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Nature of science and models: Comparing Portuguese prospective teachers' views

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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.

Keywords: geoscience education; history of science; nature of science; prospective teachers' views; scientific models

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,

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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). 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, García-Carmona, 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.

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.

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.

NATURE OF SCIENCE, SCIENTIFIC MODELS AND EARTH'S STRUCTURE MODELS

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-El-Khalick, 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).

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).

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.

Earth's structure model

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'.

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 (Fig. 1). The lithosphere is divided into plates and the relative movements of

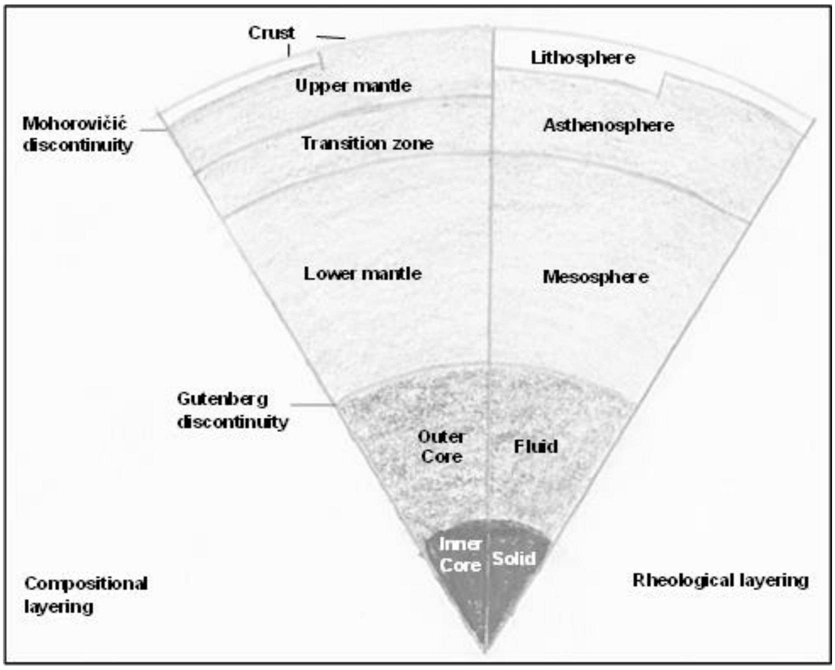


Figure 1. Earth's structure model – an example of physical and chemical model
Adapted from: Kearey, Klepeis & Vine 2009 (p. 52)
Credit: Marta Queiroz, 2015

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).

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.

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 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 (HSPPSTs). Despite their different courses, UPPSTs and HSPPSTs 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

Table 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%)

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.

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 1).

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-Technology-Society (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).

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.

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 2.

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.

RESULTS

Descriptive analysis

NOS and scientific models

The answers given to the 9 closed questions about NOS and models are presented in the tables below (table 3 and table 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 (HSPPSTs).

Table 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

Issue ------------ Category	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.

Table 3. Category and rate of responses regarding nature of science aspects

Question and Answer options	Category of answer	% U	% HS	% Tl
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.	Neutral	0	0	0
None of the options reflects my point of view.	Neutral	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.	Neutral	0	6.1	3.1
None of the options reflects my point of view.	Neutral	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.	Neutral	0	0	0
None of the options reflects my point of view.	Neutral	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.	Neutral	0	3.0	1.5
None of the options reflects my point of view.	Neutral	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.	Neutral	3.1	0	1.6
None of the options reflects my point of view.	Neutral	6.3	0	3.1
Without meaning*		0	3.1	1.6

Legend: % - percentage; U – UPPSTs; HS – HSPPSTs; Tl – Total (PPSTs)
**Without meaning: When respondents selected more than one answer.*

Table 4. Category and rate of responses regarding scientific models issues

Question and Answer options	Category of answer	% U	HS	Tl
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.	Neutral	3.1	0	1.5
None of the options reflects my point of view.	Neutral	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.	Neutral	3.1	0	1.5
None of the options reflects my point of view.	Neutral	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.	Neutral	6.3	3.0	4.6
None of the options reflects my point of view.	Neutral	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.	Neutral	0	0	0
None of the options reflects my point of view.	Neutral	6.3	3.0	4.6
Without meaning*		0	6.1	3.1

Legend: % - percentage; U - UPPSTs; HS – HSPPSTs; Tl - Total (PPSTs)
**Without meaning: When respondents selected more than one answer.*

Nature of science: Participants' understandings of NOS are presented in table 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 (HSPPSTs) 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 HSPPSTs 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.

Scientific models: Concerning scientific models (table 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.

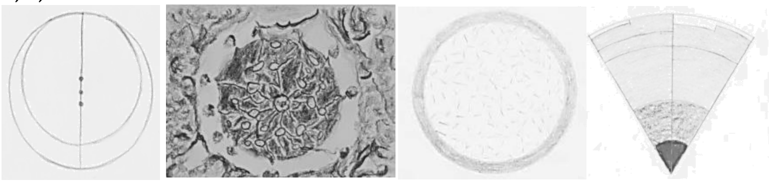
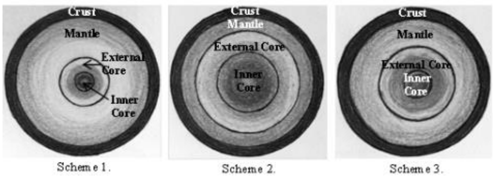
Earth's structure models

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 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.

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 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.

Table 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	Tl
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.	28.1	39.4	33.8
Q11 – Arrange the following historical models in chronological order…	2, 1, 3 and 4. 	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 proprieties 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 proprieties 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 important the 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; Tl -Total.

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 HSPPSTs' 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 HSPPSTs.

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 6). 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 HSPPSTs 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 HSPPSTs 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.

Statistical analysis

Correlational analysis

Results presented in table 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.

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 HSPPSTs, are somewhat peculiar. The results presented on table 6 show that although 43.8% of HSPPSTs 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

Table 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	Tl
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; Tl – Total

Table 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).*

Table 8. Univariate analysis of views [concerning nature of science (Q1-Q5) and current accepted earth's structure model and principles (Q13-Q22)] held by students with higher education institution

Item		Q1	Q2	Q3	Q4	Q5	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22
		Informed Answers														
Un	**f (%)**	23 (71.9)	27 (84.4)	16 (50.0)	25 (78.1)	4 (12.5)	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	**f (%)**	18 (54.5)	26 (78.8)	11 (33.3)	18 (54.5)	1 (3.1)	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)
Tl	**f (%)**	41 (63.1)	53 (81.5)	27 (41.5)	43 (66.1)	5 (7.8)	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)
χ2		2.095	0.337	1.858	4.034	1.953	3.175	1.261	9.502	2.845	16.746	12.298	37.051	0.746	13.642	18.872
p		0.148	0.562	0.173	0.045*	0.162	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; Tl – Total; χ2- chi-square; p- p value (x - p < 0.05; x** - p < 0.01).*

view regarding Earth's structure model knowledge. This result may reflect the lack of knowledge of HSPPSTs 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 HSPPSTs 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.

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 ($p>0.05$).

Regarding NOS views (table 8), 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 HSPPSTs (table 8), being the differences in questions number 15, 17, 18, 19, 21 and 22 statistically significant ($p<0.01$).

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 inconsistences 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 HSPPSTs 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 HSPPSTs 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 HSPPSTs' 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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