High School Students' Views of Nature of Science: The Case of Chemistry among Greek Students

Charoula E. Labrianaki[1] , Katerina Salta[2], Dionysios Koulougliotis[3]

Ionian University, Greece[1]
National and Kapodistrian University of Athens, Greece[2]
Ionian University, Greece[3]

Abstract

Epistemology (science as a way of thinking) along with sociology (intrinsic beliefs and values related to scientific knowledge and its development) of science are mentioned as nature of science (NOS). Based on science disciplines' similarities and differences, NOS is conceptualized as both domain-general and domain-specific. Hence, it is interesting to investigate students' views of NOS integrating the perspective of domain-specificity. Taking into consideration the strengths and weaknesses of NOS assessment tools, an adaptation of the instrument "Views of Nature of Science Questionnaire – Form C" for implementation to a specific discipline context (chemistry) and at the same time a different cultural context (Greek students) resulted in an instrument that included seven items *with open-ended questions. This instrument was used to investigate 24 Greek high school (11th* grade, *16-17 years) students' views of NOS. A qualitative analysis partially following the VAScoR rubric was carried out. The results obtained indicate that the participants' views of NOS are "mixed", as they are characterized as partially informed with respect to scientific methods and the nature of scientific theories and naïve with respect to social and cultural embeddedness. Also, most students express partially informed or naïve views regarding tentative aspect of NOS depending on the question posed. The research findings are critically discussed and their implications for chemistry education are presented.*

Keywords: *Nature of science, NOS assessment, NOS domain-specificity, chemistry education*

1. Introduction

Nature of science (NOS) has been a significant field of research in science education [1]. NOS refers to "the epistemological, ontological, and sociological aspects of science" [2] and is a term whose precise definition often becomes a topic of discussion among those involved in the philosophy and history of science, as well as among educators in the field of science [3]. According to Lederman, the term NOS pertains to the epistemology and sociology of science [4] while a more recent approach to NOS is the Family Resemblance Approach (FRA), which is based on the epistemic, cognitive, and social - institutional dimensions of science [1]. What is particularly important is the relevance of NOS at both the educational and developmental levels so that the teaching of science is conducted in a way that connects to students' lives and holds meaning for them [5,6]. Students should develop an understanding of how science operates, aiming to interpret the reliability of scientific claims concerning decision - making both at an individual and a societal level [7].

The purpose of the present study is to investigate the views of Greek high school students in their second year (grade 11) regarding the nature of science (NOS), with a particular focus on chemistry. Initially, the reasons highlighting the essential role of understanding NOS will be presented, along with an exploration of the underlying interest in this subject. Subsequently, there will be a discussion on the assessment and determination of students' views and beliefs concerning NOS, focusing on the measurement instrument upon which this research is based. Finally, the methodology employed will be outlined, followed by the results and conclusions derived from the study, which could further enrich the analytical framework of students' epistemological beliefs concerning chemistry.

2. Theoretical Framework

Research on views of nature of science (NOS) began in 1957 and has since become a significant field of study in science education. Views of NOS are fundamental to scientific literacy, as NOS is closely related to metacognitive knowledge concerning science [5,8]. The goal of science educators is not to create philosophers of science but to cultivate informed citizens capable of making scientifically

based decisions [9]. These citizens should be able to answer questions such as: "What is science? How does it develop its claims?" and, perhaps more importantly, "How does it establish their reliability? How does it evolve over time? How does it interact with society and culture?" [10]. The ultimate aim is to enable individuals to utilize scientific knowledge in making informed decisions concerning science, society, and themselves [9,11,12].
An informed citizen, who has received appropriate and adequate education as a student, will be able to interact with experts, distinguish between true and false evidence, assess the limitations and foundations of scientific claims, and understand uncertainty as an inherent characteristic of science. Such individuals will be capable of interpreting and evaluating scientific issues even without being practicing scientists [7]. NOS can support individuals living in a society where public policy and individual decision - making increasingly rely on scientific claims [10].
The assessment of NOS began in the 1960s with an emphasis on quantitative approaches, typically using traditional paper – and - pencil tests. Since the early 21st century, qualitative assessment tools, including open - ended questions, have been employed. These tools provide a broader understanding of individuals' knowledge regarding NOS, offering respondents more freedom to express their views and providing to researchers deeper insights into the thought processes of the participants [5,13].
The most widely used tool in NOS research is the VNOS (Views of Nature of Science) questionnaire [13]. Open-ended in nature, it has been instrumental in advancing NOS research. The first version, VNOS - A, consisted of seven open-ended questions and was developed by Lederman and O'Malley to be used alongside supplementary interviews about science [5]. This tool represented an initial attempt to assess students' and college students' views of NOS, undergoing systematic revisions based on responses to improve its validity. Subsequently, Abd – El - Khalick, Bell, and Lederman refined the VNOS - A and created a new version, VNOS - B, to examine secondary school science teachers' perceptions of NOS. Abd – El - Khalick further modified VNOS - B by revising existing questions and adding new ones, resulting in VNOS - C [4]. This version has been widely used with middle school and high school students, undergraduate students [9] and primary and secondary science teachers. In addition to assessing perceptions related to NOS addressed in VNOS - B, VNOS - C also focused on social and cultural embeddedness of science and the existence of a universal scientific method [4].
As mentioned in the introduction, a new framework for conceptualizing NOS is the Family Resemblance Approach (FRA), which offers a more cohesive and holistic perspective [14]. Views of NOS within this framework are assessed using the RFN (Reconceptualized Family Resemblance Approach to Nature of Science) questionnaire. This tool consists of 70 items reflecting both positive and negative perceptions of NOS [15], with responses measured on a 5 - point Likert scale (ranging from strongly disagree to strongly agree) [14]. Despite its potential, empirical applications of this approach remain limited [15]. Research has primarily focused on general aspects of science rather than specific disciplines such as physics, chemistry, biology, or geoscience - fields often introduced to students through distinct courses. Moreover, studies using RFN targeting students (primary, middle, and high school) constitute only about 10% of the total research conducted [16].
This study utilized the VNOS - C instrument which placed particular emphasis on the aspects of NOS outlined in Table 1 [13]. Details regarding the methodology employed, along with the results and conclusions drawn, are presented in the following sections.

Table 1. Elements of the NOS aspects targeted in the VNOS

NOS aspect	Elements
Empirical	Scientific claims are based on observations of natural phenomena, but these observations are mediated by human perception, the assumptions behind scientific instruments, and theoretical frameworks.
Inferential	Observations are descriptive statements about natural phenomena that are accessible to the senses and allow for easy consensus. Inferences, by contrast, are conclusions about phenomena not directly accessible to the senses, (e.g., objects tend to fall to the ground because of "gravity").
Creative	Scientific knowledge involves human creativity, with scientists inventing explanations and theoretical models. These entities, represent our understanding of reality but are not exact copies of it, reflecting the inferential and creative nature of science.
Tentative	Scientific knowledge is reliable and durable but not absolute. It evolves as new evidence emerges through conceptual and technological advances, as existing evidence is reinterpreted with new theoretical insights, or in response to cultural, social, and research shifts.
Myth of "The Scientific Method"	There is no single, universally applicable 'Scientific Method' that guarantees valid or certain knowledge. Scientific practice involves a variety of activities—such as observing, hypothesizing, and theorizing—but no fixed sequence of steps ensures

NOS aspect	Elements
	reliable outcomes.
Scientific theories	Scientific theories are well-established, internally consistent systems of explanation based on foundational assumptions or axioms and often involve unobservable entities. Direct testing is not feasible; Instead, theories are supported through indirect evidence by deriving testable predictions and checking them against observations, with agreement increasing confidence in the theory.
Social dimensions of science	This dimension highlights the values of communication and criticism within science, which enhance the objectivity of collectively scrutinized knowledge by reducing individual biases. It is distinct from relativistic views and exemplified by practices like the double-blind peer-review process.
Social and cultural embeddedness of science	Science operates within a complex cultural context, influencing and being influenced by societal values, beliefs, power dynamics, and other cultural factors such as philosophy, religion, and economics. This interaction is evident in public funding for research and the influence of perspectives like feminism on scientific explanations.

3. Methodology

In this study, a qualitative approach was employed, involving the translation and adaptation of the VNOS–C [4] questionnaire into Greek and to the context of chemistry. In the adapted instrument (VNOS-C-Ad) the word “chemistry” was used in order to denote the specific scientific discipline when needed (substituting the word “science”, e.g. “chemistry textbooks” instead of “science textbooks”). In addition, the original instrument (VNOS-C), which consists of a total of 10 items, was adapted as follows: a) The first item of VNOS-C was divided into two distinct items in VNOS-C-Ad, b) In item No 4 of VNOS-C (item No 5 of VNOS-C-Ad) the example of “evolution theory” was omitted from the parenthesis and only the one referring to atomic theory was maintained, and c) The items No 5, 7, 8 and 9 of VNOS-C were not included in VNOS-C-Ad. The final form of the adapted instrument, consisting of seven items, is presented in Table 2.
The questionnaire was administered to 24 11th grade high school students during their chemistry class.

Table 2. The items of the VNOS-C-Ad instrument

1. What, in your view, is science?
2. What makes chemistry different from other disciplines, like philosophy?
3. What is an experiment?
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.
5. After scientists have developed a scientific theory (e.g., atomic 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:
      (a) Explain why theories change?
      (b) Explain why we bother to learn scientific theories? Defend your answer with examples.
6. Chemistry textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?
7. 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. Defend your answer with examples.
    - If you believe that science is universal, explain why. Defend your answer with examples.

The analysis of participants' responses, as far as aspects of NOS are concerned, was carried out using the categories and corresponding criteria (Table 3) of the VNOS Analysis and Scoring Rubric (VAScoR). The responses of each separate item were analyzed in order to identify the target NOS aspects present in each one. Subsequently, a series of crosstabulation analyses were conducted in order to examine the consistency in students’ answers across items.

In the first step of the analysis, the target NOS aspect/s of each item were defined according to the literature [4,13]. Then, two of the authors analyzed the same responses of ten students and compared their analyses. After their discrepancies were resolved with the consensus of all authors, both the emerged NOS aspect/s of each item (Table 4) and the categorization of students' responses were revealed.

Table 3. Categories and criteria of students' responses adopted from VAScoR [13]

Category	Criteria
Silent	No relevant or irrelevant or incomprehensible or without reliable categorization response.
Naïve view	Either some or all elements of the target NOS aspect are naively addressed
Partially informed view	Only a subset of the core elements of the target NOS aspect are judged to be informed; and responses on other elements of the target NOS aspect are silent
Informed view	All elements of the target NOS aspect are judged to be informed

4. Results and Discussion

The results from the analysis of students' responses are presented in Table 4. In all the items at least one of the target NOS aspect/s was also identified in the students' responses and is reported as "emerged NOS aspect". Interestingly, in four items (No 4, 5, 6, and 7), we note the identification of emerged NOS aspects which are not included in the target ones. Of particular interest are items 5 and 6 in which the NOS aspects "scientific theories" and "tentative" respectively, emerged from the responses of all students and at the same time none of them makes part of the corresponding target NOS aspects.

Table 4. Distribution of students' reports according to target and emerged NOS aspects

Item	Target NOS aspect	Emerged NOS aspect	Silent (S)	Naïve (N)	Partially informed (P)	Informed (I)
1	Empirical Inferential Myth of "The Scientific Method"	Empirical	12	3	9	-
2	Empirical Inferential Myth of "The Scientific Method"	Myth of "The Scientific Method"	6	8	10	-
3	Myth of "The Scientific Method" Creative	Myth of "The Scientific Method"	3	5	16	-
4	Myth of "The Scientific Method" Inferential Creative	Myth of "The Scientific Method"	4	5	15	-
		Empirical	-	-	1	-
		Tentative	-	2	-	-
5	Tentative Inferential Creative	Tentative	-	11	13	-
		Scientific Theories	7	6	10	1
6	Inferential Creative	Inferential	19	5	-	-
		Tentative	5	13	6	-
7	Social and cultural embeddedness of science	Social and cultural embeddedness of science	-	13	10	1
		Creative	-	1	-	-
		Tentative	-	1	-	-
		Social dimensions of science	-	-	-	2

Regarding the categories in which the views of the participating students are classified, the data show that in the first item and the "empirical" aspect, approximately 40% of the views are classified as partially informed. An example of students' responses is the following: "(*Science is) The observation and study of the world I live in to understand it, to perceive my place in it, and how I can change/enrich it.*"

The results of a crosstabulation analysis of the students' responses to items 2, 3 and 4, which concern the NOS aspect referring to the myth of "the scientific method" are presented in Table 5. It appears that the partially informed view is consistently the largest proportion across all three items. Additionally, 5 students held partially informed views on 2 of the three items. The naïve (N) view was expressed by 2 students across all three items, while 4 students expressed it in 2 of the items.
In item 5, in addition to the target "tentative" NOS aspect, where the views are almost equally divided between naïve and partially informed, the "scientific theories" aspect emerged, although it was not one of the target aspects. The prevailing views in this case belonged to the category partially informed. An example of a partially informed view of the "scientific theories" aspect is the following:, "*Since scientific theories have been confirmed using various means to prove their validity (e.g., microscopes for the structure of the atom), they are unlikely to change. They change if it is later proven, of course, that they are incorrect (this happens over time with the advancement of knowledge and technology*)" An example of a naïve view of the "scientific theories" aspect is the following: "*A theory must be applied and practically tested (experiment) to be adopted*". In the same item (No 5), for the "tentative" aspect, an example of a response that corresponds to a partially informed view and suggests that scientific knowledge is not certain is the following: "*Scientific theories change as scientific equipment improves. New tools allow for a deeper study of things, and as a result, sometimes the study uncovers new data that invalidate previous ones*."

Table 5. Students' views for the aspect Myth of "The Scientific Method" (items 2,3,4)

Views	PPP	PPN	PPS	PNN	PNS	SSP	NNN	SNN	SSS
Number of students	9	3	2	1	1	2	2	3	1

The crosstabulation analysis of the students' responses to item 5, which pertains to the "tentative" and "scientific theories" aspects, revealed the results presented in Table 6. One student holds a partially informed (P) view regarding the "tentative" aspect and an informed (I) view regarding the "scientific theories" aspect. Seven students have partially informed (P) views and five students hold naïve (N) views on both aspects.

Table 6. Students' views for the aspects "Tentative" and "Scientific theories" (Item 5)

Views	PI	PP	PN	NP	PS	NN	NS
Number of students	1	7	1	3	4	5	3

Note: The first letter concerns the aspect "tentativene" and the second the aspect "scientific theories"

The "tentative" aspect also emerged in item 6 (although it was not target), with the majority of the responses indicating naïve views. Two illustrative responses show that students regard both scientists and the curriculum in school as authoritative, containing absolute and unchanging knowledge about the physical world: "*Scientists are very certain about the structure of the atom, as this theory has been proven to be true (through many experiments, other theories, and research) by previous scientists*" and "*I believe they are quite certain (the scientists) for chemistry to be taught in schools*." In the same item, the target aspect "inferential" also emerged, with a characteristic example of a response corresponding to a naïve view: "*With the help of special equipment, e.g., microscopes, scientists have analyzed images of atoms to determine their structure*." The students believe that conclusions arise from instruments (e.g., microscopes) rather than through reasoning. Table 7 presents the results of the crosstabulation analysis for the students' responses to item 6, which concern the "inferential" and "tentative" aspects.

Table7. Students' views for the aspects "Inferential" και "Tentative" (item 6)

Views	NP	SP	NN	NS	SN	SS
Number of students	1	5	3	1	10	4

Note: The first letter concerns the aspect "inferential" and the second the aspect "tentative"

As shown in Table 7, six students hold partially informed views regarding the "tentative" aspect and their views as far as the "inferential" aspect is concerned are naïve or unrelated. The final crosstabulation analysis of the students' responses to items 5 and 6, which concern the "tentative" aspect, yielded the results presented in Table 8.

Table 8. Students' views for the aspect "Tentative" (items 5,6)

Views	PP	PN	NN	NS
Number of students	6	7	6	5

Six students consistently express partially informed views and six students consistently express naïve views regarding the "tentative" aspect in both items. Seven students express partially informed views for the "tentative" aspect in item 5 and naïve views in item 6.

Finally, in item 7, the target and main emerged aspect was the "social and cultural embeddedness of science" where the views of the participants were divided into naïve and partially informed. Particularly characteristic examples of responses for each of the two categories are as follows: "*I believe that science reflects the values of the culture from which it originates because these values determine the conditions under which it will develop. For example, it is much easier to study and develop controversial scientific fields in a progressive country than in a religion - centered country*" (partially informed), and "*Science is universal, since we all live in the same space governed by the same physical and chemical laws*. *For example, atomic theory cannot be different in Europe and different in Asia because the culture and society are different*" (naïve). In the first response, it is clear that science is influenced by and influences cultural elements (e.g., religion) while in the second response, the opposite view is presented.

5. Conclusions

The results obtained, indicate a variety of views that depend on both the aspect and the items.

In items involving more than one target NOS aspects (No 1-5) only one aspect emerged in the students' responses. It is interesting however, that in four items (No 4-7), emerged NOS aspects which were not included in the target ones were identified.

The "inferential" NOS aspect was a target in five items (No 1, 2, 4, 5 and 6) but it emerged only in one item (No 6) with views which were categorized either as silent or naïve.

Similarly to the "inferential" aspect, the "creative" aspect did not emerge in any of the four items (No 3-6) in which it was a target, and solely appeared in one student in the response given in an item which did not include it as target (Item 7).

With regard to the categories of the identified NOS aspects, the following conclusions are reached:

The "Myth of the Scientific Method" NOS aspect appeared in total (Items 2-4) with the majority of views characterized as partially informed.

An opposite trend was observed for the "tentative" NOS aspect with the majority appearing in total to belong either in the naïve or silent categories.

With respect to the "empirical" NOS aspect a considerable amount of views (ca. 40% in total) belonged were characterized as partially informed with the remaining ones belonging to the naïve and (mostly) the silent categories.

There were no views categorized as (at least) partially informed for the "inferential" NOS aspect.

Finally, the "social and cultural embeddedness of science" NOS aspect appeared with views that were approximately divided equally between the at least partially informed and the naive categories.

The results reached in this preliminary work, once further enriched by involvement of additional students, could serve for the advancement of chemical education via the effective inclusion of nature of science aspects in order to promote chemical and therefore scientific literacy.

REFERENCES

[1] Erduran, S., Kaya, E., & Avraamidou, L. (2020). Does research on nature of science and social justice intersect? Exploring theoretical and practical convergence for science education. Nature of science for social justice, 97-113.

[2] Kaya, E., Erduran, S., & Okan, B. (2024). Nature of science and domain-specificity: investigating the coverage of nature of science in physics, chemistry and biology curricula across grade levels. International Journal of Science Education, 1-31.

[3] Schwartz, R., & Lederman, N. (2008). What scientists say: Scientists' views of nature of science and relation to science context. International Journal of Science Education, 30(6), 727-771.

[4] Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of research in science teaching*, *39*(6), 497-521.

[5] Lederman, N. G., Bartos, S. A., & Lederman, J. S. (2013). The development, use, and interpretation of nature of science assessments. International handbook of research in history, philosophy and science teaching, 971-997
[6] Adúriz-Bravo, A., & Pujalte, A. P. (2020). Social images of science and of scientists, and the imperative of science education for all. Nature of science for social justice, 201-224.
[7] Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. Science Education, 95(3), 518-542.
[8] Schwartz, R. S., Lederman, N. G., & Abd-el-Khalick, F. (2012). A series of misrepresentations: A response to Allchin's whole approach to assessing nature of science understandings. Science education, 96(4), 685-692.
[9] Priemer, B., & Lederman, N. G. (2022). Nature of Scientific Knowledge and Nature of Scientific Inquiry in Physics Lessons. In Physics Education (pp. 113-150). Cham: Springer International Publishing.
[10] Allchin, D. (2020). From nature of science to social justice: The political power of epistemic lessons. Nature of science for social justice, 23-39.
[11] Hodson, D. (2013). Nature of science in the science curriculum: Origin, development, implications and shifting emphases. In International handbook of research in history, philosophy and science teaching (pp. 911-970). Dordrecht: Springer Netherlands.
[12] Irzik, G., & Nola, R. (2013). New directions for nature of science research. In International handbook of research in history, philosophy and science teaching (pp. 999-1021). Dordrecht: Springer Netherlands.
[13] Abd-El-Khalick, F., Summers, R., Brunner, J. L., Belarmino, J., & Myers, J. (2024). Development of VAScoR: A rubric to qualify and score responses to the views of nature of science (VNOS) questionnaire. Journal of Research in Science Teaching, 61(7), 1641-1688.
[14] Schofield, L., Takriti, R., Rabbani, L., AlAmirah, I., Ioannidou, O., Alhosani, N., ... & Erduran, S. (2023). Early years education teachers' perceptions of nature of science. International Journal of Science Education, 45(8), 613-635.
[15] Kaya, E., Erduran, S., Aksoz, B., & Akgun, S. (2019). Reconceptualised family resemblance approach to nature of science in pre-service science teacher education. International Journal of Science Education, 41(1), 21-47.
[16] Bae, K., & Son, Y. A. (2024). Analysis of Research Trends in the Family Resemblance Approach to the Nature of Science in Science Education. Asia-Pacific Science Education, 1(aop), 1-37.