doi: 10.26529/cepsj.1309

Nature of Science in Greek Secondary School Biology Textbooks

Nausica Kapsala*[1], Apostolia Galani[2] and Evangelia Mavrikaki[2]

The nature of science describes what science is, how it works, and its interactions with society under the perspectives of philosophy, history, sociology, and psychology of science. Understanding it is an essential aspect of scientific literacy. Given the critical role that school textbooks hold, considering what is taught and how it is taught in schools, we find the presence of the nature of science in school science textbooks to be significant. In this research paper, all Greek biology textbooks of lower secondary education are analysed to evaluate whether principal elements of the nature of science can be found in them. The whole array of educational resources available (textbooks, workbooks, lab guides, teachers' books) was analysed as well as the corresponding official biology curricula. Content analysis was the method of choice, and the 'meaning unit' was the unit of analysis. We found that most of the nature of science references in the material that students were taught in 2021/22 was implicit and not especially designed by the curriculum. Some nature of science aspects were more commonly found (e.g., evidence is vital in science) than others (e.g., science has limits). The most opportunities for the nature of science to be introduced were found in history of science vignettes, laboratory activities, and some optional inquiry activities. However, without a structured design from the curriculum, it is the teachers' responsibility to design and facilitate nature of science instruction (or not). We conclude that lacking explicit references, the nature of science falls into the hidden curriculum and becomes falsely depicted, enforcing a positivist image of science.

Keywords: biology textbooks, Greece, nature of science, secondary education

1 *Corresponding Author. Second Lyceum of Elefsina and Faculty of Primary Education of the National and Kapodistrian University of Athens, Greece; nkapsala@gmail.com.
2 National and Kapodistrian University of Athens, Greece.

Narava znanosti v grških srednješolskih bioloških učbenikih

Nausica Kapsala, Apostolia Galani in Evangelia Mavrikaki

Narava znanosti opisuje, kaj je znanost, kako deluje in kakšni so njeni stiki z družbo z vidikov filozofije, zgodovine, sociologije in psihologije znanosti. Razumevanje je temeljni vidik znanstvene pismenosti. Upoštevajoč pomembno vlogo, ki jo imajo šolski učbeniki glede tega, kaj in kako je poučevano v šolah, ugotavljamo, da je prisotnost narave znanosti v šolskih naravoslovnih učbenikih bistvena. V tem prispevku so analizirani vsi učbeniki za biologijo v osnovni šoli v Grčiji, in sicer z namenom ovrednotenja, ali je v njih mogoče najti osnovne elemente, povezane z naravo znanosti. Preiskana je bila celotna zbirka razpoložljivih učnih gradiv (npr. učbeniki, delovni zvezki, laboratorijski vodniki, priročniki za učitelje) pa tudi pripadajoč uradni učni načrt za biologijo. Izbrana metoda je bila vsebinska analiza, pri čemer je kot enota analize služila »pomenska enota«. Ugotovili smo, da je večina sklicev na naravo znanosti v gradivih, s pomočjo katerih so poučevali v letih 2021–2022, implicitna. Nekateri vidiki narave znanosti so bili pogosteje najdeni (npr. dokazi so nujni v znanosti) kot drugi (npr. znanost ima omejitve). Največ priložnosti, ob katerih je bila narava znanosti vpeljana, je bilo vezanih na vinjete zgodovine znanosti, laboratorijske naloge in na nekatere izbirne poizvedovalne aktivnosti. Brez strukturiranega načrta, izhajajočega iz učnega načrta, je odgovornost učiteljev, da načrtujejo in vpeljejo v pouk tudi vsebine narave znanosti (ali ne vpeljejo). Sklepamo, da zaradi primanjkljaja neposrednih sklicev narava znanosti pristane znotraj skritega kurikuluma in je napačno prikazana, vsiljujoča pozitivno sliko znanosti.

Ključne besede: učbeniki za biologijo, Grčija, narava znanosti, sekundarno izobraževanje

Introduction

Textbooks hold an influential role in education. They constitute an essential source for students to obtain knowledge; therefore, inadequate and inconsistent science knowledge presented in the textbooks can affect students' conceptions. According to Dimopoulos and Karamanidou (2013, in Slapničar, 2014), science is unfortunately mispresented as static and absolute knowledge in school textbooks. This provides students with a false view of what science is and how it works.

The Nature of Science (NOS) is the field that describes what science is, how it works, and its interactions with society under the perspectives of the philosophy, history, sociology, and psychology of science (McComas, 2020). Understanding NOS affects how people conceive scientific information and how much they trust science and its exhortations (Song et al., 2021). Citizens' knowledge of the NOS positively impacts the acceptance of evolution, Global Climate Change (GCC), and vaccination, regardless of political ideology and religiosity (Weisberg et al., 2020).

Understanding NOS constitutes 'a critical component of scientific literacy that enhances students' understanding of science concepts and enables them to make informed decisions about scientifically based personal and societal issues' (NSTA Board of Directors, 2020, p. 1), making the importance of its inclusion in the school curriculum indubitable. However, the incorporation of NOS into school practice is challenging, as textbooks mostly focus on traditional science content (McDonald & Abd-El-Khalick, 2017), and as a result, teachers do not value the NOS content the same as the 'traditional' science content and tend to ignore it (Haagen-Schützenhöfer & Joham, 2018). Even when teachers attempt to teach NOS aspects, they encounter difficulties, mainly due to lack of time, lack of proper instructional material, as well as due to their own misunderstandings (Höttecke & Silva, 2011). It is indicative that NOS instruction is seen as a 'progressive' part of science education that becomes fragile in crucial times, such as during the Covid-19 pandemic (Taber, 2021).

NOS, its definition, and its components may still be a matter of controversy at a philosophical level, but at the level of school instruction, and about what NOS aspects should be taught in school, in other words, what NOS aspects concern a scientifically literate citizen, there is a great deal of consensus among researchers and education stakeholders (Clough, 2011; Lederman, 2007; McComas, 2020; Osborne et al., 2003; Scharmann & Smith, 1999). Different researchers (Lederman & Lederman, 2012; McComas, 2020; Osborne et al., 2003) provide sets of NOS aspects that generally overlap, and some may include aspects that others omit. All agree, though, that any of the proposed lists are not constraining; they are not supposed to be taught and memorised; rather, the aspects should be introduced in the form of questions and raise conversations that will broaden students' views about science. Research has shown that to accomplish effective NOS instruction, NOS aspects should be introduced explicitly, reflectively, and contextualised via inquiry learning experiences or through genuine historical and contemporary episodes of science in action (McComas et al., 2020).

There is criticism against this 'general aspects' conceptualisation of NOS, claiming that it does not adequately describe science (Allchin, 2011; and others). Kampourakis (2016) answers such criticism by stating that NOS school instruction needs to be pragmatic and that the 'general aspects' conceptualisation of NOS has proved useful and effective in introducing students to thinking about NOS and in addressing their preconceptions about science.

For the needs of this study, we adopted McComas' (2020) proposal that is in accordance with most of the relevant existing studies (Lederman & Lederman, 2012; Osborne et al., 2003) and suggests three main domains of NOS with their relevant aspects: the *tools and products of science*, the *human elements of science*, and *science knowledge and its limits*. These, along with explanations and possible misconceptions, are presented in Table 1.

Table 1

NOS aspects proposed to be included in the science curriculum

NOS domain	NOS aspect	Short explanation	Argument against possible relevant misconceptions
A. Tools and products of science	A1. Evidence is vital in science.	Evidence (direct or inferential) must exist both to inspire scientific investigation initially and to support scientific conclusions.	Scientific evidence is not a matter of opinion and cannot be discounted.
	A2. Laws and theories are related but distinct.	Theories and Laws are different kinds of knowledge: Laws are generalisations, principles or patterns in nature that are discovered. Theories are the explanations of those generalisations that are invented.	Theories are not a sort of guess, and they do not mature into laws. Hypothesis may mean a prediction or if it is generalising a 'baby law' or if it is explanatory of a 'baby theory'.
	A3. There are many shared methods in science, but no single scientific method.	There are many shared scientific methods, such as induction, deduction, inference, use of multiple data sources, making testable assertions, etc.	There is no standard stepwise scientific method that all scientists use to explore nature.

NOS domain	NOS aspect	Short explanation	Argument against possible relevant misconceptions
B. Human elements of science	B1. Creativity is everywhere in science.	Two individuals with access to the same facts may reach different conclusions based on their prior knowledge and creativity of one.	Science is not a linear mechanical process. In contrast, it is like making art, creativity and imagination are crucial in seeing problems, recognising patterns, and intuiting solutions.
	B2. Subjectivity and bias are present in science.	Scientists are more knowledgeable about what they study, but they also hold preconceptions and biases about how the world operates, which are usually based on their previous knowledge, theory-laden observation, and the paradigm, which provides direction to the research but may also limit investigation.	Scientists are not more objective than other people. Science as an enterprise, though, makes use of intersubjectivity that cancels the biases of the individuals.
	B3. Society and culture interact with science and *vice versa*.	Scientific work is a human endeavour. Humans interact with each other in various ways. These interactions affect the scientific work. Firstly, most science relies on external funding, which is controlled by governments and private foundations. Then, science is a community affair; new ideas are validated by peers.	Funding influences what scientists will investigate. They cannot work on any problems of interest. Validation by the scientific community also may limit them.
C. Science knowledge and its limits	C1. Science has limits.	There are things that science can never know. Firstly, it is impossible to make all the possible observations and to secure all relevant facts for all time. Second, some areas like religion, ethical decision-making ethics cannot be explored with the tools of science.	Science does not offer absolute proof and cannot potentially address all questions.
	C2. Science is tentative, durable, and self-correcting.	Scientific conclusions are long-lasting but might change when compelling new evidence becomes available. Science is constantly undergoing fine-tuning with the occasional radical changes.	The results of science are not final. Scientific interpretation can change through the self-correcting mechanism built into science.
	C3. Science is distinct from engineering and technology.	Science is not necessarily practical. The pursuit of knowledge for the sake of knowledge is called 'pure science' (knowledge-gaining agenda), while its exploitation in the production of a commercial product is applied science or technology facilitated by engineers (profit-gaining agenda).	Science and engineering are not parts of the same pursuit. They interact, but they are not synonymous.

Note. Adapted from McComas, 2020.

School textbooks hold a dominant role in science education as science teachers worldwide rely almost totally on them for both classroom teaching and students' homework; therefore, they significantly affect both the chosen teaching strategies and students' learning experiences (Galili, 2015; Klassen, 2006; McDonald & Abd El-Khalick, 2017 and references therein). According to McDonald and Abd-El-Khalick (2017), science textbooks become the curriculum and determine what is taught and learned in the classrooms. Therefore, NOS should be appropriately incorporated into school science textbooks.

Unfortunately, school textbooks tend globally to emphasise science as a body of knowledge; they refer to science as a way of investigating; they pay little attention to the interaction among science, technology, and society; they rarely present science as a way of thinking (McDonald & Abd-El-Khalick, 2017 and references within). In most, if not all, science textbooks, there is an introductory chapter with references to NOS but mostly focuses on a stereotypical view of the 'Scientific Method' and without any connection of the scientific knowledge to the community that produces it. In general, the authors of science textbooks tend to pay little attention to NOS content, and when they do, they portray naïve views of NOS (Abd-El-Khalick et al., 2007; Campanile et al., 2013; Irez, 2009, McDonald & Abd-El-Khalick, 2017 and references within; Niaz, 2014).

In Greece, there is only one textbook for each subject in each grade published by the Ministry of Education and distributed to students and teachers, which teachers compulsorily use, so they cannot choose among various textbooks as is the case in other countries. The biology textbooks were written by a team consisting of one university teacher of didactics of biology and two biology teachers in secondary school; they were evaluated by a university teacher, a school counsellor, and a biology teacher in secondary school. Biology textbooks have not been widely researched regarding the representations of NOS. Kampourakis (2017) analysed the Greek biology curriculum and some selective chapters of biology textbooks (the introductory chapter of textbooks for Grades 7, 9, 11, and 12 and the chapters on evolution and Mendelian genetics for Grades 9 and 12). He did not use a fixed list of NOS aspects but attempted to identify references to the nature of scientific inquiry, the nature of scientific knowledge, and the nature of scientific explanation aspects; he concluded that several learning goals related to NOS are included in the Greek biology curriculum, but they are only mentioned as general goals, they are not defined, nor explained, nor is any way of achieving them suggested. The biology textbooks under study approached those goals very superficially. Apart from an introductory chapter that presents a distorted perception of the scientific method, which is also usually not taught at all, there are no direct and explicit references to the

NOS besides some references to the History of Science (HOS) (Kampourakis, 2017). Koumara and Plakitsi (2020) have also conducted research regarding the degree that nature of scientific knowledge aspects is included in the science classes of Greek high schools, in the context of which they analysed the biology textbooks concerning the presence of seven Nature of Scientific Knowledge (NOSK) aspects (Lederman & Lederman, 2012), reaching similar conclusions with Kampourakis (2017).

We aim to analyse all the Greek biology textbooks for lower secondary education regarding NOS references based on a predefined list, such as the one in Table 1. We strongly believe that such research would be important to teachers, who will be provided with a list of NOS references that they can highlight in their teaching, as well as to textbook and curriculum developers who might recognise cases that need to be emphasised. It could also function as a guide for the analysis of other countries' biology school textbooks.

Method

Content analysis (Bryman, 2016) was the method of choice and the 'meaning unit' was the unit of analysis.

We analysed all the biology educational material (student's textbooks, accompanying workbooks, lab books, and the teachers' books) (Mavrikaki et al., 2007a, 2007b, 2007c, 2007d, 2007e, 2007f, 2007g) for Grades 7–9 (secondary school: grades 7–9, ages 12-14, which (along with the primary education) is mandatory education in Greece) as well as the corresponding curriculum (Government Gazette, 2003; Ministry of Education and Religious Affairs, 2021). We must note that the existing curriculum was created in 2003, and the books were developed according to it. Biology was at that time taught in the 7^{th} and 9^{th} grades for two hours per week in each grade. Later, the schools' timetable was changed according to the ministry's guidelines (Government Gazette, 2016), and biology is now taught for one hour per week in all three grades (out of the total school hours, which are 33 hours per week for the 7^{th} grade, 33 for the 8^{th}, and 34 for the 9^{th} grades; the school year consists of 36 weeks); therefore, the total biology teaching hours in the lower secondary education were decreased. However, the books remained the same, and teachers were asked to teach specific chapters in each grade. Every year teaching guidelines are provided to help teachers with the year's syllabus as there are changes every other year.

Two of the authors (coders) performed the analysis independently. The nine NOS aspects (McComas 2020), as presented in Table 1 along with a tenth aspect (the epistemology and the object of biology), guided our analysis. We also evaluated the presence of each NOS aspect according to the scoring rubric that has been adapted from the work of Abd-El-Khalick, Waters, and Le (2008) (Table 2). We evaluated whether each aspect is presented explicitly or implicitly, whether the representation of each NOS aspect is informed or naïve, and whether the representation of the NOS aspect is consistent across each document. With the 10 NOS aspects targeted in the analysis, the overall score for a textbook could range from -30 to +30 points.

To ensure reliability, the two authors independently analysed the educational materials. The process resulted in a high level of inter-coder agreement of 93% (O'Connor & Joffe, 2020).

Table 2

Scoring rubric for NOS references distinguishing between explicit and implicit NOS references

Points	Description
+3	explicit, informed, consistent
+2	explicit, partially informed - incomplete representation, consistent
+1	implicit, informed, consistent
0	absent
-1	implicit, naïve
-2	implicit informed combined with explicit naïve or explicit with conflicting messages
-3	explicit naïve

Note. Adapted from Abd-El-Khalick et al., 2008.

Results

In total, 221 meaning units concerning NOS were identified in the educational material under study, but not all of them are meant to be taught as many have been excluded from teaching according to the ministry's teaching guidelines for the 2021/22 school year. Table 3 presents the distribution of NOS in each document.

Table 3
Number of meaning units concerning NOS found in each of the analysed documents and the number of meaning units concerning NOS that correspond to the material to be taught according to the 2021-2022 ministry's teaching guidelines.

Document	NOS references in the documents (N)	NOS references that are meant to be taught (N)
Curriculum	28	2
2021/22 teaching guidelines	1	1
Biology textbook for Grades 7,8	41	22
Biology workbook for Grades 7,8	5	2
Biology lab guide for Grades 7,8	7	2
Biology teachers' book for Grades 7,8	15	2
Biology textbook for Grades 8, 9	72	40
Biology workbook for Grades 8, 9	12	4
Biology lab guide for Grades 8, 9	11	6
Biology teachers' book for Grades 8, 9	29	7
Total	**221**	**88**

The curriculum includes 28 NOS references, most of which are included in a general part that describes the course's purpose and some of its general goals. The same is true for the teachers' books. Many NOS references can be found in the introductory chapters of the students' textbooks (named 'The science of biology'), the corresponding parts of the curriculum, and the teachers' books, which are excluded from teaching.

The nine NOS aspects, as well as the tenth aspect about the objective of biology, were detected in all the analysed documents, though some were quite scarce and absent from the material taught to the students. Table 4 presents their distribution and score according to the scoring rubric for NOS references that grades the holistic presence of each NOS aspect, regarding them as being explicit or implicit, informed, or naïve, and consistent or with conflicting messages (see Table 2) with the higher the score, the better the way that the NOS aspect is included in the document. It must be noted that we considered it important to show in Table 4 any differences that exist between the educational material that was originally developed and the material that was supposed to be taught in 2021/22 according to the ministry's teaching guidelines for that school year (Ministry of Education and Religious Affairs 109009/Δ2/07-09-2021).

Table 4

Distribution of references to NOS aspects and scores on the target NOS aspects, considering: A) the total analysed material and B) (in parentheses) the material to be taught according to the ministry's 2021/22 teaching guidelines.

NOS aspects	Number of References	Score
Objective of Biology	14 (0)	+3 (0)
A1. evidence	28 (22)	+1 (+1)
A2. laws & theories	11 (8)	-1 (-1)
A3. shared methods	50 (16)	-2 (+1)
B1. creativity	24 (18)	+2 (+1)
B2. subjectivity	4 (2)	-1 (-1)
B3. social & cultural influence	45 (8)	+3 (+2)
C1. Limits	1 (0)	0 (0)
C2. tentative	23 (8)	+2 (+1)
C3. relationship with technology	21 (6)	+1 (+1)
Total	**221 (88)**	**+8 (+5)**

As shown in Table 4, most NOS aspects are more informed in the original material than in the taught one, except for A3: shared methods. The NOS aspect about shared methods in the scientific endeavour scores -2 in all the educational material, as there are explicit naïve references like the following activity: '*Place the following concepts in the appropriate order so that the scientific method can be applied: conclusions, hypothesis formulation, experiment design, observation*' combined with informed implicit references like the description of historical experiments: '*In 1956, a team of scientists conducted an experiment to determine the effect of fluoride on tooth decay in children*'. In contrast, in the taught material, the same NOS aspect scores +1, as the chapters with the explicit naïve references have been excluded from the taught material, and only implicit informed references are included.

Table 5 presents the distribution of the NOS references to the three grades, along with the score on each NOS aspect, considering only the material meant to be taught in 2021/22 according to the ministry's teaching guidelines. Aspects about evidence, shared methods, creativity, and relationships with technology are found in all grades. In Grade 9, there are also aspects about laws and theories, and social and cultural influences. Table 6 contains examples of NOS references found in the textbooks and an evaluation of whether they are explicit/implicit and informed/naïve. The scores in other tables regard the total presence of each NOS aspect in the whole document and cannot be estimated for each example, as it includes one more dimension: consistency throughout the document.

Table 5

Number of references to NOS aspects and scores on the target NOS aspects in each grade, considering the material to be taught according to the ministry's 2021/22 teaching guidelines

	Number of References / Score		
NOS Aspect	7th grade	8th grade	9th grade
A1. evidence	7/+1	6/+1	11/+1
A2. laws & theories	1/-1	0/0	7/-1
A3. shared methods	6/+1	2/+1	9/+1
B1. creativity	4/+1	5/+1	10/+1
B2. subjectivity	1/-1	0/0	1/+1
B3. social & cultural influence	2/+1	3/+1	3/+2
C1. limits	0/0	0/0	0/0
C2. tentative	1/+1	4/+1	4/+1
C3. relationship with technology	3/+1	3/+1	1/+1

Table 6

Examples of references to NOS aspects included in the biology textbooks

NOS Aspect	Grade	Example	Evaluation
A1. evidence	7th	The use of the optical microscope and the observation of cells enabled scientists to reveal another unique feature of organisms that is not found in inanimate objects: cellular organisation.	implicit, informed
A2. laws & theories	9th	There are two theories about the evolution of the human brain and the human's agile fingers.	implicit, naïve
A3. shared methods	7th	In 1956, a team of scientists conducted an experiment to determine the effect of fluoride on the appearance of tooth decay in children. For this purpose, the children of one area drank water to which fluoride had been added, while the children of another area drank water without fluoride. The researchers then compared the percentage of caries-free children in the two areas.	implicit, informed
B1. creativity	8th	Abu Bakr Mohamed Alrazi, better known as Razi, was a famous 9th-century Arab physician. When he had to move to Baghdad to set up a hospital, he chose the area by hanging pieces of meat in various parts of the city and selecting the place where the piece of meat was slow to rot.	implicit, informed

NOS Aspect	Grade	Example	Evaluation
B2. subjectivity	9th	Mendel first published the results of his research in 1865, thus establishing the science of genetics. His work was recognised thirty years after his death.	implicit, informed
B3. social & cultural influence	9th	Thanks to vaccination, many diseases that once plagued humanity have disappeared. A typical example is smallpox.	implicit, informed
C2. tentative	8th	People in the past did not know that many of the diseases they suffered from were caused by microorganisms. It took many years for the microscope to be discovered, and at the end of the 19th century, this situation changed. Thanks to the work of two important researchers, Louis Pasteur and Robert Koch, it turned out that the cause of many diseases was microorganisms. This discovery initially led to the opposite of the older belief. In other words, it was considered that all microorganisms are pathogenic. Today we know that this is not true.	implicit, informed
C3. relationship with technology	7th, 8th	With the help of optical and electron microscopy, we have now investigated the cells of monocytes and multicellular organisms.	implicit, informed

Discussion

The Greek secondary school biology textbooks, like most science textbooks that have been analysed in the literature (McDonald & Abd-El-Khalick, 2017 and references within), begin with an introductory chapter that discusses biology as a discipline, its objectives, and the process of the scientific method. These chapters, although part of the books, have been excluded from the official 2021/22 syllabus, so they are not taught.

The Objective of Biology. All the analysed documents begin with a reference to biology as a science and its objective, followed by examples (for the textbooks) or educational goals (for the reform documents, the curriculum and the teachers' books). The curriculum begins with the phrase *'Biology is the science that deals with the study of the phenomena and processes of life'*. In the teachers' books, there are corresponding texts; for instance, for the 7th grade, it is stated that *'[students should] acquire the ability to recognise the unity and continuity of scientific knowledge in matters concerning organisms, as well as the ability to recognise the relationship of biology with other sciences'*. This was the extra tenth aspect that we decided to include in our analysis, and it was found to be explicit, well informed (especially in the textbooks) and consistent as it was presented in all the analysed documents in more or less the same way. Unfortunately, the corresponding units are not taught.

A. Tools and Products of Science

A1 – *Science relies on empirical evidence*. This is a critical NOS aspect that can relatively easily be approached compared to others (Yacoubian, 2020). Indeed, it was one of the most commonly found aspects. There are few explicit references, in the chapter on evolution, in the unit 'Evolution and its testimonies', in which it is explicitly claimed that to draw a scientific conclusion, scientists must rely on evidence. Other than that, A1 is present in the textbooks mostly implicitly (e.g., *'In 1665 R. Hook, observing thin sections of cork under his microscope, spoke for the first time about cells'*). However, if the teacher does not grasp the opportunity to discuss it explicitly, it is doubtful that students will understand.

A2 – *Laws and theories are related but distinct*. This NOS aspect is one of the most difficult ones to deeply understand and teach (Mesci & Schwartz, 2016). In the analysed material, there is no reference to the nature of laws or theories as forms of scientific knowledge neither their inter-relationships. In the curriculum, as well as the teachers' books there is a goal that mentions laws and theories *'to acquire knowledge related to concepts, theories, laws and principles related to biology […]'*. Accordingly, in the textbooks, the only times that laws and theories are mentioned are to introduce the cell theory and Mendel's laws. An inconsistency comes up in the chapter of evolution, where the word 'theory' is not only used to convey a system of ideas based on general principles that explains phenomena but also the meaning of supposition: for example, *'There are two theories about the evolution of the human brain and the agile fingers'*. There is a common misconception that theories are a sort of guess and that they are not secure and credible enough, so they can easily be dismissed (McComas, 2020). This kind of thinking may lead to sayings like 'evolution is just a theory'. The way that the word 'theory' is used in the chapter of evolution may strengthen that misconception. To prevent that, it is essential that the biology teacher makes an intervention to explicitly address this issue.

A3 – *Thoughts about methods that scientists use*. This is the most common NOS aspect in the analysed documents. It is the only one that is explicitly mentioned and thoroughly explained, unfortunately supporting the naive conception about the one, linear, steplike, scientific method that all scientists use. In the reform documents, there are several relevant educational goals, such as *'Describe the scientific method and apply it to solving a simple problem'*. In these documents, the scientific method is parallelised with a scientific way of thinking. In the students' textbooks, in the introductory chapter, which is not currently taught, *'the scientific method'* is thoroughly described, discussed, and presented in diagrams as a stepwise linear process, like most science textbooks do throughout the world (Reiff-Cox, 2020). In the taught chapters and the corresponding activities and laboratory exercises, there is no explicit reference to the scientific method. Nevertheless, different methods that scientists use are implicitly presented via the short description of some scientists' work. There is one exception in the 9th -grade teachers' book with an indicative teaching action that explicitly mentions the scientific method: *'Next, we can refer to the discovery of the structure of the DNA molecule by J. Watson and Fr. Crick. [...] We urge them to look at the steps of the scientific method and to combine the content, the history and the significance of this discovery with the scientific way of thinking'*. With appropriate coordination, this could be a suitable activity, although it requires much preparation from the teacher. For the students to understand shared methods in science, they should experience a broad range of the paths that scientists follow (thought experiments, correlational, descriptive, exploratory studies, and serendipitous moments) (Reiff-Cox, 2020). Laboratory exercises and activities about historical scientific episodes give the opportunities to integrally address the aspect.

B. Human Elements of Science

B1 – *Creativity is part of the scientific process.* This NOS aspect is explicitly present twice: in the introductory note for the student at the laboratory guide for the 7th grade (p. 5) *'Designing and executing an experiment requires imagination and hard work'* and in the introductory chapter of the 9th-grade textbook *'The questions that are asked must be explained and this often requires the use of imagination'*. Moreover, creativity can be implicitly detected in the textbooks and the lab guides. There are a few references to HOS so that the biology teacher could present more about the scientists and the circumstances under which they were led to their discoveries and to explicitly discuss creativity as part of the process with the students . However, the provided material is not enough. For instance, in the 9th-grade textbook there is a picture of Robert Koch, accompanied by a text mentioning he is an important scientist who contributed to proving that the cause of many diseases are microorganisms. This is a very typical example of the presence of HOS in science textbooks internationally (Lin et al., 2010), which is by no means sufficient to illuminate the human nature of scientists. Such are the most HOS references in the textbooks and the lab guides (nine cases). In five more cases, the experimental procedure that led to the discovery is also described, some elements are provided to illuminate the fact that for someone to design such an experiment, creativity and imagination are needed.

B2 – *Subjectivity and bias are present in science.* This is a subtle hue of NOS that is difficult to be understood and taught, and in some cases, it is hardly accepted even by the science teachers as it may challenge their broader epistemological stance (Mesci & Schwartz, 2016). Thus, it should not come as a surprise that it is almost absent from secondary school biology. In all the material, we detected only two implicit references that could be made about scientists' subjectivity. The first one is in the 7th-grade textbook, which refers to scientists as authorities: *'Scientists have formed a food pyramid to help us choose the right food'*. In the certain context this reference is not problematic, but when the only way that scientists are pictured is as authorities, which is the case in the secondary education curriculum, then a distorted image of scientists is communicated to the students: superhuman scientists being always objective. The second detected reference is in the 9th-grade textbook: *'Mendel first published the results of his research in 1865 [...]. His work was recognized thirty years after his death.'* If this is properly utilised by the teacher, then a discussion about how a scientific discovery is approved and recognised by the scientific community may occur. Mendel's case is an example of how occasionally some innovative ideas are rejected because they fall outside the accepted paradigm. (McComas, 2020).

B3 – *Society and culture interact with science and vice versa.* This aspect has a dual nature: on the one hand, it sheds light on the socio-cultural impacts of science and, on the other hand, on the impact of science on society. The Greek biology curriculum mostly focuses on the latter. It is explicitly stated multiple times in the reform documents that students must *'[...]ascertain the contribution of Biology in the improvement of the quality of human life but also reflect on the effects (positive or negative) of the applications of Biology'*, as well as in the introductory chapters of the students' textbooks *'Thanks to advances in all fields of biology, and especially in molecular biology and genetic engineering, great strides have been made in studies directly or indirectly involving humans'*.

Later the socio-cultural impacts of science are also approached. For example, there is an activity in the 7th-grade textbook that asks students to *'gather historical and other data on the political, social and cultural situation that prevailed and write a text in which you will document the rapid development of science during the 18th century in Europe'*. Another one in the 9th-grade textbooks asks students to reflect on the rapid development of biology, and the ethical, legal, and humanitarian issues that arise. Unfortunately, these chapters are not taught. Neither is the chapter of biotechnology that illuminates the applications of genetic engineering and the related issues that arise. Thus, in the taught chapters there are very few implications about the contribution of biology to society that are (A) about the many ways that humans use germs in various applications, such as the production of alcoholic beverages, in wastewater treatment, in the food industry, and in the pharmaceutical industry, and (B) that *'Thanks to vaccination, many diseases that once plagued humanity, like smallpox, have disappeared'*. The biology teacher must seize this opportunity to introduce all the above concepts that have been excluded from the syllabus. Finally, the 9th-grade teachers' book proposes activities that refer to the impact of the historical context, society, and culture on science: for example,*'We refer briefly to Charles Darwin, his journey and his time. We can assign students to work on Darwin's views and their impact within the specific historical, political, economic and social climate of Victorian England'*.

C. Science Knowledge and its Limits

C1 – *Science has limits*. This aspect is totally absent from the Greek biology curriculum. The only relevant reference is in the 9th-grade's textbook, in the biotechnology chapter, which is not taught, where the concept of bioethics is introduced. This could provide the opportunity for discussions about the questions that science cannot answer, and which are ascribed to ethics, religion, or aesthetics. The second notion of this aspect, concerning how science cannot offer absolute proof, since induction underlies the law of falsifiability (Popper, 2005), is also absent. This omission is not the case in other countries. For example, in the AAAS, the NGSS documents, the Swedish context (Hansson, 2020) and the German curriculum (Marniok & Reiners, 2017), it is clearly stated that the students should learn about the limits of science. It is important to explicitly discuss this notion to avoid creating the feeling that science is omnipotent and that we need no other explanatory or investigative tools (McComas, 2020). Moreover, encouraging the understanding that science is compatible with many different worldviews (including religious ones) may make science meaningful for more students (Hansson, 2020).

C2 – *Science is tentative, durable, and self-correcting*. This is another NOS aspect that is hard to be accepted and understood (Mesci & Schwartz, 2016). Indeed, this NOS aspect is present in the Greek biology curriculum: *'the great development of the science of Biology and the constant updating of data'*, and it is mentioned in all the reform documents; biology is characterised as *'the science whose modern achievements surprise with the pace of revisions and upheavals, they impose on our knowledge and perceptions of them'*. In the textbooks, there are historical examples about cases in which parts of scientific knowledge were reviewed and if needed corrected. For instance, in the 7th-grade textbook it is mentioned that Schleiden and Schwann formulated the cell theory, which was later revised and completed by Virchow. In the 9th-grade textbook, what was considered to be scientifically correct about the cause of diseases is presented *'People did not know in the past that many of the diseases they suffered from were caused by microorganisms. [...] it turned out that the cause of many diseases were some microorganisms. This discovery initially led to the opposite of the older belief. In other words, it was considered that all microorganisms are pathogenic. Today we know that this is not true'*. Such descriptions are important to reveal the tentative, yet durable character of science. According to Niaz (2014, p. 44) 'various topics of the science curriculum provide an opportunity to illustrate the tentative nature of scientific knowledge, and still very few textbooks refer (explicitly) to this important aspect of nature of science.'

C3 – *Science is distinct from engineering and technology.* This NOS aspect has three dimensions; firstly, it concerns the impact of technology on the advancement of science; secondly, the impact of science on the advancement of technology; last, the fact that science is distinct from technology and engineering: they have different goals and different processes; this is contrary to the false image that tends to be created by the Science, Technology, Engineering, and Mathematics (STEM) curricula that are a trend in science teaching nowadays (McComas, 2020). In the analysed documents, the third dimension is absent. There is one explicit learning goal in the 9th-grade teachers' book concerning the biotechnology chapter which is not taught: *'Understand the importance of science and technology interactions in the advancement of biotechnology.'*. Accordingly, in the corresponding textbook's chapter there are several mentions about the ways science and technology affect each other. As far as the taught material is concerned, there are a few mentions about the advancement of the microscope and its vital contribution to the development of biology; for example (7th-grade textbook), *'The use of the optical microscope and the observation of cells enabled scientists to reveal another unique feature of organisms: cellular organization'*. There is also one reference about how science affects technology in the 9th-grade textbook: *'With the advancement of biology, vaccines are constantly evolving'*.

Based on the above, NOS is poorly presented in the secondary school biology educational material. Most NOS aspects (except for the one about shared methods in science) are slightly more informed in the total material than in the taught one. It is a fact that biology teaching in lower secondary education in Greece has been degraded the recent years with the conversion of the course to a one-hour weekly lesson, which is damaging to meaningful biology teaching. Some chapters had to be excluded and among those are the introductory chapters about Biology as a Science, and the chapter of Biotechnology; both are rich in NOS references; by excluding them from the taught material, NOS introduction is impoverished.

Overall, more NOS concepts are included in the 9th grade, and fewer in the 7th and 8th grades. This is not due to pedagogical reasons, as NOS can, and some researchers believe that it should, be introduced as soon as children begin to learn about science in the kindergarten (McComas et al., 2020). Of course, some of the NOS aspects are more difficult for younger students (e.g., 'the theory/law distinction', or 'subjectivity' than others (e.g., 'need for evidence' and 'creativity') due to cognitive development, prior knowledge, and previous experiences (McComas et al., 2020). However, lower secondary education grades that concern us in our study are appropriate for the introduction of all NOS aspects. The introduction of NOS should be included in the curriculum, and it should be designed carefully to have a sequence throughout the curriculum, revisiting the same ideas in more depth at every level, in a developmentally appropriate way at all levels from the elementary to the college level (Yacoubian, 2020).

Conclusions

Secondary school biology textbooks follow the global trend (McDonald & Abd-El-Khalick, 2017) dedicating almost all their content to declarative, or else conceptual knowledge, little content to procedural knowledge (through laboratory experiments and activities), and neglect epistemic knowledge, including NOS aspects. As it has been previously reported (Kampourakis, 2017; Koumara & Plakitsi, 2020), NOS is not sufficiently depicted in the secondary school biology textbooks.

NOS references are made implicitly, with the exceptions of a few misleading explicit references to the steplike scientific method. Other than that, there are many opportunities to introduce informed views about NOS aspects, starting from the implicit textbook references that concern the importance of empirical evidence, shared methods in the scientific endeavour, the role of creativity in science, social and cultural influences, and the tentative nature of the scientific knowledge. Less frequent are the opportunities to discuss the nature of laws and theories, and science's relationship with technology. Subjectivity in science is scarce, whereas the fact that science has limits is practically absent.

Similar are the findings of global research. Unfortunately, the myth of the stepwise, single, procedural, and/or universal 'Scientific Method' seems to immortal and present in high school chemistry textbooks in the USA

(Abd-El-Khalick, et al., 2007) and in secondary school biology textbooks in Turkey (Irez, 2007) as well as in other countries (Reiff-Cox, 2020). Most references in NOS aspects, such as the social and cultural embeddedness of science, creativity, and subjectivity in science, tend to be discussed only implicitly, while theories, laws, and the tentative nature of scientific knowledge, when approached, are presented naively. Subjectivity in science and the fact that science has limits are the rarest ones (Abd-El-Khalick, et al., 2007; Campanile, et al., 2013; Irez, 2007).

In the Greek secondary school biology textbooks that we analysed, the introductory chapters, discussing biology as a science that contain explicit NOS aspects, provide a distorted image of NOS (e.g., the step-like scientific method). However, if they were taught, they could be useful to introduce discussion about NOS and, with careful guidance from the instructor, become the spark for the introduction of accurate NOS aspects. Unfortunately, according to the ministry's guidance, they are excluded from the taught material, enforcing teachers' and students' ideas that NOS aspects are not worthy to be given teaching time especially when compared to scientific content.

The remaining chapters of the textbooks contain implicit references to NOS aspects, mostly through referral to the HOS, which has been repeatedly acknowledged as a valuable way to teach NOS (Abd-El-Khalick & Lederman, 2000; Kapsala & Mavrikaki, 2020; McComas & Kampourakis, 2015). Nevertheless, for the NOS instruction to be successful, it has to be contextualised, explicit, and reflective (McComas et al., 2020). HOS references cover the first part of providing the context. It is left to the teacher to make the hidden NOS message explicit and provide their students with the opportunity to explore it, discuss it, and reflect on it. Internationally, few science textbooks provide meaningful historical discussions about the development of science ideas (McComas, et al., 2020). References to the HOS usually focus on individual achievements that give students the false impression that science moves straightforwardly and that it always has a direct impact and wide acceptance therefore creating misconceptions about how science is integrated in our lives (Abd El-Khalick & Lederman, 2000). Thus, opportunities to discuss the dynamic nature of science, the role of creativity of the human mind, the interaction between scientists, and the influence of different contexts on the development of science are lost (Lin, et al., 2010).

Moreover, implicit NOS references can be found in the laboratory activities, some of the workbook activities and the indicative activities that are proposed in the teachers' books; it is doubtful though that teachers use this material in the context of the one-hour per week lesson and the pressure to complete the syllabus in a limited time. As for the laboratory activities, it has been reported that the experiments have been designed to accept or reject hypotheses and not as a method to structure theoretical and conceptual meanings, enforcing a distorted positivist image of science (Stasinakis & Koliopoulos, 2009).

When NOS is removed from science teaching, myths about it are reproduced in science classes. Scientific knowledge is presented as unchangeable, objective facts, and the scientific procedures as 'a strict scientific method always being applicable'. Such images of science are claimed to be part of the hidden curriculum in many science classes (Hansson, 2018). Research shows that such are the students' views about science (Hansson, 2018 and references therein). It seems that although empiricism and positivism are 'dead to philosophical circles', policy makers and curriculum writers consider them very much alive (Kokkotas, 2004 as referenced in Stasinakis & Koliopoulos, 2009).

Since textbooks have so many deficiencies in the NOS content, measures regarding the teachers' training should be taken (Solaz-Portolés, 2010). To achieve effective NOS instruction, science teachers should hold several competencies including general NOS knowledge, subject matter knowledge, knowledge of learners with respect to NOS, knowledge about NOS instructional strategies, knowledge about NOS assessment, general pedagogical knowledge, and motivations and positive beliefs about teaching NOS (Nouri, et al., 2021).

In the given circumstances, for NOS to be taught, teachers are called to put in action their 'pedagogical design capacity', and like the charismatic teacher depicted in Matić's research (2019), manoeuvre through the syllabus, utilise textbooks' sources, improvise, and create productive instructional episodes to achieve their educational goals. This requires high levels of the abovementioned competencies. Unfortunately, most science teachers in Greece have not been trained either in NOS content or in NOS instruction; they are not familiar with it, and when they approach NOS, they do so intuitively, not explicitly nor reflectively, and they do not assess their students' understandings (Koumara & Plakitsi, 2020). Such an expectation from them would be unrealistic and unfair. Only when science teachers are trained can we expect them to be able to utilise the minimum available NOS content of the textbooks, to effectively teach NOS aspects.

In conclusion, when there are no direct explicit NOS references in the taught material, NOS slips to the hidden curriculum. It is taught indirectly through the implicit messages of the textbooks. Thus, too much is left on the shoulders of the biology teacher who is called to correctly interpret the implicit NOS references, to create educational material in order to make them explicit and to employ their students in a reflective dialogue about them. All this of this is with the time pressures of the syllabus that does not include NOS in its educational goals, and with almost no official training on NOS instruction. The NOS instruction ends up depending on the teacher's worldview about science, which rarely goes along with the precise NOS. This cultivates misunderstandings and feeds myths about NOS enforcing the distorted positivist image of science and leaves no room for a different, more human, and closer-to-the-truth image of science.

Limitations of the research: in this study we analysed the Greek secondary school biology textbooks along with the curriculum and the ministry's 2021/22 teaching guidelines. It would be interesting to investigate what actually is taught in the classrooms. Perhaps some teachers could highlight ideas about NOS that are absent from the textbooks.

References

Abd-El-Khalick, F., Waters, M., & Le, A. P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 45*(7), 835–855. https://doi.org/10.1002/tea.20226

Abd-El-Khalick, F., & Lederman, N. G. (2000a). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057–1095. https://doi.org/10.1002/1098-2736(200012)37:10<1057::AID-TEA3>3.0.CO;2-C

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*(3), 518–542. https://doi.org/10.1002/sce.20432

Bryman, A. (2016). *Social research methods.* Oxford University Press.

Campanile, M. F., Lederman, N. G., & Kampourakis, K. (2015). Mendelian genetics as a platform for teaching about nature of science and scientific inquiry: The value of textbooks. *Science & Education, 24*(1), 205–225. https://doi.org/10.1007/s11191-013-9607-4

Clough, M. P. (2011). Teaching and assessing the nature of science. *The Science Teacher, 78*(6), 56–60.

Government Gazette. (2003). 304/13-03-2003. Διαθεματικό ενιαίο πλαίσιο προγραμμάτων σπουδών (Δ.Ε.Π.Π.Σ.) και αναλυτικά προγράμματα σπουδών (Α.Π.Σ.) Δημοτικού Γυμνασίου [Interdisciplinary unified framework of study programs and curricula of primary school and high school].

Government Gazette. (2016). 1640/Β΄/9-6-2016. Ωρολόγιο πρόγραμμα των μαθημάτων των Α›, Β›, Γ› τάξεων του ημερησίου γυμνασίου [Schedule of the lessons of the A›, B›, C› classes of high school].

Haagen-Schützenhöfer, C., & Joham, B. (2018). Professionalising physics teachers in doing experimental work. *Center for Educational Policy Studies Journal, 8*(1), 9–34. https://doi.org/10.26529/cepsj.333

Hansson, L. (2020). Teaching the limits of science with card-Sorting activities. In W. McComas (Ed), *Nature of science in science instruction: Rationales and strategies* (pp. 627–639). Springer. https://doi.org/10.1007/978-3-030-57239-6_34

Hansson, L. (2018). Science education, indoctrination, and the hidden curriculum. In M. Matthews (Eds.), *History, philosophy and science teaching. Science: philosophy, history and education* (pp. 283–306). Springer. https://doi.org/10.1007/978-3-319-62616-1_11

Höttecke, D., & Silva, C. C. (2011). Why implementing history and philosophy in school science education is a challenge: An analysis of obstacles. *Science and Education, 20*(3), 293–316. https://doi.org/10.1007/s11191-010-9285-4

Kampourakis, K. (2017). Nature of science representations in Greek secondary school biology textbooks. In C. V. McDonald & F. Abd-El-Khalick (Eds.), *Representations of nature of science in school science textbooks. A global perspective* (pp. 130–146). Routledge. https://doi.org/10.4324/9781315650524-6

Kampourakis, K. (2016). The "general aspects" conceptualisation as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teaching, 53*(5), 667–682. https://doi.org/10.1002/tea.21305

Koumara, A., & Plakitsi, K. (2020). The degree that nature of scientific knowledge aspects are included in the science classes of Greek high schools. *World Journal of Education, 10*(5), 1–17. https://doi.org/10.5430/wje.v10n5p1

Irez, S. (2009). Nature of science as depicted in Turkish biology textbooks. *Science Education, 93*(3), 422–447. https://doi.org/10.1007/978-94-007-7654-8_44

Kapsala, N., & Mavrikaki E. (2020). Storytelling as a pedagogical tool in nature of science instruction. In W. F. McComas (Ed.), *Nature of science in science instruction: rationales and strategies* (pp. 485–512). Springer. https://doi.org/10.1007/978-3-030-57239-6_27

Lederman, N. G., & Lederman, J. S. (2012). Nature of scientific knowledge and scientific inquiry: Building instructional capacity through professional development. In B. J. Fraser et al. (Eds.), *Second international handbook of science education* (pp. 335–359). Springer.

Lederman, N. G. (2013). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–880). Routledge.

Lin, C.-Y., Cheng, J.-H., & Chang, W.-H. (2010). Making science vivid: Using a historical episodes map. *International Journal of Science Education, 32*(18), 2521–2531. https://doi.org/10.1080/09500691003746015

Marniok, K., & Reiners, C. S. (2017). Representations of nature of science in German school chemistry textbooks. In C. V. McDonald & F. Abd-El-Khalick (Eds.), *Representations of nature of science in school science textbooks* (pp. 201–214). Routledge. https://doi.org/10.4324/9781315650524-11

Matić, L. J. (2019). The teacher as a lesson designer. *Center for Educational Policy Studies Journal, 9*(2), 139–160. https://doi.org/10.26529/cepsj.722

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007a). *Βιολογία Α΄ Γυμνασίου. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [7th grade biology students' textbook]. Textbook Publishing Organization.

http://ebooks.edu.gr/ebooks/v2/books-pdf.jsp?handle=8547/106

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007b). *Βιολογία Α΄ Γυμνασίου Τετράδιο Εργασιών. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [7th grade biology students' workbook]. Textbook Publishing Organization.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007c). *Βιολογία Α΄ Γυμνασίου Εργαστηριακός Οδηγός. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [7th grade biology students' lab-book]. Textbook Publishing Organization.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007d). *Βιολογία Α΄ Γυμνασίου Βιβλίο Εκπαιδευτικού. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [7th grade biology teachers' book]. Textbook Publishing Organization. http://ebooks.edu.gr/ebooks/handle/8547/4927

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007e). *Βιολογία Γ΄ Γυμνασίου. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [9th grade biology students' textbook]. Textbook Publishing Organization. http://ebooks.edu.gr/ebooks/v2/books-pdf.jsp?handle=8547/108

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007f). *Βιολογία Γ΄ Γυμνασίου Τετράδιο Εργασιών. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [9th grade biology students' workbook]. Textbook Publishing Organization.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007g). *Βιολογία Γ΄ Γυμνασίου Εργαστηριακός Οδηγός. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων* [9th grade biology students' lab-book]. Textbook Publishing Organization.

Mavrikaki, E., Gouvra, M., & Kampouri, A. (2007h). *Βιολογία Γ΄ Γυμνασίου Βιβλίο Εκπαιδευτικού. Αθήνα: Οργανισμός Εκδόσεως Διδακτικών Βιβλίων.* [9th grade biology students' textbook]. Textbook Publishing Organization. http://www.pi-schools.gr/books/gymnasio/biologia_a/kath/kath_1_150.pdf

McComas, W. F., Clough, M. P., & Nouri, N. (2020). Nature of science and classroom practice: A review of the literature with implications for effective NOS instruction. In W. F. McCommas (Ed.), *Nature of science in science instruction: Rationales and strategies* (pp. 67–111). Springer. https://doi.org/10.1007/978-3-030-57239-6_4

McComas, W. F. (2020). Principal elements of nature of science: Informing science teaching while dispelling the myths. In W. F. McCommas (Ed.), *Nature of science in science instruction: Rationales and strategies* (pp. 35–65). Springer https://doi.org/10.1007/978-3-030-57239-6_3

McComas, W. F., & Kampourakis, K. (2015). Using the history of biology, chemistry, geology, and physics to illustrate general aspects of nature of science. *Review of Science, Mathematics and ICT Education*, 9(1), 47–76. https://doi.org/10.26220/rev.2240

McDonald, C. V., & Abd-El-Khalick, F. (2017). Representations of nature of science in school science textbooks. In C. V. McDonald & F. Abd-El-Khalick (Eds.), *Representations of nature of science in school science textbooks. A global perspective* (pp. 1–19). Routledge. https://doi.org/10.4324/9781315650524-1

Mesci, G., & Schwartz, R. (2016). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education, 47*(2), 329–351. https://doi.org/10.1007/s11165-015-9503-9.

Ministry of Education and Religious Affairs (2021). *109009/Δ2/07-09-2021 Οδηγίες για τη διδασκαλία του μαθήματος της Βιολογίας του Ημερησίου και του Εσπερινού Γυμνασίου για το σχολικό έτος 2021-2022* [Instructions for teaching the course of biology of the day and evening high school for the school year 2021-2022].

Niaz, M. (2014). Science textbooks: The role of history and philosophy of science. In M. R. Matthews (ed.) *International handbook of research in history, philosophy and science teaching* (pp. 1411–1441). Springer.

Nouri, N., Saberi, M., Mccomas, W., & Mohammadi, M. (2021). Proposed teacher competencies to support effective nature of science instruction: A meta-synthesis of the literature. *Journal of Science Teacher Education, 32*(6), 1–24. https://doi.org/10.1080/1046560X.2020.1871206.

NSTA Board of Directors. (2020). *Nature of science/NSTA*. https://www.nsta.org/nstas-official-positions/nature-science

O'Connor, C., & Joffe, H. (2020). Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. *International Journal of Qualitative Methods, 19*, 1–13. https://doi.org/10.1177/1609406919899220

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about-science" should be taught in school science? A Delphi study of the expert community. *Journal of research in science teaching, 40*(7), 692–720. https://doi.org/10.1002/tea.10105

Popper, K. (2005). *The logic of scientific discovery*. Routledge.

Reiff-Cox, R. (2020). Exchanging the myth of a step-by-step scientific method for a more authentic description of inquiry in practice. In W. F. McCommas (Ed.), *Nature of Science in Science Instruction* (pp. 127–139). Springer. https://doi.org/10.1007/978-3-030-57239-6_6

Smith, M. U., & Scharmann, L. C. (1999). Defining versus describing the nature of science: A pragmatic analysis for classroom teachers and science educators. *Science Education*, *83*(4), 493–509. https://doi.org/10.1002/(SICI)1098-237X(199907)83:4<493::AID-SCE6>3.0.CO;2-U

Slapničar, M. (2014). Khine Swe, M. (Ed.) (2013) Critical analysis of science textbooks: Evaluating instructional effectiveness. *Center for Educational Policy Studies Journal, 4*(1), 137–141.

Solaz-Portolés, J. J. (2010). La naturaleza de la ciencia y libros de texto de ciencias: una revision. *Educación* [The nature of science and science textbooks: A review. *Education] XX1, 13*(1), 65–80. https://doi.org/10.5944/educxx1.13.1.277

Song, J., Chun, J., & Na, J. (2021). Why people trust something other than science. *Science & Education, 30*(6), 1387–1419. https://doi.org/10.1007/s11191-021-00243-w

Stasinakis, P. K., & Koliopoulos, D. (2009). *Ανάλυση εγχειριδίων βιολογίας στη δευτεροβάθμια εκπαίδευση: Η περίπτωση της έννοιας της θρέψης φυτών και ζώων. Θέματα Επιστημών και Τεχνολογίας στην Εκπαίδευση* [Analysis of biology textbooks in secondary education: The case of the concept of plant and animal nutrition]. *Issues of Science and Technology in Education, 2*(1–2), 103–125. http://earthlab.uoi.gr/ojs/thete/index.php/thete/article/view/25

Taber, K. S. (2021). The challenge to educational reforms during a global emergency: The case of progressive science education. *Center for Educational Policy Studies Journal, 11*(Sp. Issue), 67–87.

https://doi.org/10.26529/cepsj.1109

Weisberg, D. S., Landrum, A. R., Hamilton, J., & Weisberg, M. (2020). Knowledge about the nature of science increases public acceptance of science regardless of identity factors. *Public Understanding of Science, 30*(2), 120–138. https://doi.org/10.1177/0963662520977700

Yacoubian, H. A. (2020). Teaching nature of science through a critical thinking approach. In W. F. McComas (Ed.), *Nature of science in science instruction: rationales and strategies* (pp. 199–212). Springer. https://doi.org/10.1007/978-3-030-57239-6_10

Biographical note

Nausica Kapsala is a biologist and a storyteller. She is currently a secondary education biology teacher (2nd Lyceum of Elefsina) and an external teaching and research fellow of the Laboratory of Science Teaching & Epistemology and Educational Technology of the Faculty of Primary Education of the National and Kapodistrian University of Athens, Greece. She has authored and coauthored many articles or chapters in Greek and international journals, conference proceedings, and edited volumes. She holds a master's degree in Modern trends in the teaching of biology with the aid of new technologies and a PhD in Biology teaching. Her research interests lie in storytelling as an educational tool in biology teaching, nature of science, history of science and evolution understanding.

Apostolia (Lia) Galani is Associate Professor in Didactics of Geography at the National and Kapodistrian University of Athens, Greece. She has authored or coauthored many articles or chapters in Greek and international journals or books, and she is the author-coauthor of 15 books, including the Greek primary and lower secondary education geography textbooks. Her research interests focus on socio-scientific issues, on the educational approach of environmental issues with innovative methods (e.g., remote sensing), on the use of ICT in school Geography.

Evangelia Mavrikaki, holds a PhD in biology and she is a Professor and a member of the Laboratory of Science Teaching & Epistemology and Educational Technology of the Faculty of Primary Education of the National and Kapodistrian University of Athens, Greece. She has worked as an academic (lecturer, Assistant Professor) in the Aristotle University of Thessaloniki and the University of Western Macedonia before her current position. She has been a member of the board of reviewers/editorial board of several journals and she has authored or coauthored many articles or chapters in Greek and International Journals or books, and she is the author-coauthor of 15 books including the official Greek Gymnasium (lower secondary education) biology textbooks. She has served for four years as an elected member of the executive board - in charge for Educational Issues – of the Pan-Hellenic Association of BioScientists and has served as President of EvoKE (Evolutionary Knowledge for Everyone).