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Nature of Science, Scientific and Geoscience Models: Examining Students and Teachers' Views

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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.

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

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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 asses 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.

THEORETICAL BACKGROUND

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).

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.

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).

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?

METHODOLOGY

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.

a) Sample

Table 1. *Students characterization (n=415).*

Gender		Age		Failed in school	Main future courses desired	
Female	Male					
f (%)	f (%)	Mean	SD	f (%)	Course	%
239 (57.6)	176 (42.4)	17.27	0.55	55 (13.3)	Medicine	31.2
					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 1), and one hundred and forty five science teachers, with ages ranging from 23 to 63 (Table 2), from different regions of Portugal answered the questionnaire.

Table 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.

b) 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).

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 3).

Table 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 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 7 and 8).

c) Data Analysis

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 4 and 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.

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.

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.

FINDINGS

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 4 and 5.

As shown in table 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 5).

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.

Table 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.

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.

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.

Table 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.

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 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 6).

Table 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).

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 7 and 8).

Table 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.	29.6	Conditioned by time.	47.6
			Conditioned by students' age.	33.0
	You suggest students to construct their own models.	4.2	Students learn more.	50.0
			Students test the model while presenting it.	25.0
			It helps in phenomena understanding.	25.0
	Both options.	66.2	Limited by time.	19.0
			It implies an autonomous process of knowledge construction.	19.0
			To facilitate the understanding of certain phenomena.	15.5

Legend: %- percentage; STs–Science Teachers.

As shown in table 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 7 and 8).

Table 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.

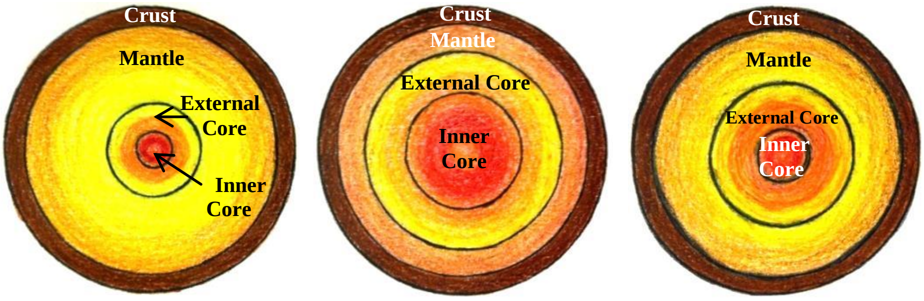
Geoscience Models

The answers related to Geoscience models are presented in tables 9 to table 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 9).

Table 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?



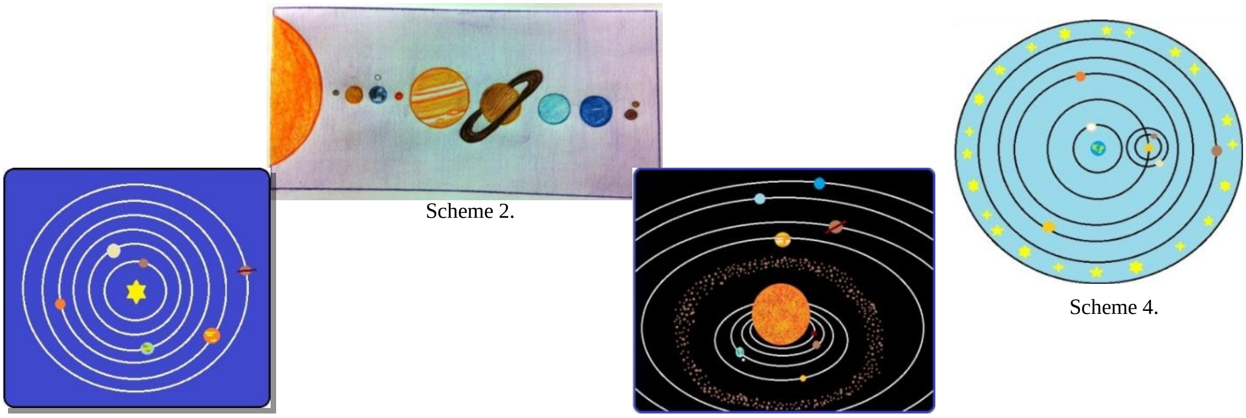
Scheme 1. Scheme 2. Scheme 3.

		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

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 10).

Table 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.



Scheme 2.

Scheme 4.

Scheme 1.

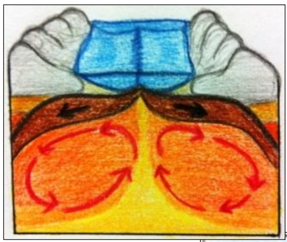
Scheme 3.

		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

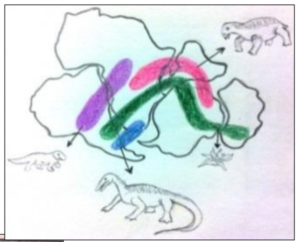
Regarding tectonic plates model it is also possible to verify that the bulk of science teachers and high school students answered correctly to this question. Furthermore, science teachers also presented a higher rate of correct answers (83,6%), when comparing with high school students correct answers (68%) - Table 11.

Table 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.

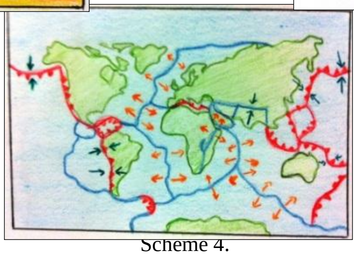


Scheme 1.



Scheme 2.

Scheme 3.



Scheme 4.

Scheme 5.

		Category of answer	**% STs**	**% HSSs**
Answers	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 12).

Table 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 13).

Table 13: *Means obtained and T-test analysis (Q11-Q14).*

Group	Mean	Std. Deviation	t-statistic t	t-statistic 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).

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.

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 were 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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