, as they may contribute to a more authentic learning of sciences. Nevertheless, it was also revealed that there is a lack of teachers who use models in classes in a systematic way and that teachers possessed an inadequate knowledge about models in science and for teaching (Khan, 2011; Akerson, White, Colak, & Pongsanon, 2011).

In Portugal, we also concluded that high school students, prospective science teachers, and in-service teachers also hold limited views concerning NOS and models (Torres, Moutinho & Vasconcelos, 2015; Torres, & Vasconcelos, 2015). Moreover, it was verified that in-service teachers use models in a very limited way (Torres et al., 2015).

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

IV.6.2.1. Nature of Science

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” (Lederman, Antink, & Bartos, 2014, p. 286). Acevedo-Díaz & García-Carmona (2016), although they assume that it is difficult to define NOS, believe that NOS is related to everything that characterizes science, as the construction of a special type of knowledge. In fact, even though NOS instruction is currently considered fundamental in science education, there remains a lack of consensus regarding the definition of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Bell et al., 2000) and the aspects of NOS that should be focused in classes (Acevedo-Díaz & García-Carmona, 2016). On the other hand, some authors consider that there are some aspects of NOS that are noncontentious and that are accessible and relevant for secondary students (Abd-El-Khalick, 2006; Bell, 2006; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). As a matter of fact, this consensus view concerning NOS is widely accepted, educationally appropriate for learners (Bartos, & Lederman, 2014) and considered to be effective as a starting point for students to start thinking about NOS and to attain an understanding of various aspects of NOS (Authors, 2015 b; Kampourakis, 2016). 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 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; (vii) both inferences and observations are fundamental in scientific knowledge construction, with it being important to distinguish between them (Abd-El-Khalick, 2006; Abd-El-Khalick et al., 1998; Lederman et al., 2002). These aspects are better exemplified in Table IV.6.1.

Studies also revealed that an explicit, embedded and reflective instruction of NOS is an effective approach both for science teachers (Deniz, & Adibelli, 2015; Wahbeh, & Abd-El-Khalick, 2014) and for advanced science teachers (Koksal, Cakiroglu, & Geban, 2013).

Table IV.6.1. Illustrative examples of informed and naïve views of the NOS aspects evaluated.

Views categories Targeted NOS aspects	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 (...)		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)
	Science differs from other disciplines because, although it is based on interpretations, scientific disciplines try to explain phenomena and processes of nature.	Q (questionnaire)_Maria (Pre)		
Scientific method	No, there is many scientific methods.		Yes, I think that, in order to construct scientific knowledge, we must employ the scientific method, in terms of a certain stepwise procedure.	Q_Francisco (Post)
	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, an experiment is to prove. (...)	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.		[A scientific experiment may involve] the manipulation of variables or not. I may perform an experiment only by observing(...)	I_Maria (Post)
		Q_Inês (Post)	Yes, I think that scientific knowledge requires scientific experiments, as ideas and hypotheses obtained after questioning, must be tested through experiments.	
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.		Yes, I think that it is possible to conduct experiments [in scientific areas, like astronomy and anatomy].	Q_I_Sofia (Pre)
		Q_Rita (Post)		
Inferential	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		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,	
Nature of scientific knowledge				

	simulating phenomena, we may construct some knowledge (...) Yes, they construct models through inferences. It is not possible to prove everything.		I believe in that.	I_Sofia (Pre)
			I_Rita (Post)	
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 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)
			I_Rita (Post)	
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.		Yes, I think that scientists only use creativity and imagination in the planning stage, as data collection follows 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)
			Q/I_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.		I think that science is universal, as water freezes at 0°C in Portugal and in Japan or in Antarctica. Science should be the same for all, as well as theories and experiments.	Q_Francisco (Pre)
			Q_Carolina (Post)	
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 (...)		A theory is something that may change, while a law is something concrete and immutable.	Q_Francisco (Pre)

	I_Rita (Post)	
	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.	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)	
	I_Rita (Post)	
	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.	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)	
	Q_Maria (Post)	
	For example, the theory of plate tectonics, that tries to explain the movement of the tectonic plates.	A theory is something that may suffer changes. On the other hand, a law is something concrete and immutable.
	Q_Francisco (Post)	
	Q_Maria (Post)	
	Because theories intend to explain phenomena/processes in order to complete or improve scientific knowledge.	We bother to learn scientific theories because we are very curious and we wonder ourselves about the world.
	Q_Sofia (Pre)	
	Q_Inês (Post)	
	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.	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)	

IV.6.2.2. Models

Models are fundamental in scientific activity, being not only products of science but also tools and processes of science (Cheng, & Lin, 2015). In fact, models may be used to describe, explain or predict (Lee, Chang, & Wu, 2015; Van Driel, & Verloop, 1999), helping scientists to think, to generate new knowledge and communicate scientific ideas to others (Kenyon, Davis, Hug, 2011; Oh & Oh, 2011). 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 (Authors, 2015 b; Chamizo, 2013).

As scientific models are fundamental in scientific activity, models are also essential in science education for students to understand the main processes and products of science (Justi, & van Driel, 2005). In fact, 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 NOS, as well as an accurate view of the nature of models and their role in science (Authors, 2015 b; Justi, & Gilbert 2002/2003).

However, to use models in an efficient way, it is necessary for teachers to understand the relevance of models in science and for teaching (Akerson et al., 2011; Oh & Oh, 2011). Based on a literature review, Oh & Oh (2011) 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; (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 (Justi, 2006; Moutinho, Moura & Vasconcelos, 2016).

In our study, we intended to improve prospective science teachers' views of NOS and models, but also to better understand the factors that mediate the translation of teachers' views into their practice. In fact, although it is a necessary condition for teachers to teach NOS (and to use models), teachers' accurate knowledge about NOS (and models) is not a sufficient condition (Abd-El-Khalick et al., 1998; Deniz, & Adibelli, 2015). In fact, it is of the utmost importance to clarify and understand the mechanisms and factors that explain how teachers translate their NOS views into their classroom practice (Bartos, & Lederman, 2014; Deniz, & Adibelli, 2015).

IV.6.3. Research Questions

The purpose of this study was to examine how prospective science teachers improve their views of 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:

- (i) How do prospective science teachers change their views of specific aspects of NOS and about models?
- (ii) Do prospective science teachers emphasize NOS instruction and the use of models in their teaching after the intervention programme?
- (iii) Which factors influence NOS teaching and the use of models in science classrooms?

IV.6.4. Methods

To attain our objectives, we planned and applied an intervention programme entitled: "Scientific models, modelling and nature of science in science teaching". This intervention programme (which is better described in Torres & Vasconcelos, in press a/b), was developed having in mind the topics mentioned above and the three major aims proposed by Justi and Gilbert (2002/2003) of models and modelling in science education. Furthermore, it was also developed according to the consensus views of NOS described above and presented in Table IV.6.1.

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 deep description of their views and to understand the reasons behind their actions when teaching NOS and when using models. To do that, we used a diversity of data sources, which included the following: questionnaires and interviews (applied to prospective science teachers before and after the intervention programme), prospective science teachers' lesson plans and portfolios, videotape and observations of classroom instruction (which were analysed according to a grid), and final interviews applied both to prospective science teachers and their school supervisors.

IV.6.4.1. 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 nature of science, as well as the use of models in biology and geology classes. However,

as is better described in the theoretical framework, teachers and students display a lack of knowledge regarding 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. Moreover, it was also found that little attention is given to models in preservice biology and geology teacher training.

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

IV.6.4.2. 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 of a public university in the north of Portugal and already hold a bachelor's degree, either in biology or geology, or even in both biology and geology. In fact, to teach biology and geology in middle and secondary schools, prospective teachers must complete this master's. 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 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.

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 study (when students attend classes of both educational and scientific subjects). Six prospective science teachers continued and participated in the second phase of this study, which occurs during the second year of their master's program and which is 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 are designated by 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 by 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.

IV.6.4.3. Procedures

With the aim of improving prospective science teachers' views of NOS and models, an intervention programme was prepared and implemented. This intervention programme was evaluated by means of a questionnaire and interviews, which were administered both before and after this intervention programme. Data was 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.

Afterwards, we observed the classes of the six prospective science teachers who remained in the study. Those classes were analysed according to a validated grid and were also filmed in order to avoid loss of information and to check the analysis previously done.

After analysing the grids and the lesson plans and portfolios of the prospective science teachers, final interviews were also conducted both to prospective science teachers and their school supervisors in order to better understand the factors that mediate the translation between prospective teachers' views and their instructional practices.

IV.6.4.4. Instruments

To evaluate prospective science teachers' views of NOS and of models in science and for teaching, two questionnaires and two interviews were administered before and after the intervention programme. Regarding their views of NOS, we administered a questionnaire that was adapted from the *Views of Nature of Science Questionnaire – Form C (VNOS-C)* (Lederman et al., 2002) 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 (Authors, 2016 a). Concerning their views of models, we administered a questionnaire that was constructed and validated in a previous study (Torres & Vasconcelos, in press c). Two interviews were also conducted after filling out both questionnaires, for them to better explain and justify certain answers and also to clarify some unclear responses.

Classes of the prospective science teachers were observed by the first author of this paper and were analysed according to a grid that was previously validated by three

experts in science education. Classes were also recorded in order to subsequently verify the analysis that is conducted during the observation of the classes.

After all these analysis, we conducted semi-structured interviews both to prospective science teachers that participated in this study since its beginning (Appendix IV.6.A) and to their school supervisors (Appendix IV.6.B), in order to better understand the factors and circumstances that mediate the translation of prospective science teachers' views into their practice. The interviews scripts 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 by means of the spoken reflection method. In general terms, they understood all the questions that were asked, giving only few suggestions in order to clarify the questions.

IV.6.5. Results

In this paper, we are going to present various data, which result from a large research project. Although some results have already been discussed in previous papers (Torres & Vasconcelos, *in press b/d*), we are going to present the results mainly on a case-by-case basis in this paper, in other words, we intend to deeply describe the views of each prospective science teacher (that participated in all the study), how they teach NOS and use models in science classes and the factors that mediate the translation of their views to instructional practice.

IV.6.5.1. Prospective science teachers' views of NOS and models

As described in Torres & Vasconcelos (*in press b*), prospective science teachers greatly developed their views of NOS after attending the intervention programme. We analysed fourteen specific aspects of NOS (see Table IV.6.1), 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 IV.6.2). 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 one regarding subjectivity in science).

Table IV.6.2. Prospective science teachers' views of the fourteen NOS aspects 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 greatly improved their views about models, an issue which is better described in Authors (2016, b). After the intervention programme all prospective teachers held informed views concerning the bulk of aspects about models evaluated (Table IV.6.3).

For example, Rita held informed views concerning all aspects evaluated about models (Table IV.6.4) and only Sofia possessed naïve views concerning three of the aspects evaluated (the others only possess naïve views concerning one or two aspects evaluated). In fact, 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.

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

Table IV.6.3. Illustrative examples of informed and naïve views of the aspects about models evaluated.

Evaluated aspects	Views	
	Categories	Examples of more naïve views
Scientific concept	model	<i>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.</i> Q_Rita (Post)
		<i>In my opinion, a scientific model is a set of ideas, theories and methods to follow towards a problem to solve.</i> Q_Sofia (Pre)
Scientific purposes	model	<i>Models are used to explain phenomena/ processes/ideas, among others. They contribute to a better understanding (...)</i> <i>And also to predict, predict, explain (...)</i> <i>In geology they may be used to explain past events (...)</i> Q/I_Maria (Post)
		<i>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.</i> Q/I_Carolina (Pre)
What can be represented by a scientific model		<i>A model may represent an idea or a phenomenon included in a scientific area, isn't it?</i> I_Rita (Post)
		<i>A scientific theory, I think that it is a theory, I think so.</i> I_Sofia (Pre)
Relationship between scientific model and theory		<i>(...) 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> I_Rita (Pre)
		<i>A scientific model intends to support in a practical way a scientific theory.</i> Q_Sofia (Pre)
Change in scientific models		<i>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.</i> Q_Sofia (Pre)

Multiplicity of scientific models	<i>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> I_Carolina (Pre) <i>Yes, since they explain and focus on what it is intended to be demonstrated (...)</i> I_Maria_ (Post)	<i>(...) 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> I_Maria (Pre)
Models contribution in science teaching	<i>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.</i> Q_Rita (Post)	<i>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.</i> Q_Inês (Pre)
Favourable conditions for students to develop models	<i>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.</i> Q_Francisco (Pre)	<i>A good theoretical background and a well-done bibliographic research. Students need a good theoretical background to create models. I also think that teacher' help is crucial.</i> Q/I_Carolina (Pre)
Differences between models in science teaching and models in science	<i>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 (...).</i> Q_Carolina (Post)	<i>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.</i> Q_Maria (Pre)

Table IV.6.4. 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

IV.6.5.2. Class observation

Although all prospective science teachers improved their views of NOS and about models, they taught NOS aspects and used models in very different ways. In Table IV.6.5, we briefly summarized the aspects that we observed in classes. It is possible to verify that while Rita and Carolina taught NOS aspects and used models in a very positive way (Carolina only missed using models for the understanding of NOS), Sofia did not teach NOS aspects 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 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 characteristics. In fact, while Rita and Carolina addressed many aspects of NOS, Maria and Inês only focused on a few aspects of NOS and Sofia and Francisco did not teach any aspect of NOS. We felt that although Rita, Carolina, Maria and Inês showed that they can teach NOS aspects in an explicit and contextualized way, they should promote more debate, especially Carolina and Inês.

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 developed, students played an active role.

More specific details about how these prospective science teachers taught 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 better discussed in the individual analysis section.

Table IV.6.5. Summarized aspects observed in classes.

Teachers		Maria	Sofia	Inês	Rita	Francisco	Carolina
Observations	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 do science	Yes	No	No	Yes	No	Yes
	For the understanding of nature of science	No	No	No	Yes	No	No

IV.6.5.3. Final interviews

IV.6.5.3.1. 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' accurate views of NOS. Although all prospective science teachers believed that NOS instruction is important in science classes, one of them did not teach NOS during the classes of her internship (more detailed information is presented in Torres & Vasconcelos, *in press* and in the individual analysis section of this paper).

IV.6.5.3.2. 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 their value in how they contribute to the development of content knowledge. In fact, 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 NOS, a fact which suggests a lack of knowledge regarding the 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 also referred 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 NOS, all of the supervisors indicated that they teach NOS in their classes; however, they restrict NOS aspects 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 NOS teaching and that it was taught as a result of “informal discussion”. Joana mentioned that she limited her use of 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 NOS teaching and understanding, we find different points of view. While Joana mentioned the fact that students are not accustomed to discussing NOS aspects, José mentioned that students are reluctant to learn NOS aspects. 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 knowledge they construct. Both Paula and Joana also mentioned the lack of reflection of students as a limiting factor.

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

The three supervisors claimed that they teach NOS to students from when they are twelve to when they are eighteen. While Paula and Joana mentioned that NOS aspects 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 NOS.

In the end of the interview, we asked several questions regarding their general knowledge about 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.

IV.6.5.4. Individual Analysis and discussion of the results

Sofia

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

When asked about the reasons for not teaching NOS, she responded that she gave priority to conceptual knowledge, thus not placing an emphasis on NOS instruction. 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 history of science and NOS. When asked about the reasons for not focusing on 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 of not focusing on aspects of NOS when teaching about the Engelmann experiment (which easily facilitates NOS instruction), 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 NOS instruction 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 NOS aspects and as she didn't even teach NOS aspects in her classes.

Moreover, we verified throughout the interview that Sofia was, as she mentioned, mostly concerned with content 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 NOS in her future practices, as she expressed that it is important that students understand the context when learning scientific content.

Sofia relied mostly in 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. 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 improved a lot his views about NOS. However, he did not feel comfortable teaching NOS, as he did not feel

confident to teach NOS, due to his lack of experience. In fact, although he believed that he had taught NOS, he did not teach NOS in an explicit way (he did it in a very subtle and implicit way and did not include any objective concerning 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)

In fact, 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 NOS aspects and did not prompt the discussion among students about NOS aspects due to time constraints. He also indicated that the content may have influenced NOS instruction, 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 NOS). Moreover, Francisco also stated that students' characteristics may hinder NOS instruction. Francisco felt that he was going to teach NOS in his future classes, as he believed that NOS instruction is important, mainly for pre-university students in order to better prepare them.

Francisco used models in his classes and felt confident to do 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, referring to his relationship with his supervisor as a demotivating factor in his work during his internship.

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. 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 NOS, namely in order to facilitate informed decision-making, he recognized that he did not plan NOS teaching, as certain aspects of NOS were taught as a result of “informal discussion”. Moreover, as Sofia mentioned, José also believed that students are reluctant to learn NOS aspects.

Maria

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

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

They understand the idea (...) and they agreed with what has been said regarding NOS.

Maria assumed that she will teach 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 use 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 of the school, did not influence her work, indicating that she did everything by herself.

Inês

Inês also significantly improved her views about models and NOS and she assumed to feel confident to teach NOS (although she recognized that it isn't an easy task) and to use models in her classes.

Although Inês had mentioned that she did not have difficulties in teaching NOS aspects, 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 NOS, 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 NOS. Inês expressed a belief that she would teach 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 NOS instruction 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, they had shown interest in the modelling activities and 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.

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.

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.

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

Carolina

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

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

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. In fact, although Carolina had mentioned that the understanding of 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 NOS during her classes. Although Carolina also mentioned that students do understand certain NOS aspects, she noted that they do not pay too much attention when talking about NOS. However, she believed that she is going to prompt NOS instruction 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 have. 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 students, mentioning only a demotivating factor. In fact, she mentioned that it is demotivating the amount of time that prospective teachers must spend observing classes, considering it a waste of time, as her school supervisor did not teach in line with what prospective teachers learn in the university. However, she claimed that the school supervisor had played an important role, as she positively influenced her work. In fact, her school supervisor had suggested resources and strategies, helping her establish a more realistic perspective of what happen in schools.

Rita

Rita also improved her views on both models and 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 NOS (although she recognized that it isn't an easy task) and to use models in her classes.

Although Rita had taught certain aspects of NOS (she was the prospective science teacher that taught more aspects of NOS), she believed that it is difficult to teach NOS, to explain how science works. Moreover, she claimed that students are not familiar enough with NOS to talk about it, a fact which may hinder NOS instruction. In fact, although Rita mentioned that students liked and understood NOS, she also indicated that they exhibit some difficulties as they are not used to NOS instruction in science classes. In this way, she also believed that the continuous training of science teachers is of utmost importance 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 NOS. They include aspects of our day-to-day life; and

science, technology, society and environmental education is highly developed, contrary to what happens with NOS instruction.

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

Rita used physical models, indicating some difficulties associated with their implementation. In fact, 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 NOS and of the nature of models (in an explicit way), as well as to develop inquiry skills and critical thinking. In fact, 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. Also, 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 didn't agree with everything that her supervisor did in classes. Furthermore, her supervisor had helped Rita in the selection of the most appropriate materials. Rita also believed that she was

influenced by other science teachers of the school, as they also suggested certain resources and strategies.

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 fact, 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 discuss 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 be prepared for dealing with unforeseeable events and to feel reassured. Like Rita, Joana also showed that students are not used to discussing NOS aspects and like Carolina, she believed that students show some lack of reflection.

In general, like the school supervisors, these prospective science teachers gave more relevance to the tentative nature of scientific knowledge, as well as to 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 more aspects of NOS and exhibited a better understanding of the contribution of models to science-teaching. For example, Rita focused on many aspects of 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.

IV.6.6. Conclusion and educational implications

With this study we may conclude that prospective science teachers greatly improved their views about NOS and models after attending the intervention programme. However, as demonstrated in other studies (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Lederman, 2007), the change of teachers' views does not directly mean an improvement in their teaching practices. In fact, we observe that prospective science teachers teach 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 NOS instruction and the majority of them shows to feel confident teaching NOS and using models, many prospective science teachers justify their options by giving priority to conceptual knowledge, perceiving NOS as less important than science content. Francisco also believed that he taught NOS, without explicitly doing that. 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 NOS, their practices and options, in order to contribute to a better use of models and NOS instruction, as is argued by Bartos & Lederman (2014).

Moreover, Sofia did not teach NOS as she agreed to do so with her school supervisor. Abd-El-Khalick et al. (1998) highlight the need for prospective teachers to have planned opportunities to teach the NOS in their internship. We also consider it of the utmost importance, being important that school supervisors understand the relevance of encouraging prospective science teachers to teach NOS.

Although prospective science teachers have identified some limiting factors to teaching NOS and using models, such as time constraints, the need of better teacher preparation, the management of students' behaviour while using models, the inadequacy of content and students' characteristics, we feel that these factors do not impede NOS instruction and the use of models. In fact, Rita showed that it is possible to do that, being confident about her work, even though she feels that her practices are different from those that students are used to.

For example, Carolina, as well as her school supervisor, mentioned that students were not critical enough to debate NOS aspects. 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.

Regarding the age of students, Paula considered it important for students to start discussing NOS aspects in years preceding the level she teaches. In fact, studies reveal that young students are more curious and more open to learning about NOS (Lederman, Bartels, Lederman, & Gnanakkan, 2014).

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 & Oztekin (2016). Rita mentioned that students were not used to discussing NOS, which explains some difficulties shown by them. Likewise, she also stated that she considered the promotion of continuous teachers training to be very important. As suggested by Capps & Crawford (2013), we also believe that it is important to rigorously support teachers in implementing NOS instruction. If NOS instruction 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. In fact, one of the supervisors recognized the need for continuous training by suggesting the organization of a training initiative for the teachers of her school concerning 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. In fact, it seems that José was very focused on content knowledge and also discouraged Sofia to teach 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 NOS in an efficient way in their internship.

Although we have taught NOS in an explicit way to prospective science teachers and we emphasized the need to teach NOS in an explicit, embedded and reflective way, more needs to be done 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” (Abd-El-Khalick et al., 1998, p.432).

Although our study reiterate once more the effectiveness of an explicit and reflected NOS instruction 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 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. Furthermore, we also agree with Abd-El-Khalick et al. (1998) concerning the indispensability of prospective science teachers to have planned opportunities to teach NOS and use models during their internships.

We think that the factors and suggestions that we have identified for the translation of prospective teachers' NOS views 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 considered 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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Appendix IV.6.A. 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 have influenced your work during your internship? How?	
	4. Do you consider that the other science teachers of 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 haven't you done that?	
	3. According to the objectives you presented in the lesson plan, it would make sense to debate certain aspects of NOS. Why haven't you 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?	1.1 If you did not use models explain 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?	
	6. Do you consider important to use models in science classes? Why?	
	7. What do students may 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?	2.1 If you did not teach NOS, explain why.
	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 instruction activities?	
	2.6 What difficulties have you faced while teaching NOS?	

	3. We verified that you did not include objectives regarding NOS instruction 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?
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 scientific model or scientific theory? 3. Please complete this sentence with <i>analogous model</i> or <i>teaching model</i>: "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 IV.6.B. 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? (You demonstrate models or do you suggest students to construct models?) 5. Do you consider 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?
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?

	- How do you teach NOS? Which strategies, resources and activities do you use to teach NOS? - Do you consider that you face difficulties when trying to clarify your students' views if NOS? Which difficulties? - From which students' age, do you teach NOS? How did the teaching of NOS evolve?
General questions	"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? "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 scientific model or scientific theory? - Please complete this sentence with <i>analogous model</i> or <i>teaching model</i>: "A model that simulates the way certain phenomena and processes occur in nature, establishing analogies in geometric, dynamic and cinematic similarities is...". - Do you consider that models in science (Geology) teaching may/should be equal or different from those used in science? Why?

CHAPTER V

Final Remarks

V.1. General Conclusions

In this section, we are going to present the main conclusions attained with this research.

Considering our first analyses, we may conclude that although it was observed that different aspects of NOS and models started to be included in science textbooks in the XXI century, it was also shown that these aspects were focused in very distinct ways. In fact, while in some textbooks different aspects of NOS and of models are pointed out, in other textbooks only some references to it or none are found. In the same way, history of science is explored in very different ways in the textbooks. These results demonstrate that there is still a lot of work to be done in order to incorporate both NOS and models in science textbooks as it is recommended in national science curriculum.

When it comes to initial science teacher training, we also found that little relevance is attributed to models and modelling activities. Moreover, little relevance is also given to history of science and models as resources to prompt NOS understanding.

Concerning Portuguese science teachers and students' views about NOS and models, it was verified that both science teachers and high school students hold naïve or even uninformed views regarding some of the aspects of NOS evaluated (mainly the tentative nature of NOS and theories and laws definition), as well as regarding models definition. These results are consistent with those of Turkoglu & Oztekin (2016). Moreover, science teachers revealed that they mainly use models for students to develop their conceptual knowledge, which reflects the relevance that teachers gave to models to the understanding of conceptual knowledge, undervaluing models' contribution to the development of inquiry skills and to the understanding of NOS. Indeed, Crawford and Cullin (2004), in a study conducted with prospective science teachers, also demonstrated that while improving prospective science teachers' views about models, it was difficult to change their intentions to teach about models.

In the same way, when evaluating Portuguese prospective science teachers' views about NOS and models, it was also verified that they possess naïve or uninformed views about some aspects of NOS and about models definition, highlighting the need for better prepare prospective science teachers regarding those aspects.

Having the above mentioned in mind, we believe that it will be important to narrow the distance between the national recommendations and what is done in the practice when it comes to NOS instruction and the use of models, namely regarding teaching materials (like textbooks) and regarding initial (and even continuous!) teacher training.

In this study, we worked with nine prospective science teachers that participated in an intervention programme with the aim of improving their views about NOS and models and we followed six of them during their internships.

Concerning our main sample views about NOS, we may conclude that, before the intervention programme, prospective science teachers hold naïve or uninformed views about several aspects of NOS, specifically associated with the empirical, tentative and inferential nature of scientific knowledge, the general structure of experiments and observationally-based disciplines and to the difference between theories and laws and theories change.

Prospective science teachers also possessed uninformed views about models before the intervention programme, namely related with the definition of model, its purpose, the relationship between scientific model and theory, models contribution in science teaching and the favourable conditions for students to develop models.

After the intervention programme, most prospective science teachers presented informed views concerning almost all aspects of NOS and of models. These results are similar with others' findings, such as with the findings obtained by Mesci & Schwartz (2016), Wahbeh & Abd-El-Khalick (2014) and Herman & Clough (2016). However, it should be noted that after the intervention programme prospective science teachers still struggled with some NOS aspects, specifically with the difference between theories and laws. Indeed, in the study conducted by Mesci & Schwartz (2016) they also concluded that preservice science teachers have more difficulties in improving their views concerning the difference between theories and laws.

After the intervention programme, prospective science teachers improved their views regarding models in science and for teaching science, expressing a greater awareness of both the potential and nature of models. Furthermore, prospective science teachers still present some uninformed views, specially concerning the relationship between models and theories.

It is also important to point out that prospective science teachers recognized by themselves that they have changed their views both about NOS and models, as well as that they have understood the relevance of NOS instruction and of the use of models, historical models, and modelling activities in science teaching. These results constitute a good indicator regarding the effectiveness of the IP, showing that prospective science teachers improve both NOS and models' views, as well as their relevance in science teaching.

The improvement of their views may play an important contribution to the effective use of models in science classes in the future, in a way that enables students to develop not only conceptual knowledge, but processual and epistemological knowledge as well.

In fact, as argued by Khan (2011), teachers need to improve their views regarding scientific models and their use in science classes, in order to implement modelling activities in classes, taking the full advantages of all its potentials.

Although prospective science teachers have improved their views both about models and NOS, their lessons plan and even the observation of their classes during their internship revealed that they value and teach NOS and use models in very different ways. It was possible to verify that while some of them teach NOS aspects and used models in a very positive and effective way, others did not teach NOS aspects and did not use models in their classes. Furthermore, although the majority of prospective science teachers have recognized the full potential of models in science teaching, only two prospective science teachers planned to use them to teach NOS aspects.

As revealed in other studies (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Lederman, 2007), there is no direct translation between the development of teachers' views and their instructional practices. Although being necessary and an important contribution, the improvement of teachers' views do not guarantee both an efficient use of models and NOS instruction.

In fact, there are many factors that mediate the translation of teachers' views of NOS and models into their teaching practices.

For example, although they recognize the relevance of teaching NOS and using models, some of them continued to perceive NOS as less important than scientific content. Moreover, some of them also believed to have taught NOS, without explicitly doing that. In fact, some lack of reflection concerning their practices was also demonstrated when asked to justify their options.

We also concluded that even one school supervisor had played a negative influence, by agreeing with the prospective science teacher that he will not teach NOS.

Some limiting factors to teach NOS and use models were also indicated by prospective science teachers, such as time constraints, the need of better teacher preparation, the management of students' behaviour while using models, the inadequacy of content and students' characteristic. Additionally, it was also mentioned that students are not critical enough for NOS instruction.

On the other hand, we also verified that Rita taught NOS and used models in an effective way, showing that these factors do not impede NOS instruction and the use of

models, thus showing that it is possible to use models and to teach NOS in Portuguese science classes.

Considering the relevance of NOS instruction and of using models in classes, we believe that although some improvements were made, more research is needed in order to contribute to an effective use of models and NOS instruction in science classes.

As our IP was considered to play an important role for prospective science teachers to develop their views about models and NOS, we considered it important to apply it (or an IP similar to it) to prospective science teachers but also to in-service teachers. Moreover, we considered of the utmost importance to apply this kind of IP to school supervisors, as, according to our results, they will play a strong influence on the prospective science teachers that will work with them. For example, Sofia agreed with her supervisor not to teach NOS. As a result, it is important to make school supervisors understand the relevance of using models and of teaching NOS, as well as the relevance of encouraging prospective science teachers to do so. In this regard, Abd-El-Khalick et al. (1998) also mentioned the importance for prospective teachers to have planned opportunities to teach the NOS in their internship.

Concerning the lack of reflection revealed by some prospective science teachers, we also believe that it is fundamental to prompt reflection among prospective science teachers concerning the relevance of NOS, the relevance of models, their practices, and options, in order to contribute to a better use of models and NOS instruction, as is argued by Bartos & Lederman (2014).

In addition to the need to reflect, we also consider fundamental that prospective science teachers try to counter some situations, namely the reluctance shown by students, as well as students' lack of critical reasoning.

Prospective science teachers also made some references to the gap that exists between what happens in schools and what is argued in science education research. For example, it was mentioned that students reveal some difficulties in discussing NOS and in using models, as they are not used to do that. As this gap is real, more efforts should be made to narrow it. Apart from the need to improve prospective science teachers' views, we believe that continuous training is fundamental for teachers to develop their views about models and about NOS.

Moreover, having in mind our results and what is suggested by Capps & Crawford (2013), we also believe that it is important to rigorously support teachers in implementing NOS instruction and in using models. In fact, in our study prospective science teachers improved a lot their views of NOS and about models, still revealing difficulties in implementing it in their teaching practices. For example, some of them considered that

teaching NOS in an implicit way was enough for students to develop accurate views about it, and others do not know how to justify their choices in their teaching practices.

Although our study reiterates once more the effectiveness of an explicit and reflected NOS instruction for improving teachers' views, it also shows different factors that mediate the translation of teachers' views into their practice. Moreover, it also highlights for the need of prospective science teachers to be closely followed in their internship and the need for them to better reflect on and justify their practices and options.

We believe that more research should be done, more precisely concerning the second part of this study. Nevertheless, it will also be important to conduct more research regarding the first phase of this study, specifically in order to attain the promotion of a better development of the less understood aspects of NOS and models and to investigate further the factors that may influence science teachers' views of NOS and models.

Although we present some factors that mediate the translation of teachers' views into their teaching practice, more research is needed in order to deeply understand these factors. We may better understand, for example, the influence of the school supervisors and of other teachers in the school in the practices of prospective teachers (regarding the working atmosphere they provide, regarding their teaching objectives, regarding their knowledge, among others).

As we performed a deep analysis of each prospective science teacher views and actions, we consider this study to give a major contribution for a further study of the factors that mediate the translation of teachers' views into their practice.

V.2. References

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APPENDICES



✱Questionário sobre Natureza da Ciência✱

Este questionário enquadra-se num estudo sobre concepções acerca da Natureza da Ciência, no âmbito de um trabalho de doutoramento.

O preenchimento do questionário não tem limite de tempo.

Não há respostas certas nem erradas, pedimos que dê a sua opinião sincera relativamente a diversos aspetos acerca da natureza da ciência.

Desde já agradecemos a sua colaboração!

- a. Idade _____
- b. Sexo: ☐ M ☐ F
- c. Licenciatura em _____ (área científica)
- d. Mestrado em: _____ (área científica)
- e. Data: _____
- f. Código de identificação: _____ (nº telemóvel e/ou nome)

[illegible]

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[illegible]

- Se sim, explique porquê. Dê um exemplo para defender a sua posição.
- Se não, explique porquê. Dê um exemplo para defender a sua posição.

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

5 – Depois de os cientistas desenvolverem uma teoria científica (ex.: teoria celular, teoria da evolução), a teoria alguma vez se altera?

- Se acredita que as teorias científicas não se alteram, explique porquê, fornecendo exemplos.
- Se acredita que as teorias científicas se alteram:
 - (i) Explique porque é que as teorias se alteram.
 - (ii) Explique porque é que nos preocupamos em aprender teorias científicas.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

6- Há alguma diferença entre uma teoria científica e uma lei científica? Ilustre a sua resposta com um exemplo.

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on the right side, suggesting it's resting on a surface.

7 – Os manuais escolares representam sempre o interior da Terra como um conjunto de camadas concêntricas com características diferentes. Quão certos estão os cientistas acerca da estrutura interna da Terra? Que dados específicos **considera** que os cientistas usam para determinar como é o interior da Terra?

[illegible]

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on its right side, suggesting it's resting on a surface.

[illegible]

10 – É defendido que a ciência está imbuída de valores sociais e culturais, ou seja, que a ciência reflete valores sociais e políticos, pressupostos filosóficos e normas intelectuais da cultura onde é praticada. Por outro lado, de acordo com outras visões, é defendido também que a ciência é universal, ou seja, que a ciência transcende barreiras nacionais e culturais e não é afetada por valores sociais, políticos e filosóficos e normas intelectuais da cultura onde é praticada.

- Se considera que a ciência reflete valores sociais e culturais, explique porquê. Justifique a sua resposta com exemplos.
- Se considera que a ciência é universal, explique porquê. Defenda a sua resposta com exemplos.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

11 – Os cientistas realizam experiências/investigações quando tentam resolver problemas. Os cientistas usam a sua criatividade e imaginação durante as suas investigações?

- Se sim, em que etapas da investigação considera que os cientistas usam a sua imaginação e criatividade: na fase de planificação do trabalho de investigação, na recolha de dados ou após a recolha de dados? Explique porque é que os cientistas usam a imaginação e criatividade. Forneça exemplos, se considerar apropriado.
- Se considera que os cientistas não usam a imaginação e a criatividade, explique porquê. Forneça exemplos se considerar apropriado.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and extend across the width of the page. There are no margins, text, or other markings on the paper.

12 – Depois das aulas deste ano-letivo considera que alterou as suas concepções sobre ciência?

- ☐ Se considera que não alterou as suas concepções sobre ciência, assinale esta alternativa com uma cruz.

- ☐ Se considera que alterou as suas concepções sobre ciência, assinale esta alternativa com uma cruz e indique:

- (i) As principais mudanças ocorridas. Alterou as suas visões sobre ciência de que visão(ões) para que visão(ões)?
- (ii) Quais as principais fontes responsáveis por essa alteração (exemplo: disciplinas, leituras pessoais, outros...)

[illegible]

(ii) _____

Obrigada pela colaboração!

✱Questionário sobre Modelos Científicos✱

Este questionário enquadra-se num estudo sobre concepções acerca de Modelos Científicos, no âmbito de um trabalho de doutoramento.

O preenchimento do questionário não tem limite de tempo.

Não há respostas certas nem erradas, pedimos que dê a sua opinião sincera.

Desde já agradecemos a sua colaboração!

- a. Idade _____
- b. Sexo: ☐ M ☐ F
- c. Licenciatura em _____
(área científica)
- d. Mestrado em: _____
(área científica)
- e. Data: _____
- f. Código de identificação: _____
(nº telemóvel e/ou nome)

1. O que é, na sua opinião, um modelo científico?

1.1 Quais as principais funções dos modelos científicos? Em que circunstâncias são usados?

1.2 Que relação estabelece um modelo científico com uma teoria científica? Justifique a sua resposta.

1.3 Considera que os modelos científicos se alteram ao longo do tempo? Defenda a sua resposta com exemplos.

2. Na sua ótica, como podem os modelos ser usados no ensino das ciências? Qual a importância dos modelos para o ensino das ciências?

**3. Considera importante que os estudantes produzam os seus próprios modelos?
Porquê?**

3.1 Quais as condições necessárias para os alunos construírem modelos científicos?

4. Como pensa usar os modelos em sala de aula? Apresentando os seus modelos ou dando aos alunos a oportunidade de construírem modelos? Justifique.

- 5. O que considera apresentar mais dificuldades para um aluno: compreender um modelo fornecido (pelo professor, ou pelo manual, ou por outras fontes) ou produzir o seu próprio modelo? Porquê?**

- 5.1 Qual das opções considera mais vantajosa para um aluno: compreender um modelo fornecido ou produzir o seu próprio modelo? Porquê?**

6. Ao produzir modelos para o ensino de um dado assunto, que aspetos considera que devem ser tomados em consideração? Justifique. Quais os cuidados a ter relativamente ao uso de modelos em sala de aula?

7. Na sua opinião, podem/devem os modelos usados no ensino ser diferentes dos usados na ciência? Porquê? Quais devem ser as principais diferenças? Quais os cuidados a ter?

- 8. De acordo com a sua perspetiva, quais são as características de um bom modelo para ser usado no ensino das ciências? Porquê?**

9. Depois das aulas deste ano-letivo considera que alterou as suas concepções sobre modelos científicos e sua utilização em sala de aula?

☐ Se considera que não alterou as suas concepções, assinale esta alternativa com uma cruz.

☐ Se considera que alterou as suas concepções, assinale esta alternativa com uma cruz e indique:

(iii) As principais mudanças ocorridas. Alterou as suas visões sobre modelos e sua utilização em sala de aula de que visão(ões) para que visão(ões)?

(iv) Quais as principais fontes responsáveis por essa alteração (exemplo: disciplinas, leituras pessoais, outros...)

(iii)

(iv)

Obrigada pela colaboração!

Guião Geral de Entrevista sobre Natureza da Ciência – Futuros professores de Ciências

É fornecido aos participantes o seu questionário previamente preenchido, para participarem na entrevista:

1. Pode ler a sua resposta à **questão 1** e explicar e aprofundar a sua resposta?
2. Como distingue a ciência das outras disciplinas?
3. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

4. Pode ler a sua resposta à **questão 2** e explicar e aprofundar a sua resposta?
5. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

6. Pode ler a sua resposta à **questão 3** e explicar e aprofundar a sua resposta?
7. Entende que os cientistas usam um método específico, seguindo um procedimento científico passo-a-passo? Que o conhecimento científico se constrói sempre da mesma forma, segundo o método científico?
8. O que entende aqui por experiência? Refere-se aqui a experiência no sentido da manipulação de variáveis ou refere-se a procedimentos mais gerais? Aprofunde.
9. Quando os cientistas realizam experiências manipulativas, eles mantêm certas variáveis constantes e variam outras. Os cientistas à partida já possuem uma ideia do resultado da sua experiência?
10. É argumentado que estas expectativas podem influenciar os resultados da experiência. O que acha?
11. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

12. Pode ler a sua resposta à **questão 4** e explicar e aprofundar a sua resposta?
13. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

14. Pode ler a sua resposta à **questão 5** e explicar e aprofundar a sua resposta?
15. Que fatores são responsáveis pela alteração das teorias?
16. Se as teorias mudam, porque nos preocupamos em aprender teorias científicas?
17. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

18. Pode ler a sua resposta à **questão 6** e explicar e aprofundar a sua resposta?
19. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
20. Pode ler a sua resposta à **questão 7** e explicar e aprofundar a sua resposta?
21. Como os cientistas constroem o modelo da estrutura interna da Terra? Através de que dados?
22. E relativamente ao modelo do átomo? Estão os cientistas certos do modelo do átomo?
23. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
24. Pode ler a sua resposta à **questão 8** e explicar e aprofundar a sua resposta?
25. Como é que os cientistas definem o conceito de espécie?
26. Considera que os cientistas estão certos relativamente ao conceito de espécie?
27. Há algumas espécies de lobos e cães que se reproduzem e originam descendência fértil. Como é que isto se ajusta na noção de espécie, se diferentes espécies originam descendência fértil?
28. Será o conceito de espécie um conceito objetivo? A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
29. Pode ler a sua resposta à **questão 9** e explicar e aprofundar a sua resposta?
30. Como é que os cientistas chegam a conclusões diferentes com os mesmos dados?
31. Que característica da ciência é aqui evidente?
32. Apesar de as duas explicações em simultâneo poderem explicar o mesmo acontecimento, os cientistas são muito inflexíveis e mantêm forte a sua posição. Porque é que isso acontece?
33. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
34. Pode ler a sua resposta à **questão 10** e explicar e aprofundar a sua resposta?
35. A sua visão mudou desde que respondeu ao 1º questionário. Se sim, como/ De que forma?

36. Pode ler a **questão 11** e explicar e aprofundar a sua resposta?
37. Considera que a imaginação e a criatividade são apenas usados em algumas fases (na de planificação, por exemplo) ou em todas as fases da investigação?
38. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
39. Relativamente à **questão 12** quer acrescentar algum aspeto?

Exemplos de outras questões gerais:

40. O que quis dizer por (...)?
41. Pode dar-nos um exemplo do que quis dizer por (...)?
42. Como é que a sua resposta em (...) se relaciona com o que disse em (...)?

Obrigada pela colaboração!

Guião Geral de Entrevista sobre modelos – Futuros professores de Ciências

1. Pode ler a sua resposta à **questão 1** e explicar e aprofundar a sua resposta?
2. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

3. Relativamente à **questão 1.1**, pensa que essa será a principal função de um modelo?
4. Alguma função que queira acrescentar?
5. Na Geologia quais as funções dos modelos?
6. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

7. Pode ler a sua resposta à **questão 1.2.** e explicar e aprofundar a sua resposta?
8. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

9. Considera que **podem existir diferentes modelos** para representar diferentes aspetos do mesmo sistema alvo?
10. Podem existir **modelos múltiplos** para estudar o **mesmo alvo**?

11. Pode ler a sua resposta à **questão 1.3** e explicar e aprofundar a sua resposta?
12. O que provoca a alteração dos modelos?
13. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

14. Pode ler a sua resposta à **questão 2** e explicar e aprofundar a sua resposta?
15. Como podem os modelos ser usados em sala de aula?
16. Acrescentava algum aspeto acerca da importância da utilização dos modelos em sala de aula? Considera que um modelo contribui essencialmente para a compreensão de um fenómeno ou considera que o modelo para além de facilitar a compreensão em sala de aula, apresenta outras vantagens?
17. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

18. Pode ler a sua resposta à **questão 3** e explicar e aprofundar a sua resposta?
19. Que capacidades/ competências desenvolvem os alunos? O que aprendem? Pensa que a construção de modelos pode promover algo mais?
20. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
21. Pode ler a sua resposta à **questão 3.1** e explicar e aprofundar a sua resposta?
22. Acrescentaria algum aspeto? Os alunos apenas necessitam de conhecimento para construírem modelos?
23. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
24. Pode ler a sua resposta à **questão 4** e explicar e aprofundar a sua resposta?
25. Pode justificar a opção?
26. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
27. Pode ler a sua resposta à **questão 5** e explicar e aprofundar a sua resposta?
28. Quer acrescentar algum aspeto?
29. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
30. Pode ler a sua resposta à **questão 5.1** e explicar e aprofundar a sua resposta?
31. Porque acha importante que um aluno construa o seu próprio modelo? Apenas por questões relacionadas com o conteúdo?
32. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
33. Pode ler a sua resposta à **questão 6** e explicar e aprofundar a sua resposta?
34. Acrescentava alguma característica ou cuidados a ter para usar modelos em sala de aula? Nomeadamente algum tipo de alerta ou discussão com os alunos?
35. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
36. Pode ler a sua resposta à **questão 7** e explicar e aprofundar a sua resposta?
37. Acrescentava alguma diferença? E cuidado a ter?
38. Considera que os modelos usados no ensino só são importantes na compreensão de algo?
39. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?

40. Pode ler a sua resposta à **questão 8** e explicar e aprofundar a sua resposta?
41. Acrescentava alguma característica?
42. A sua visão mudou desde que respondeu ao 1º questionário? Se sim, como?
43. Relativamente à **questão 9** quer acrescentar algum aspeto?

Obrigada pela colaboração!

Grelha de observação de aulas

Escola: _____

Data: _____

Estagiário: _____

Temática: _____

Ano de escolaridade: _____

Categoria	Subcategorias	Verificação	Indicadores
Natureza da Ciência	Aborda aspetos da Natureza da Ciência		
	Quais		
	Importância dos modelos na construção do conhecimento científico (na Biologia e na Geologia)		
	Outros: _____		

Recursos	Recorreu a modelos para discutir aspetos da Natureza da Ciência					
	Recorreu a outros recursos para discutir aspetos da Natureza da Ciência: _____					
Abordagens	Abordou aspetos da Natureza da Ciência de forma contextualizada curricularmente					
	Abordou aspetos da Natureza da Ciência de forma explícita					
	Abordou aspetos da Natureza da Ciência de forma implícita					
	Abordou aspetos da Natureza da Ciência partindo de cenários problematizantes e do quotidiano					
	Usa modelos no decorrer da aula					
Uso de modelos		Tipos	Modelo físico			
			Modelo digital			
			Modelo histórico			
		Propósito	Como contributo para a compreensão de conteúdo conceptual			
			Como contributo para a compreensão de como se faz ciência			
			Como contributo para a compreensão da Natureza da Ciência			
		Estratégia	Professor demonstra com o modelo			
			Professor fornece o modelo e o aluno interage com o modelo			
			Aluno constrói o modelo			
Observações						

Guião de Entrevista FINAL – Estagiário
(após a prática de ensino supervisionada)

Objetivos das aulas	- De uma forma geral, quais os principais objetivos que estabeleceu para as aulas que lecionou no 11º ano de escolaridade? - Considera que os atingiu? - Qual considera ter sido o objetivo mais bem conseguido? - E o menos bem conseguido? - De uma forma geral, quais os principais objetivos que estabeleceu para as aulas que lecionou no 8º ano de escolaridade? - Considera que os atingiu? - Qual considera ter sido o objetivo mais bem conseguido? - E o menos bem conseguido?
Visão Geral	- Se voltasse a planificar estas aulas alteraria algo? Porquê? - Quais são para si os aspetos mais importantes a ter em conta no ensino das ciências? - Considera que o seu orientador cooperante influenciou o seu trabalho desenvolvido ao longo do ano letivo? - De que forma? - O seu orientador sugeriu recursos e estratégias para utilizar nas suas aulas? - Considera que o seu trabalho foi influenciado pelos outros professores do grupo de ciências (Biologia e Geologia) ou pelos professores de outras áreas disciplinares? - De que forma? - Sugeriram recursos e estratégias para utilizar nas suas aulas? - Considera que estava motivado para trabalhar ao longo deste ano letivo? - Porquê? - Que fatores contribuíram para a sua motivação? - Que fatores contribuíram para a sua desmotivação?

Análise de atividades em particular	<i>(Com a planificação, questionar acerca de uma atividade em particular, relacionada com a natureza da ciência e modelos)</i> 1. Na primeira aula de 11^o ano, sobre erosão costeira, recorreu a uma atividade de modelação. 1.1 Com esta atividade o que pretendeu trabalhar com os alunos? O que pretendeu que os seus alunos desenvolvessem? Porquê? 1.2 Acha que o conseguiu? 1.3 Quais as dificuldades que enfrentou na aplicação desta atividade? 1.4 O que considera que poderia melhorar se aplicasse esta atividade novamente? 1.5 Como reagiram os alunos à atividade de modelação? (Gostaram/estavam interessados...) 1.6 A atividade de modelação foi essencialmente desenvolvida pelo professor. Pode justificar a sua opção? 1.7 Depois da atividade de modelação, solicitou aos alunos o preenchimento de Vs de Gowin. Pode justificar a sua opção? 1.8 Considera importante o preenchimento de Vs de Gowin? 1.9 Porque não se corrigiu o V de Gowin na aula? 1.10 Nesta mesma aula, apesar de ter efetuado bastantes referências à natureza da ciência, não promoveu muito o debate e reflexão dos seus alunos sobre estes aspetos. Porquê? 2. Na sua 3^a aula ao 11^o ano (pós-viagem) usou organismos modelos. 2.1 Considerou relevante o recurso aos organismos modelos? 2.2 Como reagiram os alunos? 2.3 No debate que estabeleceu no final da aula foi possível debater aspetos da natureza da ciência? Porquê? 3. Verifiquei que na aula de 8^o ano não recorreu a modelos nem à natureza da ciência. Porquê?
Modelos Científicos	1. Utilizou modelos nas suas aulas? 1.1 Que tipos de modelos utilizou? 1.2 Com que objetivo os utilizou? Com que propósitos? 1.3 Como os utilizou? De que forma explorou os modelos na sua aula? 1.4 Porque os utilizou dessa forma?

	1.5 Porque não deu aos alunos a oportunidade de construírem modelos? 2. Considera que os alunos compreenderam o que é um modelo científico? 2.1 Porquê? O que foi realizado nesse sentido? 2.2 Como é que sabe? Avaliou o conhecimento dos alunos sobre modelos? Como? 3. Considera que compreenderam as características de um modelo científico? 3.1 Quais? 3.2 E a importância dos modelos científicos para a construção do conhecimento científico? 4. Teve algumas precauções ao usar os modelos em aula? 4.1 Quais? 4.2 Porquê? 5. Considera importante utilizar modelos nas aulas de ciências? Porquê? 6. O que podem desenvolver os alunos através do uso de modelos? 7. Considera importante discutir aspetos relacionados com as características dos modelos e suas limitações? 7.1 Porquê? 7.2 Conseguiu fazê-lo com os seus alunos? Porquê? 8. Sentia-se seguro para usar modelos em sala de aula? Porquê? 8.1 Que dificuldades enfrentou? 9. Como reagiram os alunos às atividades desenvolvidas com os modelos? 9.1 Pensa usar modelos na sua prática futura? Porquê? 9.2 Com que objetivos?
	1. Considera importante ensinar a natureza da ciência? Porquê? 2. Abordou a natureza da ciência nas suas aulas?

Natureza da Ciência	2.1 Que aspetos? 2.2 Como abordou a natureza da ciência? 2.3 Porque a abordou desta forma? 2.4 A que recursos recorreu para abordar a natureza da ciência? 3. (Se não abordou a NdC) Porque não o fez? 4. Considera que os alunos aprenderam alguns aspetos da Natureza da Ciência? 4.1 Porquê? O que foi realizado nesse sentido? 4.2 Como é que sabe? Avaliou o seu conhecimento acerca da Natureza da Ciência? Como? 5. Observei que não promoveu a discussão entre os alunos acerca da natureza da ciência. Porquê? Mas disse-me que fez isso no debate. 6. Sentia-se segura para abordar a natureza da ciência em sala de aula? Porquê? 6.1 Que dificuldades enfrentou? 7. Como reagiram os alunos às atividades desenvolvidas acerca da natureza da ciência? 8. Considera que era importante, se calhar, a formação contínua de professores sobre estes aspetos? 9. Pensa abordar a natureza da ciência na sua prática futura? 9.1 Porquê? 9.2 Com que objetivos?
Plano Anual de atividades	1. Verifiquei que os estagiários desta escola propuseram aos alunos de 11º ano a construção de modelos da estrutura do DNA. 1.1 Quais os objetivos desta atividade? 1.2 Como reagiram os alunos a esta atividade? 1.3 Qual o impacto desta atividade na comunidade educativa?

Questões gerais	1. Atente na afirmação: “Na ciência, a observação depende do referencial teórico do observador”. Considera que a afirmação traduz uma perspectiva positivista ou pós-positivista de ciência? 2. Atente na afirmação: “Uma representação que resulta de um modelo concetual do cientista que o criou e que pretende representar uma ideia, um objeto, acontecimento, processo ou sistema”. Considera que afirmação corresponde à definição de modelo científico ou de teoria científica? 3. Complete a afirmação: “Um modelo que simule a forma como alguns fenómenos e processos ocorrem na natureza, estabelecendo analogias nas similaridades geométricas, dinâmicas e cinemáticas é...”. Um modelo análogo ou um modelo para o ensino? 4. Considera que os modelos no Ensino da Geologia podem/devem ser iguais ou diferentes dos utilizados na ciência? Porquê?

Obrigada pela Colaboração!

Guião de Entrevista – Orientador cooperante

Desde já gostaríamos de agradecer a sua colaboração e disponibilidade demonstrada. Pedimos que dê a sua opinião sincera relativamente às questões colocadas.

Objetivo	Questões
Caracterização Profissional	- Qual o seu tempo de serviço docente? - Há quantos anos consecutivos leciona nesta escola? - Quais as suas habilitações académicas? - Quais os anos e disciplinas que leciona atualmente?
Caracterização do grupo de trabalho	- Considera que há um princípio orientador de base do modo de atuação dos professores de Biologia e Geologia desta escola? Qual? (Considera que existem metodologias que sejam mais utilizadas por este grupo de ciências nesta escola? Quais?) - Como caracteriza o grupo de ciências (Biologia e Geologia)? Considera que os professores de Biologia e Geologia trabalham em equipa? - Os estagiários trabalham juntamente com os professores da área disciplinar de Biologia e Geologia? Ou trabalham um pouco à margem desse grupo? Porquê? - Considera que o trabalho desenvolvido pelos estagiários é influenciado pelo grupo de ciências (Biologia e Geologia)? Ou até pelos restantes professores de outras áreas disciplinares? Quais? - E por si (orientador cooperante)? Considera que influencia o trabalho dos seus estagiários? De que forma? Essa influência tem por base algum princípio orientador de como se deve ensinar ciências? - Trabalha em conjunto com os seus estagiários? - Sugere aos estagiários recursos e estratégias a usar nas aulas? Quais?
Caracterização Logística	- Considera que há facilidade na realização de reuniões ou encontros informais dos professores? Quais as dificuldades encontradas? - As salas estão bem equipadas? O que falta? Algum equipamento que pudesse ser útil/melhorar a qualidade do ensino? - Que dificuldades encontram os professores/alunos na utilização do equipamento da escola?
Visão Geral da Educação em Ciências	- Para si, qual o papel da Educação em Ciências no século XXI? - Quais os principais objetivos que estabelece para o desenvolvimento dos seus alunos através da sua prática letiva?

	(O que pretende que os alunos desenvolvam nas suas aulas de ciências?) 17. Que metodologias e estratégias utiliza na sua aula (leitura do manual, atividades investigativas, resolução de problemas, etc.)? 18. Que tipo de atividades é que costuma desenvolver (observação de fenómenos naturais, recolha de dados, interpretação de gráficos e tabelas, leitura/produção de textos)? 19. Que tipo de recursos utiliza (manual escolar, livro de exercícios, recursos da internet)? Como?
Visões sobre o uso de modelos	20. Costuma usar modelos nas suas aulas de ciências? Que tipo de modelos? Porquê? (por exemplo, modelos físicos, computacionais e históricos) 20.1 Com que frequência usa modelos em sala de aula? Em que circunstâncias? 21. Considera importante o uso de modelos no ensino das Ciências? Porquê? 22. O que pretende que os alunos desenvolvam quando usa modelos nas aulas de ciências? (Caso não use modelos, o que considera que se pretende que os alunos desenvolvam ao usar modelos no ensino das ciências? Porque não os usa?) 23. Como usa/explora os modelos em sala de aula? (Demonstra os modelos disponíveis ou sugere que os alunos construam modelos?) 24. Considera importante que os alunos construam modelos? Porquê? O que desenvolvem? 24.1 Que diferenças encontrou quando os alunos constroem, exploram ou observam os modelos? O que preferem os alunos? 25. Considera que existem limitações (logísticas, etc...) ao uso de modelos no ensino das ciências? Quais? 26. Quais as características que um modelo deve ter para ser usado em sala de aula? 27. Que aspetos/cuidados devem ser tidos em consideração quando se usam modelos em sala de aula?
Visões sobre a Natureza da Ciência	28. Costuma abordar aspetos da natureza da ciência/características da ciência com os seus alunos? Se sim, quais?

	29. Considera importante abordar os aspetos relativos às características da ciência/ que os alunos compreendam o que é a ciência/ como se desenvolve a ciência? Porquê? 30. Que estratégias e recursos utiliza para abordar estes aspetos com os seus alunos? 31. Que tipo de atividades promove para trabalhar com os seus alunos uma conceção adequada da ciência? 32. Considera que existem limitações na clarificação da visão de ciência dos seus alunos? Que dificuldades enfrenta? 33. A partir de que idade trabalha estes aspetos com os seus alunos? De que forma evolui o trabalho acerca destes aspetos? (relativos às características da ciência/ ao que é a ciência/ como se desenvolve a ciência) 34. Atente na afirmação: “Na ciência, a observação depende do referencial teórico do observador”. Considera que a afirmação traduz uma perspetiva positivista ou pós-positivista de ciência? 35. Atente na afirmação: “Uma representação que resulta de um modelo concetual do cientista que o criou e que pretende representar uma ideia, um objeto, acontecimento, processo ou sistema”. Considera que afirmação corresponde à definição de modelo científico ou de teoria científica? 36. Complete a afirmação: “Um modelo que simule a forma como alguns fenómenos e processos ocorrem na natureza, estabelecendo analogias nas similaridades geométricas, dinâmicas e cinemáticas é...”. Um modelo análogo ou um modelo para o ensino? 37. Considera que os modelos no Ensino da Geologia podem/devem ser iguais ou diferentes dos utilizados na ciência? Porquê?

Obrigada pela Colaboração!