Views of nature of science: adaptation of a questionnaire for Portuguese prospective science teachers

Visiones sobre la naturaleza de la ciencia: adaptación de un cuestionario para futuros profesores de ciencias

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Abstract

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

Key words: *science education, nature of science, prospective science teachers' views, questionnaire, validation.*

Resumen

El desarrollo de visiones informadas de los alumnos sobre la naturaleza de la ciencia es actualmente considerado un objetivo crucial (pero también difícil) de las clases de ciencias. En consecuencia es importante que los propios profesores tengan visiones informadas sobre estos aspectos. Este estudio está integrado en una investigación más alargada y pretende proveer evidencias sobre la validez de un cuestionario adaptado para evaluar las visiones de los futuros profesores de ciencias portugueses sobre la naturaleza de la ciencia y presentar un análisis de sus visiones. Concluimos que los datos obtenidos por medio de las respuestas a los cuestionarios en conjunto con los datos obtenidos con entrevistas proporcionan un conocimiento profundo de las visiones de los futuros profesores de ciencias sobre la naturaleza de la ciencia. Así mismo el análisis de los datos revela que los futuros profesores de ciencias aún tienen visiones ingenuas relativamente a algunos aspectos de la naturaleza de la ciencia, lo que sugiere la necesidad de mejorarlas sobre ese aspecto.

Palabras clave*: educación en ciencias, naturaleza de la ciencia, visiones de futuros profesores de ciencias, cuestionario, validación.*

INTRODUCTION

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

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

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

This study is part of a broader research project whose aim is to improve the perceptions of NOS held by prospective science teachers, emphasising models nature in science and for science teaching. In this study, one questionnaire was adapted and validated for Portuguese prospective science teachers from the *Views of Nature of Science Questionnaire – Form C (VNOS-C)* (Lederman et al., 2002). To verify the adaptation made, we have examined student views of NOS at the end of the curricular component of their first year as students in biology and geology teaching master's course.

METHODOLOGY

Participants

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

Data Sources

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

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

METHODOLOGY

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

Given its acknowledged validity, we have chosen to adapt the *VNOS-C* questionnaire in view of the deep and meaningful analysis that it provides (Lederman et al., 2002). However, we have decided to validate this adapted questionnaire in the context in which it is used, considering the specificity of the sample and the inclusion of different questions. As a result, in order to verify if the questionnaire indeed measured what it aimed to measure, we previously analysed the answers so as to verify if respondents addressed the predefined targets regarding different aspects of NOS and to determine its validity (Table 1). Follow-up interviews were then used to get a clearer understanding of the participants' views as well as to verify the researchers' analysis of the answers and establish the reliability of the questionnaire. We compared the NOS profiles generated by the separate analysis of questionnaires and interview scripts, and the discrepancies were analysed. Afterwards, data were analysed in order to reach an understanding of the views of NOS held by prospective science teachers. To guarantee coherence, this final analysis was established by resorting to the same data source, that is, by using the information provided by the questionnaires. The analysis focused on the previously defined target aspects and a comparison with the contemporary conceptions of NOS was established. The views of NOS held by prospective science teachers were classified as "naive", "transitional" and "informed". Informed views match current conceptions whereas naïve views do not. Participants are considered to have transitional views when they show informed views only in a few (not all) questions. The category "without information" is related to those few cases in which participants did not address the aspect under analysis.

RESULTS AND DISCUSSION

Validity and Reliability of the Adapted Questionnaire

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

As shown in table 1, the majority of respondents addressed the predefined targeted NOS aspects, except for the item "scientific method". This difficulty was overcome since this item was specifically focused on during the interviews (see table 2). Thus, it was confirmed that questions were understandable and the respondents proved to be capable of presenting a wide range of views (Table 1).

Table 1. Answers to the questionnaires

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

By comparing the NOS profiles generated by the separate analyses of the questionnaires and the transcripts of interviews, a high degree of congruence was achieved, as only a few discrepancies were identified (Table 2).

While the discrepancies were few, it is important to analyse the ones which were identified. A high rate of discrepancies (11 – 10.2%) results from the lack of information, mainly verified in the questionnaires. For example, discrepancies related to the "scientific method" aspect result from the fact that six respondents did not address this aspect in the questionnaire (Table 2). As a consequence, by analysing the interviews, four of these respondents were classified as holding a naïve view and two as holding an informed view regarding the nonexistence of a single scientific method.

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

> *Both theories and laws may be subject to change. So, maybe I changed my view (...) (Prospective teacher 8 – PT8)*
>
> *Scientific experiments (...) now I think that it is something that implies the change of a variable. (PT11)*

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

Views of nature of science

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

Empirical Basis of Scientific Knowledge

The majority of respondents did not reveal adequate understandings regarding the empirical basis of scientific knowledge. In fact, 52.9% (Table 1) respondents considered that scientific knowledge is proven true based essentially on experimental evidence:

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

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

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

Table 2. Answers to the interviews and discrepancies between the analysis of questionnaires and interviews.

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

Scientific Method

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

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

On the other hand, one respondent considered that:

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

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

General structure of experiments

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

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

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

Observationally based disciplines

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

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

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

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

Inferential Nature of scientific knowledge

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

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

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

Subjectivity in science

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

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

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

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

Creativity and imagination in Science

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

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

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

Social and cultural influences

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

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

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

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

Tentativeness of scientific knowledge

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

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

Theories change

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

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

Difference between scientific theories and laws

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

> *Yes, there is [a difference between scientific theories and laws]. A law has less coverage than a theory. In general, a theory explains or integrates diverse laws. Furthermore, a law is based on more observations, while a theory constitutes an endeavour to explain these observations. For example, the law of gravity tells us that two objects attract each other, whereas the theory explains why. (PT3)*

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

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

The nature of scientific theories

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

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

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

Functions of scientific theories

When asked about the usefulness of learning scientific theories, nine respondents held informed views: 29.4% (n=5) of the respondents recognized that theories provide a theoretical framework that allows the understanding of current knowledge; 11.8% (n=2) considered that scientific theories provide a theoretical framework for future investigations and 11.8% (n=2) recognized that scientific theories have both functions. On the other hand, 29.4% (n=5) of the respondents considered the learning of scientific knowledge only as a contribution to the understanding of how science develops (Table 1).

The history of science and historical models

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

> *History of science is important in science teaching for students to understand scientific knowledge development, how this development occurs and how society influences and is influenced by this process. In other words, it is essential for students to understand the nature of science. (PT3)*

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

The change of their views about science

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

CONCLUSIONS

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

In this study, we have verified that Portuguese prospective science teachers hold naïve views concerning some NOS aspects, especially related to the following ones: the empirical and tentative nature of scientific knowledge; scientific method and general structure and coverage of experiments; difference between theories and laws. In the same way, in a study conducted by Liu & Lederman (2007) with Taiwanese prospective science teachers, it was also verified that they generally hold naïve views concerning NOS aspects. For example, all of them have naïve views on the relationship between theories and laws and a great majority did not demonstrate adequate understandings about the empirical basis and the tentativeness of scientific knowledge. Moreover, in a study conducted with fifteen Turkish preservice science teacher educators, the majority of the participants revealed inadequate views concerning NOS, being the "scientific method" and "tentative nature of scientific knowledge" the most problematic aspects (Irez, 2006). Likewise, in a study conducted with Portuguese university students it was revealed that they do not held informed views regarding NOS, so the need to improve NOS instruction in Portuguese educational institutions has been emphasized (Figueiredo & Paixão, 2010). Accordingly, it was also verified, in two pilot studies previously done (Torres & Vasconcelos, 2015; Torres, Moutinho & Vasconcelos, 2015), that Portuguese prospective science teachers, in-service teachers and students hold naïve views concerning some NOS aspects. However, this adapted and validated questionnaire provided an in-depth understanding of the views of NOS by Portuguese prospective science teachers.

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

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

Question 1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g. religion, philosophy, or art)?
Question 2. What is the relevance of history of science and historical models for science education?
Question 3. What is an experiment?
Question 4. Does the development of scientific knowledge require experiments? • If yes, explain why. Give an example to defend your position. • If no, explain why. Give an example to defend your position.
Question 5. After scientists have developed a scientific theory (e.g., cell theory, evolution theory), does the theory ever change? • If you believe that scientific theories do not change, explain why. Defend your answer with examples. • If you believe that scientific theories do change: Explain why theories change. Explain why we bother to learn scientific theories. Defend your answer with examples.
Question 6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example
Question 7. Science textbooks often represent the interior of the Earth as a set of concentric layers with distinct characteristics. How certain are scientists about the structure of the interior of the Earth? What specific evidence, or types of evidence, do you think scientists used to determine how the interior of the Earth looks like?
Question 8. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?
Question 9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the Earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
Question 10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. • If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples. • If you believe that science is universal, explain why and how. Defend your answer with examples.
Question 11. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations? • If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate. • If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.
Question 12. After the classes that you attended during this academic year, do you consider that you have changed your views of the nature of science? • If so, identify and explain the main changes and the main reasons (and sources) for those changes.

Appendix B. VNOS Interview Protocol

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

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