Understanding epistemic aspects of the nature of science in Spain's new curriculum for compulsory-secondary education since the LOMLOE law

La comprensión de aspectos epistémicos de la naturaleza de la ciencia en el nuevo currículo de Educación Secundaria Obligatoria, tras la LOMLOE

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Abstract:

This study analyses the attention to understanding of epistemic aspects of the *nature of science* (NOS) in Spain's new science curriculum for the compulsory secondary education (ESO) stage, which was approved following the entry into force of the new LOMLOE education law (Organic Law 3/2020). To this end, the curricular provisions for the biology and geology and physics and chemistry subjects (Royal Decree 217/2022) are examined using qualitative content analysis. The theoretical reference used in the analysis of the document is the set of epistemic aspects of NOS included in the latest PISA conceptual framework for scientific competence. The results show that Spain's science curriculum for compulsory secondary education is not consistent in either quantity or depth with the PISA framework in relation to the understanding of the epistemic aspects of NOS. In conclusion, understanding of these aspects is regarded as a minor or secondary educational challenge in the new curriculum for basic science education. Therefore, it represents another missed opportunity to give greater importance to such key dimension of public scientific literacy.

Keywords: compulsory-secondary education, curriculum, epistemic aspects, LOMLOE, nature of science, scientific literacy.

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Resumen:

Este estudio analiza la atención que se presta a la comprensión de aspectos epistémicos de la *naturaleza de la ciencia* (NDC) en el nuevo currículo de ciencias para la etapa de Educación Secundaria Obligatoria (ESO), aprobado tras la entrada en vigor de la LOMLOE (Ley Orgánica 3/2020). Con este propósito, se examinan las disposiciones curriculares de las materias de Biología y Geología y Física y Química (Real Decreto 217/2022), mediante un método de análisis cualitativo de contenido. El referente teórico usado en el análisis es el conjunto de aspectos epistémicos de la NDC, recogido en el último marco conceptual de PISA sobre la competencia científica. Los resultados revelan que el currículo de ciencias para la ESO, en España, no sintoniza, ni en cantidad ni en profundidad, con el marco de PISA en lo que respecta a la comprensión de aspectos epistémicos de la NDC. Se concluye que la comprensión de tales aspectos es considerada un reto educativo menor, o secundario, en el nuevo currículo para la educación científica básica. Por tanto, supone otra oportunidad perdida de haber dado un mayor protagonismo a esta dimensión clave de la alfabetización científica de la ciudadanía.

Descriptores: alfabetización científica, aspectos epistémicos, currículo, Educación Secundaria Obligatoria, LOMLOE, naturaleza de la ciencia.

1. Introduction

Understanding basic concepts about the *nature of science* (NOS) is, nowadays, regarded as a key component in achieving the desired scientific literacy among the general population (National Science Teaching Association [NSTA], 2020). It is a type of *metaknowledge* about science, which principally arises from interdisciplinary studies and reflections by historians, philosophers and sociologists of science[1] (Acevedo & García-Carmona, 2016; McComas & Clough, 2020).

There are various reasons that justify introducing NOS content in basic scientific education. Of these, two fundamental ones can be emphasised. One is that explicit attention to aspects of NOS in science classes might favour the comprehension of scientific ideas (NSTA, 2020), if accompanied by a conscious reflection on the complex process that leads to the establishment of such ideas (García-Carmona & Acevedo, 2018). The other important reason is that NOS provides a framework of basic ideas about the characteristic features of scientific activity, the factors that influence it, and the knowledge produced (Acevedo & García-Carmona, 2016), which is ideal for critical analysis of personal and social matters relating to science (Almeida et al., 2022). In effect, a person who is well educated in aspects of NOS will be able to handle arguments that go beyond simple personal valuations when analysing and taking a position in socio-scientific disputes; for example, understanding the need to evaluate the reliability of sources of information used by different parties. Equally, a basic comprehension of *how science works* helps detect *pseudosciences*, which base their arguments on false beliefs and untested suppositions. One of the characteristics of science is that it is evidence-based (Bell, 2009); this means that scientific knowledge must overcome many verification tests, through rigorous evaluation processes, before being accepted by the scientific community (García-Carmona & Acevedo, 2018). Therefore, the scientific validity of any knowledge *proposal* that has not passed through all of these filters, should always be put to the test.

Possessing basic NOS knowledge also makes it possible to counter the arguments of science *deniers*, who often believe in conspiracy theories or false experts or believe that science must be perfect if it is to be reliable (McIntyre, 2021). One paradigmatic case is that of *creationists*, who object to the *theory of evolution* with the argument that it is "only a theory", which has still not become a scientific law that can be accepted (Rennie, 2002). However, this is easy to refute because scientific laws and theories are two different types of knowledge and so are not in a hierarchical relationship or a relationship of subordination in which it is possible for scientific theories to become laws (Lederman et al., 2013).

Similarly, NOS explains, for example, why there were changes of scientific consensus during the Covid-19 pandemic, with the aim of preventing the spread of this coronavirus (García-Carmona, 2021a). Scientific knowledge is built on the basis of the data available at each moment. Consequently, although certain ideas or explanations are regarded by the scientific community to be the most acceptable at a given moment in the development of research, they are accepted as *tentative*. In other words, they are ideas that are liable to change in the light of new evidence that might call them into question (Lederman et al., 2013). Similarly, scientific progress is not just because of practices that are *epistemic* or exclusively *rational* in nature, but it also depends to a great extent on extrascientific or *non-epistemic* aspects, such as funding received, the socio-political interests of each period, or scientific competition, to cite a few (García-Carmona, 2021b). This last element, for example, was apparent in the development of the Covid-19 vaccines. These were created in an extremely short period of time, something that had not happened before with other vaccines, thanks to the governmental support that laboratories received. By the same token, a "race for the vaccine" between countries was apparent, to see which would develop one first; in other words, a sort of scientific *nationalism* (Acevedo & García-Carmona, 2017). Nonetheless, the present work will only consider the *epistemic perspective* of NOS for the reasons set out below.

Consequently, the robustness of the arguments that members of the public develop in relation to socio-scientific questions will largely depend on how well-trained they are in aspects of NOS (García-Carmona & Acevedo, 2018). Because, what didactic research shows is that when people with limited training in NOS opine on topics related to science and technology, they usually limit their arguments to personal values, morals/

ethics, and social concerns (Bell & Lederman, 2003). Therefore, the development of an informed understanding of basic aspects of NOS is a central challenge for science education from the most basic levels (Akerson et al., 2011).

Nonetheless, the importance of learning basic concepts about NOS has not yet permeated the basic scientific education promoted in Spain. Proof of this is the scant attention it has traditionally received in Spanish publications on teaching of sciences, in comparison with other school science content (García-Carmona, 2021c). Didactic research also notes that science teachers do not usually have adequate training in NOS and how to teach it (García-Carmona et al., 2011; García-Carmona, 2021d). Meanwhile, some studies indicate that even science teachers with good training in this metaknowledge do not include it in the basic content of their plans (Akerson & Abd-El-Khalick, 2003). One possible explanation for this could be the limited importance of content relating to NOS in the regulations governing basic scientific education; something that has been noted in official curriculum documents from other countries (Olson, 2018). It is, then, important to question whether the situation is similar in Spain's new science curriculum for basic education (Royal decree 217/2022), which was approved following the enactment of the most recent education law (Organic Law 3/2020), known as the LOMLOE. In order to answer this, we carried out a piece of qualitative research guided by the following research question: What attention is paid to the comprehension of epistemic aspects of NOS in science curriculum provisions for compulsory secondary education in the framework of the LOMLOE?

2. Theoretical Framework

2.1. The nature of science in international reports and documents on scientific education

Twenty years ago, the theoretical framework of the TIMSS (Trends in International Mathematics and Science Study) international project, which evaluates educational performance of basic educational students in sciences and mathematics, set out the need to acquire basic concepts of NOS as follows:

> It is expected that students (…) will possess some general knowledge of the nature of science and scientific inquiry, including the fact that scientific knowledge is subject to change, the importance of using different types of scientific investigations in verifying/testing scientific knowledge (…). (Mullis et al., 2002, p. 79)

Some years later, the report by the Nuffield foundation on the state of scientific education in the European Union (*Science education in Europe: Critical reflections*), noted the following in relation to comprehension of NOS:

> Improving the public's ability to engage with such socio-scientific issues requires (…) not only a knowledge of the content of science but also a knowledge of 'how science works' – an element which should be an essential component of any school science curriculum. (Osborne & Dillon, 2008, p. 8)

Recently, the theoretical framework of the PISA project for evaluating scientific competence, states that "Understanding science as a practice also requires 'epistemic knowledge', which refers to an understanding of the role of specific constructs and defining features essential to the process of building scientific knowledge" (Organization for Economic Co-Operation and Development [OECD], 2019, p. 100). It should be made clear that, in international literature on science teaching, *epistemic knowledge* of science is another of the terms used to refer to aspects or content of NOS. Although it is also necessary to note that this term has limitations for representing the NOS construct holistically, given that it only refers to the *rational aspects* of the development of science, disregarding the *non-epistemic* ones that also influence it (García-Carmona, 2021b, 2021c; García-Carmona & Acevedo, 2018), as noted above.

Outside Europe, the main country driving NOS as basic content of science teaching is the USA (NSTA, 2020). For decades, the educational authorities of this country have explicitly suggested it in successive documents on science curriculum reform (Lederman, 2018). The most recent of these documents is *A framework for K-12 science education* (National Research Council [NRC], 2012), which states:

> Understanding how science has achieved [its] success (...) is an essential part of any science education. Although there is no universal agreement about teaching the nature of science, there is a strong consensus about characteristics of the scientific enterprise that should be understood by an educated citizen. (NRC, 2012, p. 78; ellipses added)

This broad review, of various of the most influential international reports on scientific education, reflects the extensive consensus around the promotion of a comprehension of basic concepts of NOS, in order to achieve the desired scientific literacy among the public.

2.2. What learning about the nature of science means and how to teach it

As noted above, NOS is metaknowledge about science. Therefore, learning it involves developing a comprehension of the most characteristic features of the practices that people dedicated to science carry out, the many factors that influence such practices, and the knowledge produced (Acevedo & García-Carmona, 2016; Adúriz-Bravo, 2005). So, while *learning science* generally refers to understanding scientific concepts, laws, models and theories, as well as developing different skills, such as observing, formulating hypotheses, taking measurements, recording data, etc., NOS relates to a comprehension of the epistemological, ontological and sociological characteristics of these aspects (Acevedo & García-Carmona, 2016; McComas & Clough, 2020). For example, it is one thing to know certain scientific models (atomic model, model of the double helix of DNA, etc.), and another different one to understand that these are partial and limited representations of reality that try to explain and predict the behaviour of nature, and that their validity is constantly being reviewed by the scientific community. Similarly, acquiring skills to observe phenomena is not the same as understanding that scientific observation is conditioned by scientists' expectations, by the limitations of their senses, and by the instruments used, and that what is observed can be interpreted in various ways, according to different observers, etc. In summary, knowledge *of* sciences and *about* science are two complementary but different perspectives; and our attention here is centred on the second of them.

As for how to teach aspects of NOS, didactic research has repeatedly shown that the best way to learn about it is with an *explicit-reflexive* didactic focus (Acevedo, 2009; Lederman, 2007). This means that NOS must be regarded as (*i*) curriculum content with its own learning objectives, whose introduction in class requires (*ii*) activities that promote reflection by students on questions about it, as well as (*iii*) a specific plan to evaluate the students' achievements and learning difficulties (García-Carmona, 2021d; Schwartz et al., 2004). So, simply participating in scientific enquiry at school does not necessarily mean that students will understand the most characteristic traits of scientific practice if no conscious reflection on it is undertaken, in parallel with the tasks required in the development of this enquiry (García-Carmona, 2012). Metaphorically, it is equivalent to saying that a person does not learn about the phenomenon of vision just by seeing.

Regarding how to introduce NOS content into the school science curriculum, there are various possibilities (Acevedo & García-Carmona, 2016): (*i*) integrated into the habitual school science content, (*ii*) as independent content, or (*iii*) through a combination of both of these strategies. Students' comprehension of NOS does not seem to depend on whether this is planned as specific content or integrated into other science content (Khishfe & Lederman, 2007). Nonetheless, the option of integrating NOS into the other content from the science curriculum has the advantage that it barely alters the planning of the school science course, which would encourage science teachers to introduce NOS in their syllabuses (Bell et al., 2012). Similarly, reflecting on aspects of NOS in authentic contexts of scientific development, such as scientific debates about a particular socio-scientific topic, can favour a more realistic vision of scientific activity (Acevedo & García-Carmona, 2017).

2.3. What should be taught about the nature of science

Give the multifaceted character of the NOS construct, establishing which aspects of it should be taught is a complex question that is constantly being debated (Acevedo & García-Carmona, 2016). Nonetheless, there are some interesting and viable proposals for introducing NOS content into the school science curriculum (e.g., Lederman, 2007; Erduran & Dagher, 2014; García-Carmona & Acevedo, 2018). Setting out a detailed comparative review of the different proposals in international literature on this topic would require a lot of space (see, for example: Acevedo & García-Carmona, 2016). Consequently, we will only consider the proposal from one of the most influential or representative documents at an international scale:

the recent PISA theoretical framework for scientific competence (OECD, 2019). This document combines much of the consensus on the minimum NOS content to be taught. This consensus is basically restricted to the *epistemic* perspective on NOS; in other words, that which focusses on the rational or cognitive aspects of this metaknowledge. There is somewhat less agreement regarding the *non-epistemic* perspective on NOS (García-Carmona, 2021b).

Under the label of *epistemic knowledge*, the theoretical framework of PISA makes a proposal for content relating to the *rational* or *epistemic* component of NOS.[2] Table 1 shows general indicators of the basic ideas in this regard, which — according to this document — should include this dimension of scientific competence, along with the other two key dimensions of this competence (knowledge of scientific content and procedural knowledge). Without entering into a debate about whether this proposal should be more comprehensive, given that it does not consider the non-epistemic perspective of the NOS, what does seem reasonable is that — in order to be consistent — all of the countries that participate in the PISA programme, including Spain, should feature, such ideas in their official school science curricula as a minimum. Therefore, the proposal from this document will be used as framework of reference in this study.

Table 1. Epistemic aspects of NOS in the theoretical framework of PISA 2018 for evaluation of science competence.

A. The constructs and defining features of science, that is:

1. The nature of scientific observations, facts, hypotheses, models and theories.
2. The purpose and goals of science (to produce explanations of the natural world), as distinguished from technology (to produce an optimal solution to human needs), what constitutes a scientific or technological question, and what constitutes appropriate data;
3. The values of science, such as a commitment to publication [of results and research conclusions], objectivity and the elimination of bias;
4. The nature of reasoning used in science, such as deductive, inductive, inference to the best explanation (abductive), analogical and model based;

B. The role of these constructs and features in justifying the knowledge produced by science, that is.

1. How scientific claims are supported by data and reasoning in science;
2. The function of differing forms of empirical enquiry in establishing knowledge, including both their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies);
3. How measurement error affects the degree of confidence in scientific knowledge;
4. The use and role of physical, system and abstract models, and their limits;

5. The role of collaboration and critique and how peer review helps to establish confidence in scientific claims;

6. The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

Source: OECD (2019, p. 108).

3. Method

To answer the research question, we considered the curricular provisions in Spain set out in the LOMLOE for science subjects in compulsory secondary education (Royal Decree 217/2022). We did this by applying standard qualitative content analysis procedures (Mayring, 2000). As noted above, the framework of reference for the analysis was the list of *epistemic aspects of NOS*, shown in Table 1 (OECD, 2019).

The information was analysed in three progressive filtering phases (Cáceres, 2003) using an *intraobserver* analysis method. In the *first phase*, we located explicit mentions to epistemic aspects of NOS in the different parts of the curriculum for the Biology and Geology (B-G) and Physics and Chemistry (P-C) subjects from the four years of compulsory secondary education in Spain. This resulted in the detection of a total of 50 mentions of epistemic aspects of NOS, distributed across the following sections of the curriculum for both subjects: (I) *course objective of the STEM competence*[3]; (II) *presentation/justification of the subjects*; (III) *list of specific competences of the subjects*; (IV) *evaluation criteria*; and (V) *basic knowledge*.

In the *second phase* of the analysis, carried out approximately one month later, the information was filtered. This process entailed considering only those mentions to epistemic aspects of NOS, the comprehension of which forms part of the evaluable learning. To do so, the corresponding evaluation criteria were consulted, given that these are the reference points that ultimately provide guidance about students' expected performance levels in relation to scientific competence. As a result, mentions of epistemic aspects of NOS, that are only in the document to justify the value or importance of science subjects in basic education were eliminated. For example, in the B-G curriculum, the role of modelling in the development of science is referenced in two different sections:

– In the description of *specific competence 4*, which states: "(…) in certain empirical sciences (…) data about reality are obtained, that must be interpreted in accordance with logic to establish models of a biological process (…)." (Royal Decree 217/2022, p. 41608).

– In the proposal for basic knowledge, included in block "A. Scientific project", for the courses from years one to three of compulsory secondary education: "Modelling as a method of representation and comprehension

> of processes or elements of nature" (Royal Decree 217/2022, p. 41611).

However, none of the evaluation criteria for the B-G subject for these academic years refers to a basic comprehension of the nature of scientific models, nor to the role of modelling in the development of the science. Therefore, these mentions were rejected. The same process was followed in the other cases.

As a result of this filtration, the initial list of epistemic aspects of NOS was reduced to 41 mentions. It should be noted that the mention of NOS in the *course objective* for the STEM competence, is not explicitly considered in the evaluation criteria for either of the two subjects. Nonetheless, we decided to consider it as evaluable learning in the curriculum because, as the regulation itself states, "The Course Objective is (…) the cornerstone of the whole curriculum, (…) towards which the objectives of the different stages converge (…) and the reference point of the evaluation (…) of the students' learning (…)" (Royal Decree 217/2022, p. 41594).

After two weeks, we examined the information again (*third phase*). As a result, this list of 41 mentions to epistemic aspects of NOS was reduced to 35 mentions with explicit attention in the evaluable learning. In terms of reliability, this gave a degree of intraobserver agreement of 88% and a *kappa* index equal to 0.67, and so, the analysis had a *substantial* level of agreement (Abraira, 2001). Of the difference between phases 2 and 3, 14.6% was because six mentions were finally eliminated as after analysing their content and wording again, it was not clear to the researcher that they actually represented a metaknowledge. A key part of this decision was the theoretical framework's position regarding how the promotion of learning of content relating to NOS should be clear and explicit in terms of how it involves achieving a *metascientific* comprehension of them.

4. Results

The first thing we should note is that, unlike what is stated in the international reports about scientific education consulted (e.g., Mullis et al., 2002; NRC, 2012; OCDE, 2019), in the curricular provisions analysed there is no clear reference to the fact that comprehension of NOS (i.e. a metaknowledge about science) comprises a key component of the scientific competence. Attention to aspects of NOS in the official science curriculum for compulsory secondary education in Spain must be inferred from more or less explicit references to it, which are scattered arbitrarily through the different sections in which this curriculum is organised. This is not in accordance with the PISA theoretical framework for scientific competence (OECD, 2019), which clearly states that comprehension of epistemic aspects of NOS is one of the three pillars of this key competence.

Table 2 shows the distribution of mentions of epistemic aspects of NOS, which have an impact on evaluable learning for science subjects. It is worth noting that, in the *course objective* relating to the STEM competence, conceived as the *cornerstone* of the curricula for science subjects, there is only a brief and general mention of NOS in one of the five operative descriptors of this competence: "STEM2. Uses scientific thinking (…), appreciates the importance of precision and veracity and displays a critical attitude towards the scope and limitations of science" (Royal Decree 217/2022, p. 41599).

As for the presentation of the subjects and the description of the specific competences, it should only be noted that references to epistemic aspects of NOS appear in a proportion similar to (and integrated with) those that are made about learning *of* sciences. However, given that this proportion was hard to quantify, we decided not to calculate the percentage of its weight.

The other notable piece of data is the limited attention to the learning of concepts about NOS in the evaluation criteria

Table 2. Mentions of epistemic aspects of NOS that affect evaluable learning from the science subjects (B-G and P-C) in compulsory secondary education, in the curriculum framework of the LOMLOE.

	Section of the curriculum				
	Course objective*	Presentation of the subject	Description of the specific competences	Evaluation criteria**	Basic knowledge***
B-G	1	3	5	6 (17.5%)	5 (6.9%)
F-Q		2	4	5 (16.7%)	4 (8.0%)

* Common to both subjects, in the framework of the STEM competence.
** Percentages calculated from the total evaluation criteria for the subjects: 35 criteria for B-G, and 30 criteria for P-C, corresponding to the four years in the stage.
*** Percentages calculated from the total of basic knowledge for the subjects: 72 criteria for B-G, and 50 criteria for P-C, corresponding to the four years in the stage.

Source: Own elaboration.

and basic knowledge, both in B-G (17.5% and 6.9% respectively) and in P-C (16.7% and 8% respectively). As noted above, the evaluation criteria, along with the corresponding basic knowledge, are the principal indicators or referents for teachers to develop their teaching plans. Therefore, the curriculum of both subjects gives the idea that the comprehension of aspects of NOS is something subsidiary or secondary compared to the acquisition of scientific knowledge and skills, and of particular attitudes. This perspective also differs from the approach of the PISA theoretical framework (OECD, 2019), where the weight of the comprehension of epistemic aspects of NOS is balanced with that of the other two basic dimensions of the scientific competence. In this sense, the Spanish science curriculum would be more or less consistent with this framework, if it allocated to the comprehension of NOS approximately a third of the evaluation criteria and basic knowledge.

Moreover, we analysed which epistemic aspects of NOS, of those identified in the PISA theoretical framework, were mentioned in the different sections of the curriculum for the science subjects from ESO. Table 3 summarises these results. It shows that, of the 10 epistemic aspects that this framework identifies, only four of them are suggested, reasonably explicitly: *A.3 the values of science*, *B.1 scientific claims are supported by data and reasoning*, *B.5 the role of collaboration and critique in science*, and *B.6 the role of science in the development of technology and society*. However, only the last three are present in the different specific sections of the curriculum for both subjects. The references to the values of science are very short and occasional: one in the operative descriptor of the course objective, cited above, when the importance of precision and veracity in science is discussed; and the other, in one of the evaluation criteria for biology and geology, when it refers to "adopting a critical and sceptical attitude towards information without a scientific basis" (Royal Decree 217/2022, p. 41610). Table 4 contains, as examples, extracts from mentions to these three aspects of NOS that most recurrent in the compulsory secondary education science curriculum. It is apparent that the mentions are, in general, fairly brief and linked to other types of content and learning, which are omitted in the extracts to underline only what relates to NOS.

TABLE 3. Epistemic aspects of NOS proposed in the PISA theoretical framework, which are referred to in the evaluable learning of the science subjects in compulsory secondary education, in the curriculum framework of the LOMLOE.

Epistemic aspects of NOS*	Course objective	Presentation of the subjects	Description of the specific competences	Evaluation Criteria	Basic knowledge
A.1 Nature of scientific knowledge (models, theories, etc.)					
A.2 Objectives of science and its difference from technology					
A.3 Values of science	✓			✓	
A.4 Nature of the types of scientific reasoning					

B.1 Scientific knowledge is based on data and reasoning	✓	✓	✓	✓
B.2 Function of the different forms of research				
B.3 The role of error in science				
B.4 Modelling in science				
B.5 Role of collaboration and critique in science	✓	✓	✓	✓
B.6 Role of scientific knowledge in technology and society	✓	✓	✓	✓

* To simplify the descriptors of the epistemic aspects of NOS, established in the PISA theoretical framework (Table 1), a brief identifying tag was used for each of them.

Source: Own elaboration.

The lack of attention to epistemic aspects of NOS in the compulsory secondary education science curriculum is striking given that there is broad consensus in the international bibliography about what to learn about NOS. For example, absorbing the importance of error in the development of science (García-Carmona & Acevedo, 2018); or understanding the characteristic traits of scientific observations, models, laws and theories (Lederman, 2007). It is also notable that even when the goals of science are discussed in the presentation of subjects and the description of their specific competences, assimilating these goals is not considered in the evaluable learning.

With regards to the epistemological relations and differences between science and technology (Acevedo & García-Carmona, 2016), there is also no attempt to establish them in the curriculum; something essential in an educational framework that advocates for the integration of different subjects under the umbrella of STEM. Similarly, it is important to note that, while the compulsory secondary education science curriculum refers to the use of a variety of methods and reasonings in scientific research, it does not specifically refer to them[4]. It restricts itself to general comments such as "(…) the use of the methodologies typical of science" (Royal Decree 217/2022, p. 41658).

TABLE 4. Extracts of mentions to the epistemic aspects of NOS, established in the PISA framework, with more presence in the curricular provisions in the LOMLOE framework for the science subjects in compulsory secondary education.

Epistemic aspects of NOS	Presentation of the subjects	Description of the specific competences	Evaluation Criteria	Basic knowledge
B.1 Scientific knowledge is based on data and reasoning	"The principal reliable sources (…) coexist with biased, incomplete or false information, and so (…) responsible and critical use of information and communication technology will be fostered (…)." (p. 41605, B-G)	"… developing the critical sense and the necessary skills to evaluate and classify information (…)." (p. 41661, B-G)	"To recognise information (…) with a scientific basis, distinguishing it from pseudosciences, hoaxes, conspiracy theories and unfounded beliefs (…)." (p. 41610, B-G)	"Trustworthy sources of scientific information: recognition and use." (pp. 41611 & 41614, B-G)
B.5 Role of collaboration and critique in science	"team work is fostered (…) as cooperation and communication are an essential part of the methodologies of scientific work." (p. 41605, B-G)	"Scientific development is rarely the result of work by isolated individuals and so it requires the exchange of information and collaboration between individuals, organisations and even countries." (p. 41607, B-G)	"… valuing the importance of cooperation in research (…)." (p. 41610, B-G)	"The historical evolution of scientific knowledge: science as a collective endeavour (…)." (pp. 41611 & 41614, B-G)
B.6 Role of scientific knowledge in technology and society	"…valuing the fundamental role of science in society." (p. 41605, B-G)	"… the vertiginous advance of science and technology is the driver of important social changes that occur increasingly often and with more palpable impacts." (p. 41607, B-G)	"Recognising and valuing, through historical analysis of scientific advances (…) that there are mutual repercussions between current science and technology, society and the environment." (p. 41663, P-C)	"Valuing scientific culture and the role of scientists in the principal historical and current milestones of physics and chemistry in the advance and improvement of society." (pp. 41663 & 41666, P-C)

*Note: B-G: Biology and Geology; P-C: Physics and Chemistry.
Source: Own elaboration based on Royal decree 217/2022.

There are important epistemic aspects of NOS, which are mentioned in the description of the specific competences of the science subjects, but which, sadly, have no impact on the evaluable learning. This is the case, for example, of recognising the importance of the knowledge established in the development of the new scientific knowledges. In fact, the observations in a piece of scientific research are already *theory laden* (Lederman et al., 2013). The B-G curriculum refers to such an aspect in the description of one of its specific competences, as follows: "Any process of scientific research must start with the collation and critical analysis of the publications in the area of study, building the new knowledge of the already existing foundations" (Royal Decree 217/2022, p. 41607).

One notable aspect, in favour of the new science curriculum for compulsory secondary education, is that it considers two ideas of special importance within NOS, and that it does not consider the PISA theoretical framework, at least, explicitly. These ideas are:

Knowing and emphasising the contribution of women in science (García-Carmona & Acevedo, 2018), with mentions such as: "Valuing the contribution of science to society (…) emphasising and recognising the role of female scientists (…)" (evaluation criteria, B-G, Royal Decree 217/2022, p. 41610); and

Understanding that science is a field in constant construction (García-Carmona & Acevedo, 2018; Lederman et al., 2013), with references such as: "Valuing the contribution of science (…) understanding research as an undertaking (…) in constant evolution" (evaluation criteria, B-G, Royal Decree 217/2022, p. 41610); and "Recognising and valuing (…) that science is a process in permanent construction (…)" (evaluation criteria, P-C, Royal Decree 217/2022, p. 41663).

5. Conclusions

Based on the results of the analysis carried out, we conclude that comprehension of NOS is regarded as a minor or secondary educational challenge in the new basic scientific education curriculum. Firstly, because the curricular provisions analysed (Royal Decree 217/2022) do not explicitly emphasise that NOS should be a key part of the development of the STEM competence, with a view to improving the scientific literacy of the students (NSTA, 2020; OECD, 2019). Secondly, and perhaps as a cause of the foregoing, because the curriculum gives a fairly limited weight or position to NOS in the list of evaluable learning for science subjects (B-G and P-C) in compulsory secondary education: 17.5% of the total of them, in the best of cases. Consequently, Spain joins the countries that undervalue NOS in comparison with other content in their school science curricula (Olson, 2018).

In relation to the quantity and types of epistemic aspects of NOS, the new science curriculum for compulsory secondary education has little coherence with the PISA theoretical framework for scientific competence. This is disconcerting, given that Spain has participated officially in this programme since its beginnings. It has been found that the Spanish curriculum only refers to four of the 10 epistemic aspects proposed in this international framework, with three of them standing out in particular: *scientific knowledge is supported by data*, *the role of collaboration in science*, and *the role of science in the development of technology and society*. Therefore, it omits various epistemic aspects of NOS, despite there being a broad international consensus on attention to it in the teaching of sciences (Lederman, 2007; García-Carmona & Acevedo, 2018). Nonetheless, the fact that the Spanish curriculum emphasises the role of women in science and the dynamic or evolving character of science should be noted, as a difference with regards to the PISA theoretical framework. Even so, the great majority of the mentions to epistemic aspects of NOS in the curriculum are scant and fairly general in their wording. Furthermore, in the evaluation criteria, for example, these mentions are almost always linked to other different perspectives on NOS; consequently, they affect its central position, since it is *shielded* by these other educational challenges that are more classical or consolidated in scientific education.

Ultimately, it can be said that an opportunity has been lost to bring Spain's educational provisions on the scientific competence into line with international frameworks such as PISA in relation to the comprehension of basic concepts about NOS. As a result, it can be predicted that, as has been happened so far in the Spanish educational context, NOS will continue to receive little attention in basic scientific education (García-Carmona, 2021c). The hope is now in the training of science teachers (García-Carmona, 2021d), which should: (1) accentuate the educational value of tackling aspects of NOS in basic scientific education; (2) improve teachers' comprehension of NOS; (3) help teachers make visible in official curricular provisions – as a prescriptive framework for their didactic designs – mentions to NOS in basic scientific education; and (4) provide appropriate didactic materials to integrate NOS content into science classes.

Notes

[1] The history, philosophy and sociology of science are also known as *metasciences* (Adúriz-Bravo, 2005).

[2] This work, therefore, identifies *epistemic knowledge* with *epistemic aspects of NOS.*

[3] This English initialism is used in the new curricular provisions corresponding to compulsory secondary education to refer jointly to *mathematical competence and competence in science, technology, and engineering* (Royal Decree 217/2022, p. 41598).

[4] The first operative descriptor of the STEM competence cites the inductive and deductive methods, but in relation to mathematical thinking; at no moment are they covered in the development of the B-G and P-C subjects.

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