

The Degree that Nature of Scientific Knowledge Aspects are Included in the Science Classes of Greek High Schools

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Abstract

The present study examines the integration level of the Nature of Scientific Knowledge in secondary school science classes in Greece. The research was designed and organized on the basis of the Cultural-Historical Activity Theory. The activity system of the researchers, who use the proper tools each time, are in network relations with the activity system of Science Education. Major components of the educational system are studied (the curriculum, textbooks, teachers' know-how and teaching methods, school inspectors' viewpoints, students' knowledge) in relation to the nature of scientific knowledge, to ensure valid results. The curriculum and textbook content is decoded, the knowledge of teachers and students is assessed with the use of an internationally validated questionnaire, and interview protocols are analyzed. Research results reveal that the nature of scientific knowledge is included in a small degree in the curriculum and textbooks, teachers refer intuitively to some of these aspects, without assessing the knowledge of students, and, finally, the majority of high-school graduate students have naïve views regarding the nature of scientific knowledge.

Keywords: nature of science, secondary education, Greece

1. Introduction

1.1 The Problem

This study presents the results of the research that took place in Greece aiming to examine the integration level of the Nature of Scientific Knowledge (NOSK) in science classes in the secondary education system (grades 7-12, students aged 12-18). It is part of a wider project which started with the Need Analysis, as presented here, and was later followed by the design and implementation of a professional development (PD) program for science teachers, regarding NOSK teaching (see paragraph 4).

An initial research (Koumara & Plakitsi, 2017) revealed that NOSK teaching in Greece is problematic. The present study aims to expand the research in the entire secondary education system (the former study focused on Lower Secondary School, grades 7-9), using more tools, statistical analysis and interviews conducted both with teachers and students. Another goal is to study the cultural characteristics of teachers, their historicity and the activity system of science classes, and analyze them based on the Cultural-Historical Activity Theory (CHAT) in order to facilitate the design of a PD-program for science teachers in the future (Roth & Lee, 2007). CHAT serves to the multi-faceted depiction of the problem.

The views of students and pre-service and in-service teachers regarding NOSK (e.g. Akerson & Abd-El-Khalick, 2005; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz & Lederman, 2008; Stefanidou & Skoroulis, 2018) have been recorded and researched since the early days of this field (Lederman, 1992) and their analysis continues until today (e.g. El-Takach and Yakoubian, 2020). There are many assessment tools specifically designed to achieve valid results (Abd-El-Khalick, 2014). The initial studies were conducted in North America but have now expanded to the rest of the world, e.g. BouJaoude and Santourian (2012) in Lebanon, Dogan and Abd-El-Khalick (2008) in Turkey, Leden, Hansson, Redfors and Ideland (2015) in Sweden, Thye and Kwen (2004) in Singapore. Especially in Turkey, this study is part of a wider government-funded project, named BIDOMEG, the initials of

which stand in Turkish for “Continuing Professional Development to Support the Teaching about Nature”. The researchers designed, among others, an assessment questionnaire and activity books (Yalaki, Dogan, Irez, Dogan, Cakmakci, & Kara, 2019). Regarding NOSK in school textbooks, Abd-El-Khalick, Waters and Le (2008) turned their work in this field in a book, edited by Abd-El-Khalick and McDonald (2017). There is a chapter in this book with Kampurakis’ study (2017) on Greek biology textbooks. Finally, there are studies on curricula, like Naser’s (2018) for Palestine or the review of the United Kingdom curriculum (Jenkins, 2013).

The present study differs from the ones mentioned above because it concerns Greece and contains the study of all the components of its educational system: the curriculum, textbooks, student and teacher views on NOSK aspects (see 2. Method), in order to a) draw broader conclusions about NOSK teaching in this country and b) create a PD-program for science teachers, taking into consideration the cultural characteristics of teachers and the curriculum and textbook requirements.

1.2 The Nature of Scientific Knowledge and Why its Teaching is Important in Compulsory Education

For the past 100 years, the definition of Nature of Science (NOS) and its aspects has been a matter of constant debate between philosophers/historians/sociologists of science and educators. Until today, there is no consensus on its definition and its aspects (Lederman, Antink & Bartos, 2014; Piliouras & Plakitsi, 2015; Lederman, 2019; McComas, 2017; Clough, 2007; Allchin, 2011; Matthews, 2012; Erduran & Dagher, 2014; Van Dijk, 2011). However, all of them acknowledge the importance of NOS aspects in Science teaching. They argue that NOS a) provides a better understanding of the limitations of science, b) increases interest in classroom, c) achieves better understanding of scientific knowledge, and d) achieves scientific literacy (Matthews, 1997; Lederman, 2019). Especially, scientific literacy is widely recognized and incorporated in the global science curricula (Allchin, Andersen & Nielsen, 2014, Lederman et al, 2014). They also agree that teaching needs to be carried out in an explicit and reflective manner. In the present study, we prefer to use the term “Nature of Scientific Knowledge” (NOSK) to refer to the characteristics of scientific knowledge that are inherently derived from the manner in which it is produced (Scientific Inquiry). In this context, we accept the framework proposed by Lederman (Lederman et al, 2014, Lederman 2019). The main reasons for this decision is a) the great volume of implementation studies in various countries and populations (students, pre-service teachers, in-service teachers) and the extensive availability of highly validated and reliable assessment tools (VNOS questionnaires). This allows us to compare our results with other studies and facilitates b) the design and implementation of a PD-program for science teachers with NOSK aspects for the continuation of the project. The Lederman group was chosen because their thirty-year research experience makes them probably the most cited and influential researchers in this field (Matthews, 2012). According to our estimations, their suggestions are the easiest to adopt in Greece, in comparison to other frameworks.

The NOSK aspects are (Lederman et al 2014):

(A1) Scientific knowledge is empirical

Scientific knowledge is based on /derives from empirical data.

(A2) Observations and inferences are different

“Observations” are descriptions of natural phenomena that are directly accessible to the senses, or expansion of them. They are subject to limitations of existing equipment and the dominant theory, but observers usually reach consensus on what they see, hear, feel, etc. “Inferences” are the explanation of observations and the same observations could lead to different inferences, according to the background of researchers.

(A3) Scientific knowledge is creative

Scientific research – contrary to common belief – is not a rational and orderly process. Creativity and imagination is required in every part of the research: in design, data collection and creation of interpretations; it is similar to the creative process of an artistic work.

(A4) Even though objectivity is the goal, subjectivity within scientists is unavoidable

All scientists are susceptible at every stage – interpretation of results, observations and research design – to their own personal beliefs, prior knowledge, training, expectations, etc. Therefore, even though objectivity has always been the goal in Science (through the use of standard scales and precision in measurement), subjectivity is unavoidable. Also, Science is a social activity. Scientists are interacting with each other through scientific publications; their reviews and the continuous testing are meant to enhance the objectivity of their methods.

(A5) Scientific knowledge is durable, but subject to change in the light of new evidence

Scientific knowledge is reliable and durable, albeit relative and uncertain. It is subject to change every time new evidence comes to light due to the evolution of technology or new interpretations of older evidence.

(A6) Socio-cultural embeddedness of Science

Science is a human endeavor that affects and is affected by all societal, cultural, philosophical, religious, political and economic factors.

(A7) Scientific Laws and Theories are different types of knowledge

Laws are generalized descriptions of relationships among observable phenomena and are based on many observations. They describe what happens in the (usually idealized) natural world, but never explain why. Those inferred explanations are provided by Theories.

1.3 CHAT Framework

Cultural-Historical Activity Theory (CHAT) is a “cross-disciplinary framework to study how humans purposefully transform natural and social reality, including themselves, as an ongoing culturally and historically situated process (Roth et al, 2012). Vygotsky introduced CHAT and Leontiev (1978) expanded on it, with his perception on a collective system of human activity. Engeström (1987) presented Leontiev’s views using the triangle for human activity systems (see Figure 1).

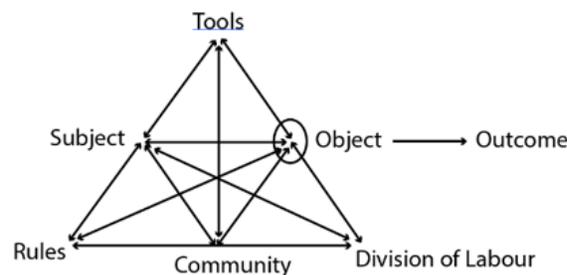


Figure 1. The Structure of a Human Activity System

The relations between the Subject (usually people, lately they are also corporations, moving towards a desired goal) and the Object (the activity goals) are mediated through tools, the community, the rules and division of labor. Tools/artefacts are culturally-produced means that subjects use to perform the activity. They may be material, like a magnet, a telescope, or mental, like language. Community refers to all the participants who share the same object that shapes and directs individual actions to the collective activity. Division of labor refers to the way subjects, as members of the community, divide their responsibilities during an activity. The triangle of the activity system refers both to the horizontal actions and interrelations between the members of the community and the vertical distribution of power, resources and relative societal/professional status. The nodes of an activity system are not static and isolated to each other, but they are dynamically connected; the system is regarded as a unity (Hasan & Kazlauskas, 2014; Kolokouri & Plakitsi, 2016; Barma, 2011; Plakitsi, 2013; Kornelaki & Plakitsi, 2018; Igira & Gregory, 2009).

In the present study, we use Engeström’s model because it fits to the needs of our research, indicating the factors that need to be studied in order to answer our research question. The results of the educational activity system are more complex due to its interaction with other activity systems (Engeström, 2001, Engeström, 2009; Kornelaki & Plakitsi, 2018; Plakitsi, 2013). The entire CHAT framework is presented in another paper (Koumara & Plakitsi, 2019) and will be applied for the continuation of this project.

2. Method

Education, in general, and more specifically in Science, is a complex activity system with various parameters. Its complexity could be illustrated using CHAT (Kolokouri & Plakitsi, 2016), as shown in Figure 2.

In order to evaluate the level of integration of NOSK aspects in the teaching of Greek secondary school science classes, all components of the educational system recorded in Figure 2 are studied, apart from the educational policy makers and textbook authors. The research focuses on science classes from 7th Grade until 11th Grade. 12th Grade is not included in our research, because it is a preparatory year for university entrance exams and students specialize in particular subjects; as a result, not all students follow Science courses. For the purposes of this research, we examine

what all students are taught in Secondary Education.

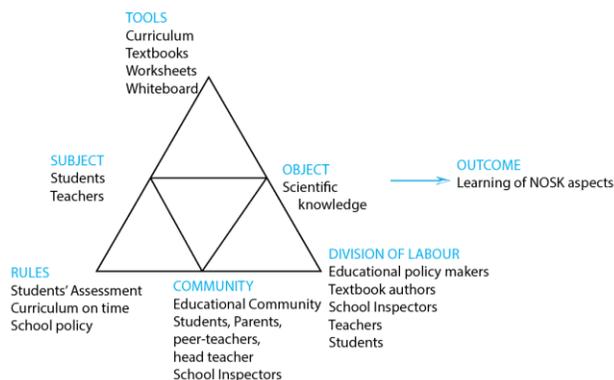


Figure 2. Activity System of Science Education in Secondary Schools in Greece

The researcher, the Subject in their own activity system (see Figure 3), in order to assess:

1. Whether the teaching of NOSK aspects was suggested in science curricula and included in textbooks (tools in Figure 2), studied 1) the science curricula, and 2a) all subject textbooks, and also studied and classified 2b) the recommended textbook exercises.
2. Whether science teachers (subjects in Figure 2) were aware of NOSK aspects, 1) asked 50 science teachers from Thessaloniki, Greece to complete the VNOS-D+ questionnaire (Lederman et al. 2002) and 2) interviewed 10 of them.
3. Whether science teachers assessed (rules in Figure 2) NOSK aspects in the final exams, the researcher analyzed the final exam content.
4. Whether school inspectors (members of the community in Figure 2) knew if NOSK aspects were taught in science classes, they interviewed 7 School Inspectors from all regions of Greece.
5. Whether high-school graduates¹ (subjects in Figure 2) were taught and were aware of NOSK aspects, the researcher 1) asked 149 students to complete the VNOS-D+ questionnaire (Lederman et al. 2002) and 2) interviewed 30 of them.

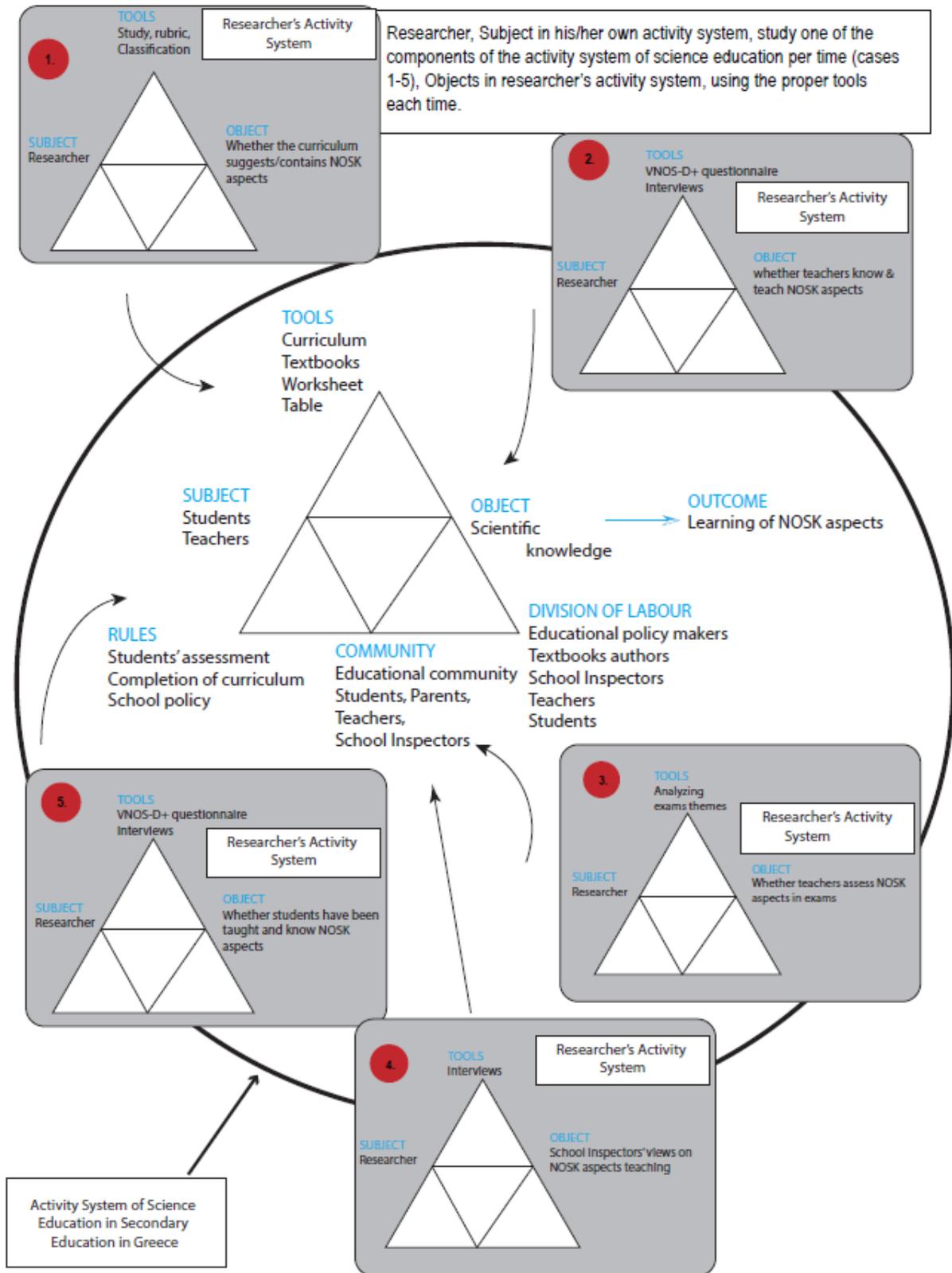


Figure 1. Research on the Activity System of Science Education in Secondary Education in Greece

3. Results

3.1 Curriculum

Curricula for all Science subjects in Lower Secondary School, apart from 7th Grade Physics, were published in 2003 and used in the school year 2007-08. Regarding 7th Grade Physics, the curriculum was published in 2013 and used in the school year 2013-14, when the subject was introduced for the first time.

The general part of all curricula is oriented towards scientific literacy, but neither the NOSK term (or any similar one), nor any of its aspects are mentioned.

The special part of curricula includes primarily cognitive goals and secondarily goals for inquiry skills. NOSK is not mentioned explicitly. However, if teachers are aware of NOSK aspects and wish to integrate them in their lessons, the curriculum allows them to do so. It is noted that a new Physics curriculum (Plakitsi et al., 2011) included NOSK, but, even though it was successfully piloted in 100 schools, it was not generally applied and did not lead to the writing of new textbooks.

Regarding Higher Secondary Education, the textbook content was based on the Science Curricula published in 1999. In recent years, there have been many changes, mainly the removal of specific chapters and rearrangements in the curriculum, i.e. some chapters that were originally written for one grade are taught in another. In other words, new curricula have been published, as modified versions of the 1999 ones, and no new books have been written.

In Science Curricula of Higher Secondary Education, no NOSK aspects are included, nor the term itself. However, there are objectives upon inquiry and references to everyday life which allow science teachers to include NOSK aspects in their lessons, if they are aware of them and they wish to do so.

3.2 Textbooks

3.2.1 Content of Textbooks

It is internationally recorded that Curricula are regularly substituted by textbooks, which control what is taking place inside the classroom (Abd-El-Khalick et al, 2017). Teachers usually rely on textbooks for daily instructions and use of their recommended student exercises, either for use in the classroom (75-90% of teachers) or for homework (90% of teachers). This happens either due to lack of time, or due to lack of knowledge², or because there is only one official textbook (DiGiuseppe, 2014; McDonald & Abd-El-Khalick, 2017a).

Greece has only one official textbook for each subject, which is compulsory in all private and public schools in each grade. Teachers traditionally work with the textbook and not the curriculum. The content of textbooks and their proposed exercises play an important role in the teaching of science and consequently in learning, since they are extensively used in the daily teaching process determining to a great extent the final learning outcome (Anagnostopoulou, 2015, p.175).

In order to assess the reference of NOSK aspects in textbooks, a rubric, adjusted from Abd-El-Khalick et al (2017), is used. The scoring of each NOSK aspect is based on the criteria described in Table 1:

Table 1. Criteria for Textbooks Scoring

Score	Representation of each NOSK aspect	Grade	Representation of each NOSK aspect
3	Explicit, informed, consistent	-1	Implicit, naive
2	Explicit, partially informed	-2	Explicit, naive
1	Implicit, informed, consistent	-3	Explicit, naïve, non-consistent
0	Not addressed		

An initial study on textbooks, prior to scoring with the use of the rubric, indicated that the reference of NOSK aspects is limited. Phrases like “nature of scientific knowledge” and “this is how scientists think/work”, and other similar ones, were missing from textbooks. Direct references on NOSK aspects were few. Therefore, the explicit representation score would be near 0 for all textbooks. However, this will not allow us to identify the actual differences between textbooks, for example, the significant differences between 8th Grade Chemistry and Biology.

We considered the possibility of reaching conclusions regarding the reference of some NOSK aspects examining the vocabulary used in textbooks, for instance, the use of verbs such as “observe”, “conclude”, etc. Consequently, we decided to be more lenient regarding the explicit/implicit representation of these aspects. Therefore:

- The representation of a NOSK aspect was categorized as Explicit/Implicit; this was determined by the content of written information that teachers would receive and whether this allowed them to make reference to these aspects or not.
- The representation of a NOSK aspect was categorized as Informed/Partially Informed/Naïve based on its reference in school textbooks. If an aspect was addressed correctly it was categorized as “informed”; if it was addressed to the correct direction but its formulation was problematic, it was categorized as “partially informed”; and, if it was addressed incorrectly and was misleading, it was deemed as “naïve”. The “correct” and “incorrect” directions are defined by the international literature on NOSK aspects.
- The content was assessed based on the consistency of the representation of each NOSK aspect in the entire textbook.

The rubric is limited since scoring does not include the position of each recorded aspect. For example, introductions and appendixes are not usually read by students, contrary to the main body of the text.

Results of the study are summarized in Table 2:

Table 2. Scoring the Science Textbooks Using the Rubric

Grade NOSK aspect	Physics					Chemistry				Biology		
	7 th	8 th	9 th	10 th	11 th	8 th	9 th	10 th	11 th	7 th	8 th -9 th	10 th
A1	2	3	3	3	3	3	1	2	2	1	0	0
A2	2	2	2	1	1	2	1	1	1	0	1	0
A3	0	0	0	0	0	1	1	1	0	1	0	0
A4	1	0	0	0	1	2	1	2	0	0	0	0
A5	1	-1	-1	2	2	2	1	3	2	1	1	0
A6	1	0	0	0	0	3	2	0	2	0	0	0
A7	0	-3	-1	0	0	0	0	-2	0	0	0	0
Total	7	1	3	6	7	13	7	7	7	3	2	0

The conclusions from Table 2 are:

- 1) Apart from Biology textbooks, the rest of them provide the opportunity to teachers to refer to NOSK aspects, if they are aware of them and should they wish to do so.
- 2) The empirical aspect in Lower and Higher Secondary School textbooks, the difference between observations and inferences in the Lower Secondary School textbooks and the tentative aspect in Higher Secondary School textbooks have the highest scores. The lowest scores are on the creative thinking aspect both in Lower and Higher Secondary School, the social and cultural embeddedness for Higher Secondary School, while the difference between theories and laws receives negative scores.
- 3) Regarding Biology, our results are in agreement with Kampourakis (2017), who claims that both textbooks and the Curriculum provide opportunities – some very implicitly though – for integration in teaching to those who are aware of NOSK aspects. Kampourakis raises the question which will also preoccupy us later, whether teachers are actually aware of NOSK aspects.

However, despite their scores, the total absence of the term “nature of scientific knowledge” is highlighted in textbooks, whereas when NOSK aspects are mentioned, these appear exclusively in chapter introductions or appendixes, which are not usually assessed. As a result, it is highly likely that these parts are not being taught.

3.2.2 Student Exercises in Textbooks

Most of the suggested exercises for students in textbooks test cognitive knowledge and almost none of them is related to NOSK aspects. Specifically, only 15 out of 2261 (0.7%) questions/exercises were related to aspect A2 (observations and inferences) but the difference between observations and inferences was not clear. Regarding the suggested projects, which could also be used for assessment, around half of them in each subject could be related to NOSK aspects. However, their formulation is very generic, and they could incorporate NOSK aspects only if the teacher wishes to provide that direction in their lessons. Another study concluded that the recommended exercises in Lower Secondary School textbooks test cognitive knowledge by 92.7% and only a 7.3% assesses the knowledge of science, part of which is related to NOSK (Anagnostopoulou, 2015, p.270).

3.3 Teachers

3.3.1 VNOS-D+ Questionnaire

Apart from the Curricula and the textbook content, teachers can interpret instructions as they wish. Therefore, an interesting question is whether teachers are aware of NOSK aspects (Lederman & Lederman, 2014). To study the above question, in April 2018, 50 science teachers were asked to complete the internationally validated VNOS-D+ questionnaire (Lederman et al, 2002).

VNOS-D+ questionnaire is an acronym for “Views of Nature of Science” and consists of 10 open-ended questions, which target directly or indirectly the knowledge of one or more NOSK aspects. “Directly” means that the answer on a question is linked to an aspect, whereas “indirectly” means that the answer on a question may or may not be linked to that aspect (Lederman et al, 2014). Question 4 has four sub-questions.

According to the guidelines provided by the creators of the questionnaire³, NOSK aspects are detected from the questions as presented in Table 3:

Table 3. Questions and Targeted NOSK Aspects

Targeted NOSK aspects	Questions
Empirical	4d and 2 indirectly
Difference between observations and inferences	4a, 4b, 4c, 5, 6 and 3 indirectly
Based on creative thinking	7 and 2 indirectly
Subjective/Objective	4c, 7 and 1, 2, 3 indirectly
Tentative	3, 4b, 5, 9 and 1 indirectly
Social and cultural embeddedness	10
Difference between theories and laws	8

The sample consists of 50 science teachers in public and private schools in the region of Thessaloniki, Greece, of whom 18 were men and 32 women; there were 32 physicists, 3 geologists, 6 biologists and 9 chemists. All but one had permanent placements, and were aged between 35 and 60, with an average around 50. Since their placement in Thessaloniki was permanent, they had either many years of teaching experience or high academic qualifications (Master’s or PhD degrees). Science teachers would participate voluntarily in a PD-program on NOSK taking evening classes (see paragraph 4) and their answers were the pre-test. Teachers who traditionally attend those PD-programs are motivated to learn and improve their teaching, as they do not receive certificates of attendance [which would otherwise be useful for promotions or similar use].

Questionnaires were scored twice within four months by the first author, after being trained by the creators of the questionnaire. At the same time, she trained two other researchers enabling them also to score. The three researchers attributed the final scores in unison, reaching consensus of agreement at 91%.

Each question was scored in 4 categories:

- N-Naïve: when the answer indicated that the teacher had a misrepresented view on the specific NOSK aspect
- M-Mixed: when the answer indicated that the teacher knew some elements on the specific NOSK aspect, but not sufficiently
- I-Informed: when the answer indicated that the teacher had an informed (correct) view about the specific NOSK aspect
- I⁺-Super Informed: when the given answer was well-documented, well-formulated and could be given as an excellent correct example for the specific NOSK aspect in question
- U-Unanswered: for questions that teachers did not answer

The difference between informed (I) and super-informed (I⁺) responses is defined by the vocabulary used (for example, the use of certain keywords), whether an example is mentioned or if there is a more analytical description in I⁺ responses in comparison to I. Both categories include correct responses.

To score the responses, it was important to create the “profile” of each participant for every NOSK aspect. To enhance their “profile”, the first author interviewed 20% of the participants, as instructed by the creators of the questionnaire. Interviews took place after the researcher scored the questionnaires for the first time. At each interview, the interviewee answered each question of the VNOS-D+ orally. If the researcher discovered a mismatch

between what they meant and what they had written (or between what the researcher thought they meant) she changed her score and noted it down for the other researchers.

The overall results are presented in Figure 4 and Table 4:

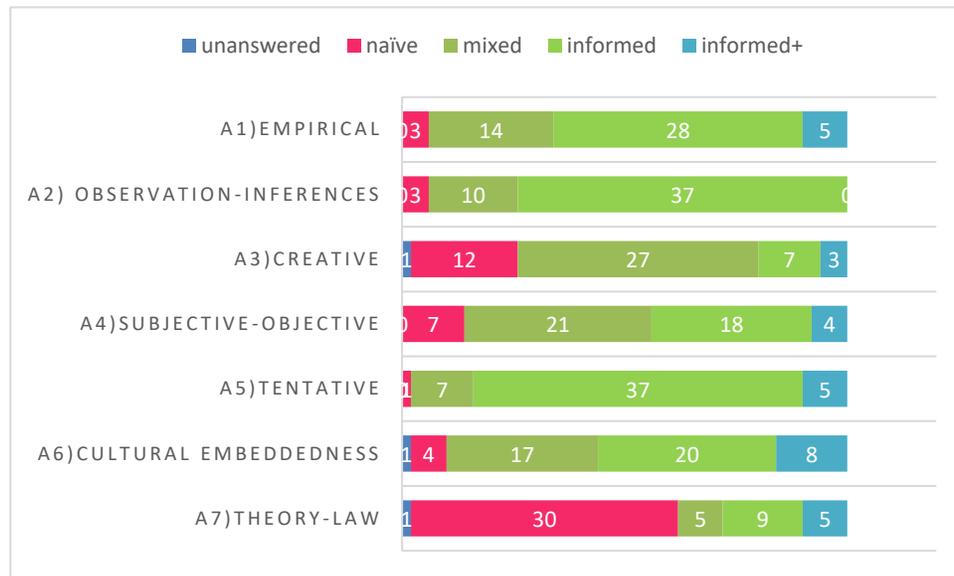


Figure 4. Results of VNOS-D+ Questionnaire from Teachers

Table 4. Results of VNOS Questionnaire from Teachers

NOSK aspects	I ⁺	I	M	N	U
1. empirical	5	28	14	3	0
2. difference between observations and inferences	0	37	10	3	0
3. is a product of creative thinking	3	7	27	12	1
4. subjective/objective	4	18	21	7	0
5. tentative	5	37	7	1	0
6. cultural and social embeddedness	8	20	17	4	1
7. difference between theories and laws	5	9	5	30	1

For our statistical estimations, we used confidence intervals to ensure, at a percentage defined at the beginning, that we have an interval within the range of the real value of the parameter we are interested in. The 95% confidence interval of the real range of teachers who give super informed and informed answers is provided by the relation (Kounias, Kolyva, Bagiatis & Bora, 2009, p. 141-142):

$$p - Z_{\frac{\alpha}{2}} \sqrt{\frac{p(1-p)}{n}} < p < p + Z_{\frac{\alpha}{2}} \sqrt{\frac{p(1-p)}{n}} \tag{1}$$

where $p = \frac{\text{Number of people from the sample who give the desired answer}}{\text{number of people from the sample}}$,

n is the number of people from the sample

the desired confidence interval is (95%), $Z(\alpha/2) = 1,96$.

The sample results are presented in Table 5:

Table 5. Statistical Analysis of Teachers' VNOS Results for I/I+ Answers

	NOSK aspects	Range of values for 95% confidence interval
1.	empirical	66 ± 13,1 (52,9 – 79,1)
2.	differences between observations and inferences	74 ± 12,2 (61,8 – 86,2)
3.	creative	20 ± 11,1 (8,9 – 31,1)
4.	subjectivity/objectivity	44 ± 13,8 (30,2 – 57,8)
5.	tentative	84 ± 10,2 (73,8 – 94,2)
6.	social and cultural embeddedness	56 ± 13,8 (42,2 – 69,8)
7.	difference between theories and laws	28 ± 12,4 (15,6 - 40,4)

Table 5 reveals three groups: the first group contains aspects 1, 2 and 5 and the second contains aspects 3 and 7. These two groups are statistically different – there is no overlap between them. The third group contains aspects 4 and 6 and there is a small overlap with the first and the second group.

The conclusions from Figure 4 and Tables 4 and 5 are:

- More than 2/3 of the teachers are well aware (I/I+) of aspects 1, 2 and 5: the empirical aspect (33/50), the difference between observations and inferences (37/50), and the tentative aspect (42/50).
- Almost half of the teachers are well aware of the subjective aspect (22/50) and the aspect about social and cultural embeddedness (28/50). Teachers' mixed views are higher for these aspects (21/50 and 17/50 respectively).
- The biggest issues seem to be a) on the difference between theories and laws, where only 14/50 are aware of it and 30/50 teachers have naïve views, the most common being that Law is superior to Theory, something like a proven theory and b) that scientific knowledge is a product of creative thinking, since only 10/50 know of it. More than half (27/50) have mixed views.

It is noted that teachers who completed the questionnaire are superior to the average Greek science teacher, and consequently the results cannot be generalized for the whole population. However, they are still important, since they clearly demonstrate that even if those teachers who care to improve their teaching performance find difficulty in answering this questionnaire, then average teachers, with traditionally basic lessons, would provide worse responses (this is an inductive conclusion, there is no data from random sample).

3.3.2 Interviews with Teachers

Semi-constructed interviews took place with ten of the above teachers. The topics for discussion were the questions of the VNOS-D+ questionnaire, which NOSK aspects they were aware of and which they used in their lessons, each subject's relative chapters and some general school life questions. The interviews took place in May 2018 and additionally in October/November 2018.

Six out of ten teachers claimed that they had never heard of NOSK aspects before and had not thought of what these might be – or they might have heard the term but did not remember it. Four teachers who claimed to have previously heard of it, had either completed a PhD in Science Education (2 teachers) or attended PD-programs and conferences (2 teachers). They had no recollection of having been taught about it during their studies, definitely not explicitly.

Even though they did not know the collected NOSK aspects, they claimed that they teach intuitively some of them: all of them teach that scientific knowledge is empirically-based, through which scientists come to inferences, but they do not stress the difference between observations and inferences. They also teach the tentativeness of scientific knowledge. Two teachers claimed that they partially teach the subjectivity and creativity in scientific knowledge. Three teachers claimed that they teach the interactions between science and society. Regarding the difference between theories and laws, only one teacher knew of it and claimed to teach it. They all answered that they do not teach NOSK aspects explicitly and reflectively and they never assess students' knowledge on them.

All teachers claimed that the educational system does not incorporate NOSK in its lessons, but some of its elements may be included, although not taught, in textbooks, mostly in introductions and appendixes, which students traditionally do not read.

Their biggest teaching anxiety was to complete the curriculum in time and prepare their students for the exams, while avoid having problems with principals and parents. As they mentioned, "success in teaching is defined by how well you have prepared your students for exams and how successful they were."

3.4 Students' Assessment by Teachers in Relation to NOSK Aspects

Students' studying (and, in general, trainees of every age) is mainly determined by the assessment type and the characteristics of the exams they take. What they will finally learn is not determined as much by the content of textbooks but by the exam type. The evaluation requirements affect students' studying strategies (Anagnostopoulou, 2015, p.177-178; Green & Oates, 2009; Arons, 1990, p.365-366). To study whether students are assessed in their NOSK knowledge, we analyzed the topics of final exams.

For Lower Secondary School, Anagnostopoulou (2015) concluded that 4233 out of 4288 exam topics (1476 Physics, 1413 Chemistry, 1359 Biology), at a percentage of 99.6%, assessed the body of knowledge. Only 15 exam topics, a percentage of 0.4%, assess the knowledge "of science", where scientific research is included, part of which might be the knowledge of NOSK (p. 284). As for Higher Secondary School, almost no topic was related to NOSK – apart from 3 out of 1630 – as included in the Test Bank created by the Ministry of Education.

3.5 Interviews with School Inspectors

Seven Science School Inspectors from all regions of Greece were interviewed during January – June 2017 either face-to-face or via telephone. Four of them held a PhD in Science Education and one was a member of the authors' team for a textbook. The interview was a semi-constructed discussion on NOSK aspects and school life in the Secondary Education. Their responses did not differ significantly from teachers' opinions (see paragraph 3.2.2); however they emphasized the limited time for teaching and preparation for National Exams (which students take to enter university), a restriction that forces most teachers to prioritize solving complex mathematical exercises. School Inspectors claimed that only 15% of teachers use inquiry-based learning and around 2-5% of them teach most NOSK aspects regularly and explicitly⁴. They estimated that in most cases teaching contains the empirical and the tentative aspects, the latter as a path towards the truth.

In conclusion, School Inspectors argued that NOSK is not an objective in Science Education and it is not included in everyday teaching. They also claimed that most teachers are not aware of NOSK and are not being taught how to integrate it into their lessons.

3.6 Students

The final recipients of all the above are the students. Consequently, what graduates know about NOSK is another source of information, whether NOSK is being taught – and, most importantly, if it is being learned – in Secondary School. Our research continues with the VNOS-D+ questionnaires and the interviews with graduate students.

3.6.1 VNOS-D+ Questionnaire

The sample consists of 149 first-year students in the School of Education of the Aristotle University of Thessaloniki. University students were chosen, instead of 12th Grade students, as a means to obtain more objective results for the total student population. Specifically, university students in a big city come from all over Greece, from urban, rural and island areas, they have attended schools with different science teachers, and they potentially have received different stimuli. Furthermore, we considered that first-year graduates who attended university for only one month are not adjusted to university life yet and, as a result, they maintain the same mindset and have similar characteristics with high-school students. We conducted 30 interviews (20% of the sample), where we discussed the VNOS questionnaire and other general questions. The research took place in November 2017.

Total results from students' answers for each category are presented in Figure 5 and Table 6 as follows:

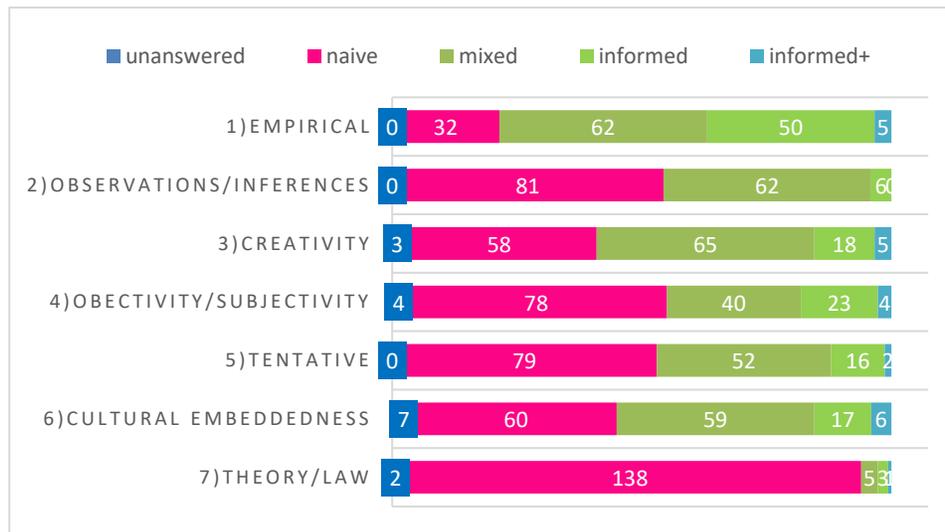


Figure 5. Results of VNOS-D+ Questionnaire from Students for Each NOSK Aspect

Table 6. Results of VNOS Questionnaire from Students

NOSK aspects	I+	I	M	N	U
1. empirical	5	50	62	32	0
2. difference between observations and inferences	0	6	62	81	0
3. is a product of creative thinking	5	18	65	58	3
4. subjective/objective	4	23	40	78	4
5. tentative	2	16	52	79	0
6. social and cultural embeddedness	6	17	59	60	7
7. difference between theories and laws	1	3	5	138	2

Table 7 results from the data of Table 6. On its second column there is the number of students that give informed and super informed answers and on the third column is the 95% confidence interval (Kounias et al, 2009, p.141-142) where the value of the wider population of Greek graduate students can be found.

Table 7. Statistical Analysis from Students' VNOS Results for I/I+ Answers

NOSK aspects	Number of I/I+ answers	Range of values for 95% confidence interval
1. Empirical	55	36,9±7,7 29,2 – 44,9
2. difference between observations and inferences	6	4,0±3,2 0,8 – 7,2
3. creative	23	15,4±5,8 9,6 – 21,2
4. subjective/objective	27	18,1±6,2 11,9 – 24,3
5. tentative	18	12,1±5,1 7,0 – 17,2
6. social and cultural embeddedness	23	15,4 ±5,8 9,6 – 21,2
7. difference between theories and laws	4 ⁵	Lower than 3.4±2,9

The conclusions which arise from Table 7 are:

- Students' knowledge on the empirical aspect is statistically distinguished, since 30-40% of students seem to be aware of it.
- Students' knowledge on the tentative and subjective aspects, the aspect about creative thinking and the social and cultural embeddedness do not differ significantly. Students' knowledge on all these aspects is around 10-20%.
- The difference between observations and inferences and between Theories and Laws seem not to be understood by students, even though the former is included in textbooks and teachers seem to be aware of it. This will be further

discussed in paragraph 4.

3.6.2 Interviews with Students

After having scored the answers on VNOS-D+ questionnaires for the first time, we interviewed 30 students (20% of the total sample, as guided by the creators of the questionnaire), during December 2017 – January 2018. Each interview consisted of three parts: a) every student was asked to answer again all the VNOS questions orally and explain what they wrote. The results of this part of the interviews formed the final scoring of the questionnaire. b) Students were asked to answer whether they were taught about NOSK during their school years and whether they were assessed on that. They were also asked to comment on c) various general matters about their school life and education, which were used in a different research stage.

All students claimed that they had never heard the term “nature of scientific knowledge” before, or at least they did not remember it. When asked whether their daily lessons included NOSK aspects (in order to understand the question, they were given a sheet of paper with the NOSK aspects and discussed them briefly with the researcher), 10 students answered that they had never referred to any of them in any subject, whereas 15 students remembered having heard that knowledge is empirically-based (the empirical aspect) and has an inferential character, but they were not aware of the difference between observations and inferences. Three students claimed that in their Physics classes there were extensive references on the evolution of scientific ideas. They discussed that scientific knowledge is subject to change over time (the tentative aspect), but it seemed as if they only referred to the past. Also, students had the impression that these references were only for their own information and were not part of the actual lesson. Finally, one student participated in an eTwinning program regarding “how science works”, where most NOSK aspects were presented, although not in an organized and explicit manner.

To sum up, the questionnaires and interviews with students indicated that students were not taught about the NOSK aspects in an organized manner and any knowledge originates from implicit teaching.

4. Discussion

In conclusion, the Greek educational system is not oriented towards the integration of NOSK aspects in science teaching. The curriculum objectives do not contain it and textbooks, which tend to follow the curriculum, include only a few aspects, mainly the empirical and, at a smaller degree, the tentative one, but without referring to them by their names. Also, the term “nature of scientific knowledge” or any similar term is not used. Teachers usually follow the textbooks and do not mention NOSK in their lessons. However, even when they do, they do not assess them. School inspectors, with a wider understanding of what is happening in schools, regard that NOSK is not a goal for Science Education and, generally, it is not included in daily lesson planning. This is consistent with the observation that most students have naïve views on NOSK aspects. Regarding the difference between observations and inferences, interestingly, even though it is clearly mentioned in textbooks, teachers are the only ones who are aware of it. This indicates that probably teaching is not explicit and reflective, as suggested in the literature (Lederman & Lederman, 2014), and students are not becoming aware of it.

Schematically, all of the above are illustrated in Figure 6, using the sub-triangles of CHAT (Plakitsi, 2013):

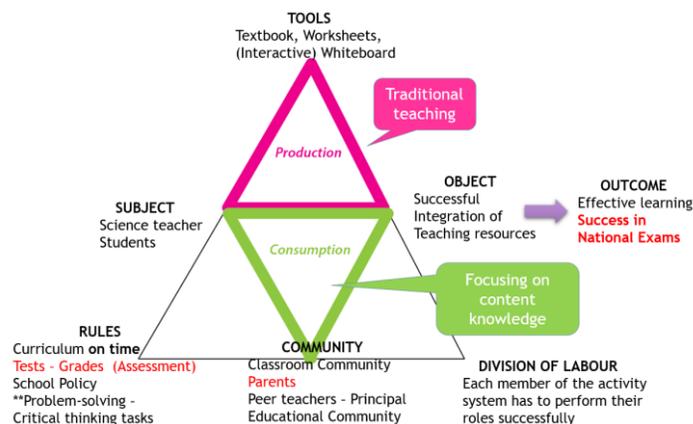


Figure 6. A typical Science Class Activity System in Greek Secondary Education, as Resulting from Our Research

Contradictions arisen from students, parents and principals who insist that teaching should lead to success in all National exams. However, at the same time, students feel that what they are being taught does not reflect their interests.

In relation to the embeddedness of NOSK aspects, the sub-triangle of production is interesting, since teachers who wish to integrate NOSK in their teaching must design new lesson plans that demand extra time and effort. The sub-triangle of consumption is also interesting, since the same teachers need to persuade the community (parents, students, principals and peer teachers) that NOSK teaching is in favor of the evolutionary learning route of students, in order to be accepted.

Other studies from Greece (e.g. Kampourakis, 2017) and abroad, draw similar conclusions, validating our research. For instance, in Lebanon (El-Takach & Yakoubian, 2020) NOSK is not included in the curriculum and teachers have no formal pedagogical training. Regarding books, Abd-El-Khalick et al (2017) claim that NOSK aspects are included in the introduction chapters of most books. Lederman and Lederman (2014) in their review article, claim that a plethora of studies conclude that both teachers and students have naïve views on most NOSK aspects and that NOSK teaching, when it takes place, is not explicit and reflective. The case of Greece is not disheartening; on the contrary, it has many similarities with other countries.

5. Conclusion

In this study it was presented the multi-faceted method that we used to study all the components of the Greek Secondary Education system in relation to NOSK. The fact that all tools gave the same results and agreed with each other, is a factor that validates our research. Other factors are the agreement with other Greek studies, that examine specific components of the Greek Secondary Education, plus the consistency with international studies.

Furthermore, the particularities of the Greek educational system were brought out, which are useful for the whole project. Following up in the wider project, a PD-program for science teachers can be organized which would take into consideration: i) the results of the present research, ii) the literature of NOSK and iii) the CHAT framework. The objective of the program would be the training of teachers on a) NOSK aspects, b) possible teaching approaches and on c) ways of being incorporated in the present curriculum, through the design of competent lesson plans.

In the future, we consider that the Greek government could organize a wider project, similar to the Turkish BIDOMEG one (see Introduction). The project could start with a quantitative record, similar to the one presented here, for a wider and more representative number of teachers and students. The method of the present study could be used as a model.

Notes

1. First-year students in their first month of university were regarded as graduate students, because they come from all regions of Greece and have followed all specializations.
2. In some countries, teachers have no subject-specific university degrees and may feel unfamiliar with the subject they are teaching (McDonald & Abd-El-Khalick, 2017a). This is not the case with Greece.
3. <https://www.physport.org/assessments/assessment.cfm?A=VNOS>
4. School inspectors mean that this is the rate of teachers nationally that are aware of NOSK aspects and teach them.
5. The relation that gives the confidence interval is valid if $np \geq 5$, so it is not valid on this case. But, if 5 students gave this answer instead of 4, then $np \geq 5$, it would be valid and the respective interval would be 3.4 ± 2.9 , which means 0.5 – 6.3. So, in our case it is a bit smaller, which is obvious enough.

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