

The Nature of Science in the French high school science syllabuses, role of the History of Science and innovative pedagogical proposals

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ABSTRACT

We present here the main results of two studies we conducted in our laboratory in the NoS research field. One study deals with the representation of science conveyed by the French science high school syllabuses of two school subjects (biology-geology, physics-chemistry) and of two majors (scientific and economic-literary). We demonstrate how we designed an analysis tool, a matrix, adopting a broad definition of NoS and choosing an approach which privileges the individual and his practices but takes also into account the social and temporal dimensions of the scientific enterprise. We show how we used this NoS multidimensional matrix in order to analyze the programs and the representations of sciences they convey. We discuss the place the syllabuses give to the NoS teaching and the role accorded to the history of science. The second study concerns the design of innovative pedagogical units based on the history of physics in order to convey a greater authenticity of NoS in teaching. We show how our NoS multidimensional matrix can help to elicit and characterize epistemological learning goals. We outline how classroom activities involving collective inquiry based on the implementation of documents can be generated.

KEYWORDS

Nature of science, history of science, curriculum, innovative pedagogical units, secondary education

RÉSUMÉ

Nous présentons les principaux résultats de deux études réalisées dans notre laboratoire dans le domaine de recherche désigné par NoS (Nature of Science). Une étude porte sur la représentation des sciences véhiculée par les programmes de l'enseignement secondaire français de deux disciplines scolaires scientifiques (biologie-géologie, physique-chimie) et de deux filières d'enseignement (scientifique et économique-littéraire). Nous explicitons comment nous avons conçu notre outil d'analyse en choisissant de caractériser la NoS par une approche qui privilégie l'individu et ses pratiques et qui prend également en compte les dimensions sociales et temporelles de l'entreprise scientifique. Nous montrons comment nous avons utilisé cet outil, une matrice multidimensionnelle, afin d'analyser les programmes d'enseignement et les représentations des sciences qu'ils véhiculent. Nous discutons de la place accordée par les programmes à l'enseignement de la NOS et au rôle accordé à l'histoire des sciences. La seconde étude porte sur la conception de séquences d'enseignement innovantes visant à transmettre une image plus authentique de la nature des sciences grâce à l'introduction de l'histoire de la physique dans l'enseignement. Nous montrons comment cette matrice multidimensionnelle peut aider à définir et caractériser des objectifs opérationnels d'apprentissage épistémologique. Nous détaillons comment des situations d'investigation fondées sur l'étude collective de dossiers documentaires peuvent être élaborées afin de les atteindre.

MOTS-CLÉS

Nature des sciences, histoire des sciences, programmes d'enseignement, innovations pédagogiques, enseignement secondaire

INTRODUCTION

The French science syllabuses have changed in the last decade. The underlying stake is not only to attract more students towards scientific careers but also to give all students a cultural and scientific background that allow them to become responsible citizens. The idea is to act early in primary schools and to ensure continuity between the different levels of education. Recommendation is given to teachers to implement innovative pedagogical strategies based on inquiry activities and to introduce elements of the history of science.

As knowledge *about* science is considered to be a critical component of scientific literacy (Driver et al., 1996; Bybee & Ben-Zvi, 2003) we decided to start a research program in the field of research called in the English-spoken countries by the acronym NoS (Nature of Science). In our laboratory, we are conducting three types of studies: one focuses on the science syllabuses of the secondary education, other deals with the elaboration and implementation of innovative pedagogical units based on the history of science, the latest concerns the exploration of the representations of science of scientific freshmen (Maurines et al., 2014). This research program led us to examine the choices made about the NoS construct in the literature and to elaborate our own theoretical framework. Indeed, introduced for educational purposes, the acronym NoS refers to different approaches and ways of characterizing science (Mc Comas, 1998; Adúriz-Bravo, 2004; Lederman, 2007; Allchin, 2011; Irzik & Nola, 2011; Abd-El-Khalick, 2012a; Matthews, 2012). Besides, different strategies are advanced for the NoS teaching (Abd-El-Khalick, 2012b; Duschl & Grandy, 2012; Allchin, Andersen & Nielsen, 2014).

First, we present the NoS framework we elaborated and the main results of a study focused on the high school science syllabuses (Maurines et al., 2012, 2013). One of the questions was to identify which NoS contents the syllabuses include and which representation(s) of science(s) they convey. Another one was to identify the pedagogical strategy(ies) the syllabuses suggest for the NoS teaching. In particular we emphasize the place and role accorded to the history of science and the types of history of science evoked. Second, we outline the innovative pedagogical units based on the history of science we designed in order to convey a greater authenticity of the nature of science in teaching (Maurines & Beaufils, 2011, 2012a; Maurines et al., 2012). In conclusion, we give some information about the first teachers' feedback on our proposals and direct to the study of Slaïmia (2014) for the results of the first controlled experimentation of one unit (Slaïmia & Maurines, 2011).

A MULTIDIMENSIONAL NOS FRAMEWORK

Even if there is a long tradition advocating the benefits of NoS understanding for students studying science, there still exist debates on the NoS construct itself. Considering that there is an acceptable level of generality on which there is little disagreement between experts and that the goal of NoS teaching at the grade 12 level is to provide students a general understanding, Lederman (2007) proposed a “*consensus view*” formulated in seven tenets. This view consists in choosing as teaching goals consensual features about science, formulating them according a general approach which characterizes science, more precisely scientific knowledge. This approach is being discussed in recent years.

In 2011, Irzik and Nola defend “*the Family Resemblance Approach*” in order to highlight specificities and similarities between disciplines. Their *FRA* approach is mainly focused on

practices inside the scientific community and pays little attention to the socio-cultural and temporal aspects¹. Matthews (2012) recommends a change of terminology and of focus from the Lederman approach, which he describes as essentialist and based on epistemology, to a more contextual and heterogeneous approach, which he calls FoS (Features of Science). The list of features he suggests is open and grounded on the complete spectrum of academic disciplines encompassed by the term “*science studies*”. Allchin (2011) supports too that the nature of science cannot be fully or adequately expressed by a list of explicit tenets. Based on the principle that the aim of science education is to enable students to become scientifically literate citizens, he advances a NoS characterization, which he presents as moving “*from the experimental to the social-namely, to Whole Science*”. His characterization frames NoS as a set of dimensions shaping reliability in scientific practice, that is to say emphasizing “*how reliability is achieved as knowledge develops and how it is preserved as it moves from one place to another*” (Allchin, 2011, p. 524).

As we adopt the position defended by thinkers who look to transcend the opposition between the advocates of an internalist and rationalist view of science and the advocates of an externalist and relativist vision (Chalmers, 1991; Pestre, 2006), we elaborate our NoS framework in considering the various academic disciplines of the science studies field. Thus, we join the position supported in the NoS research field by Matthews (2012) and Mc Comas and Olson (1998), for whom this is the only way to permit a rich description of this complex and multifaceted object that science is. Moreover, this is the only way to elaborate a framework opening to a wide range of possible for research and teaching.

The approach we choose in order to formulate the NoS characteristics privileges the individual and his practice but takes also into account the social, temporal and psychological dimensions of the scientific enterprise. Indeed, for us, knowledge is embedded in social practices conducted by human actors (scientist, engineer, technicians...), interacting in a scientific community and living in a given society. We agree with Duschl (2008) and Sandoval (2014) that scientific inquiry and NoS are inseparably intertwined with each other.

We refer to the theoretical framework of social practices advanced by Martinand (1986): “*a social practice of reference can be defined as any social activity taken as a reference for school content. This social practice can be present-day, old, virtual, evolving or not. The point at stake in this theoretical framework is to characterize the practice in*

1 It has to be noticed that in 2014, Irzik and Nola enrich their cognitive-epistemic *Family Resemblance Approach* by introducing a social-institutional dimension. The reader can refer to the recent work of Erduran and Dagher (2014): they present the evolution of the Irzik and Nola’s approach before extending it by considering more aspects in the social-institutional dimension, and advancing another FRA. In both approach, science is not inscribed in society in general.

all their dimensions in order to inform pedagogical choices”. Different dimensions can be considered to objectivize the practice: the actors, their relations, the kind of projects, the equipment, the knowledge, the products, the attitudes expected, etc. In order to emphasize that science evolve with time, we consider also a historical dimension. The table I presents the nine dimensions we choose to retain in order to objectivize science as a social practice evolving with time.

Our position can be compared to the one adopted by Irzik and Nola (2011) since both privilege the individual and his practice. However, it differs from it since we consider also socio-cultural and historical features and base our NoS framework on more than four dimensions (activities, aims and values, products, methods and methodologies) and one academic discipline (philosophy)². If we propose to frame NoS with multiple dimensions as Allchin (2011), we inscribe science in society in general and not only in the scientific community. If a heterogeneous approach of NoS is also the one recommended by Matthews (2012), our approach differs from his proposal of a FoS list by the fact that the dimensions we retain are articulated through the concept of social practices.

TABLE 1

Science as a social practice described through the nine dimensions of Matrix 1(Maurines et al., 2012)

Matrix I : NoS dimensions	
Aims and general characteristics (Presuppositions, Values)	human actors
Objects of study	
Resources	
Products	
Elaboration (activities, methods, processes, rules)	
Attitudes	
Scientific community	
Society	
History	

2 In the second FRA approach proposed by Irzik and Nola in 2014, two dimensions are considered: science as cognitive-epistemic system and science as a social-institutional system. The first dimension includes the four categories of the first FRA, the second is decomposed into four other categories: professional activities, scientific ethos, social certification and dissemination of scientific knowledge, social values. Here also, the reader can refer to the presentation of Erduran and Dagher (2014) who add three other categories to the Irzik and Nola’ social-institutional dimension. The FRA holistic model they propose considers three other aspects: financial system, political power structures, social organization and interactions.

THE NATURE OF SCIENCE IN THE FRENCH HIGH SCHOOL SCIENCE SYLLABUSES

Research questions and methods

French education is centralized: the curricula are national and guide strongly the authors of textbooks and the teachers. So knowing how the NoS is taken into account by the science syllabuses is a crucial issue. We looked to answer several questions:

- Which place is given to the NoS teaching in the science syllabuses at the secondary school level? Which strategy (ies) is (are) recommended to teachers?
- Which NoS elements are included in these syllabuses and which representation (s) of science do they convey?
- Do these NoS elements and representation (s) of science depend on the school discipline, the level of teaching, and the major -scientific or economic-literary?

We analysed the syllabuses³ of two school subjects (Physics and Chemistry noted here PC; Life and Earth sciences noted here SVT), from grades I0 to I2, and of two types of majors (scientific and economic-literary⁴).

It has to be noticed that the syllabuses consist of two very different parts. The introduction part explains and justifies the missions of science teaching; the content part describes the contents to be taught (knowledge, abilities). It has also to be noted that the syllabuses consist of two types of discourse. One deals explicitly with science, the other focuses on the school subject. As our main hypothesis is that implicit statements concerning school science convey information on the NoS, we decided to analyse both types.

We used a mixed methodology which combines features associated with both qualitative and quantitative approaches and followed a dialectical process between the theoretical and the empirical.

First, on the basis of an epistemological analysis, we designed the matrix I composed of nine dimensions.

Second, we identified the dimensions evoked by each sentence of the syllabuses of the grade I0. We coded all the sentences of the syllabuses by specifying whether the

3 The syllabuses are published in the BOEN (Bulletin Officiel de l'Éducation Nationale) and can be uploaded from the Eduscol website [<http://eduscol.education.fr/pid26017/programmes-du-lycee.html>].

4 The compulsory teaching ends at the age of I6 in France. There are two scientific school subjects: SVT and PC. All students received the same PC and SVT teaching from grade 6 to grade I0, and then it depends on the major. The students in the economic and literary majors follow the same science syllabus which concerns PC and SVT. There is no science teaching in grade I2. The examination is taken for the science subject in grade II.

dimensions are considered explicitly as a characteristic of science(s) or implicitly as a characteristic of school science. The table 2 shows an example of how the sentences of the syllabuses were coded. Four researchers made several encodings in order to reach consensus. We then realise a quantitative analysis in counting the number of sentences in which a dimension appears. We finally calculate the percentages of phrases which consider a specific dimension on the total number of sentences of the syllabuses or of each part of the syllabuses.

TABLE 2

Extract of the encoding table
 (The first NoS dimension includes aims and general characteristics noted here GC)

GRADE 10 PHYSICS – CHEMISTRY											
Syllabus (BOEN n° 4 -29/04/10)	Speech about science		Matrix I: selection of 9 aspects of scientific practices								
Examples of syllabus' sentences	Explicit	Implicit	Aims + GC	Objects	Resources	Products	Elaboration	Attitudes	Community	Society	History
18	Unlike dogmatic thinking, science is not made of inviolable revealed truths, but of questions, research and responses which evolve and enrich over time.		✓			✓		✓	✓		✓
19	Introduce students to the scientific process is to allow them to acquire skills that enable them to implement a reasoning in order to identify a problem, formulate hypotheses, compare them with experimental findings, and exercise their critical thinking.					✓		✓	✓		

Third, we categorized the NoS elements extracted at a finer grain in various sub-dimensions and categories, and obtained a matrix 2, which retains only the sub-dimensions and categories identified in the syllabuses of the grade 10 (see table 3 for the sub-dimensions and table 4 for the categories identified in the “aims” dimension). We follow the same procedure for the analysis of the syllabuses of the grade II and I2.

Some results on the quantitative analysis

Which place is given to the NoS by the science syllabuses?

We illustrate this point in taking the example of the grade 10 syllabuses. Similar results are obtained with the grades II and I2 syllabuses.

Concerning the type of discourse about science, the quantitative analysis on the whole syllabuses shows that for the two school subjects, PC and SVT, the implicit

TABLE 3

The sub-dimensions identified in the grade 10 syllabuses (Maurines et al., 2012b)

Dimensions (a priori)	Sub-dimensions (a posteriori)
Aims and general characteristics	Aims
	Values
Objects of study	Types
	Problems explored
Resources	Intellectual
	Material (instruments, tools, technologies)
Products	Intellectual
Elaboration	General processes
	Activities
	Methods and rules
Attitudes	Cognitive
	Affective and behavioral
Scientific community	Characteristics of the community' s members
	Collective construction
	Relations within the scientific community
Society	Sciences' roles within the society
	Relations between sciences and society
History	Scientific knowledge evolves
	The temporal context in which scientists live evolves
	Elaboration's ways throughout time
	Type of history (e.g. succession of special dates)

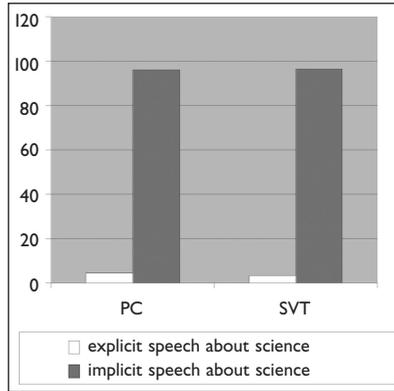
discourse is the most frequent whereas the explicit one is almost missing (figure 1). Concerning the two parts of the syllabuses, the implicit discourse is the most frequent in both cases; the explicit one is only present in the justification parts of the syllabuses (figure 2) and completely missing in the content-parts of the syllabuses (figure 3).

Which NoS dimensions are considered by the science syllabuses?

We first illustrate this point in taking the example of the grade 10 syllabuses. We then discuss the resemblances and differences between grades (10-11-12) and majors (scientific, economic-literary).

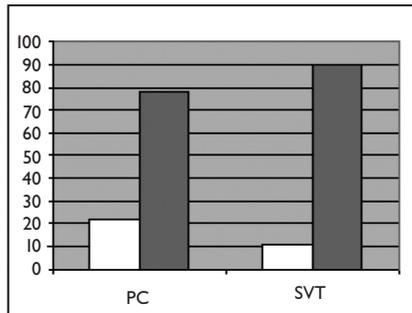
On the figure 4, which concerns only the explicit speech about science present in the justification parts of the grade 10 syllabuses, we notice that both syllabuses evoke all the NoS dimensions but that the representation of the different dimensions is more balanced in the PC syllabus and that the SVT syllabus emphasizes the dimensions “aims” and “elaboration”.

FIGURE 1



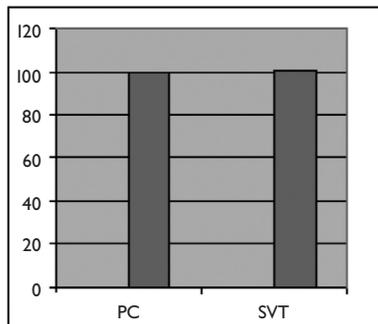
The distribution of explicit and implicit speeches about science in the whole grade 10 syllabuses

FIGURE 2



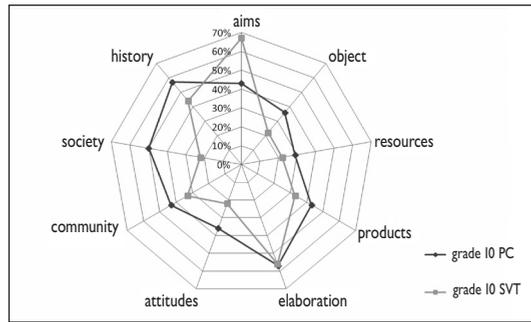
The distribution of explicit and implicit speeches about science in the justification parts of the grade 10 syllabuses

FIGURE 3



The distribution of explicit and implicit speeches about science in the content parts of the grade 10 syllabuses

FIGURE 4

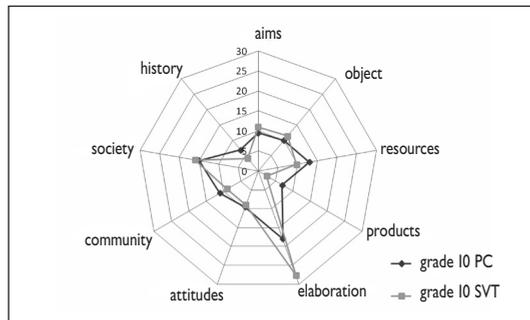


The NoS dimensions in the explicit speech about science present in the justification parts of the grade 10 syllabuses

When considering not only the explicit discourse about science included in the justification parts of the syllabuses but also the implicit one (figure 5), we notice that the distribution of the different dimensions emphasises the dimension “elaboration”, particularly in the SVT syllabus, and that the dimension “history” is one of the less evoked.

On the figure 6, which concerns the content parts of the syllabuses constituted of an implicit speech about science only, the representation of the different dimensions is limited to three dimensions “objects”, “products” and “elaboration”.

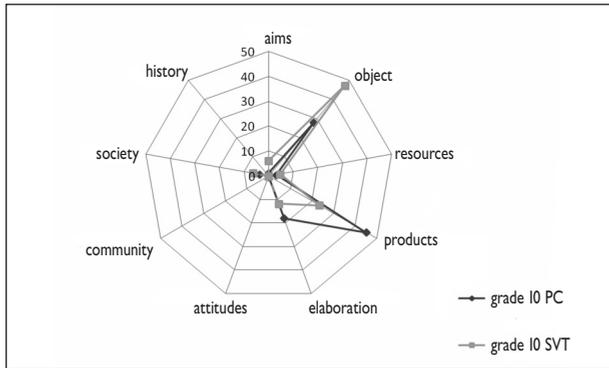
FIGURE 5



The NoS dimensions present in the justification parts of the grade 10 syllabuses (implicit and explicit speeches about science)

The distribution of the different dimensions in the justification parts of the PC and SVT syllabuses of different grades depends on the school discipline in the scientific major (figures 7 and 8). This distribution is more balanced in the PC syllabuses than in the SVT syllabuses. All the syllabuses emphasise the dimension “elaboration”. In the justification parts of the PC syllabuses, we notice an increase in the dimensions “objects”, “products”, “elaboration” and a reduction in the dimensions, “society”, “community”, “attitudes” going from grade 10 to grade 12.

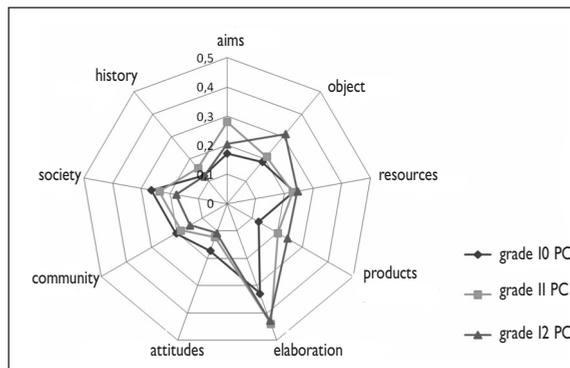
FIGURE 6



The NoS dimensions present in the content parts of the grade 10 syllabuses (implicit speech about science only)

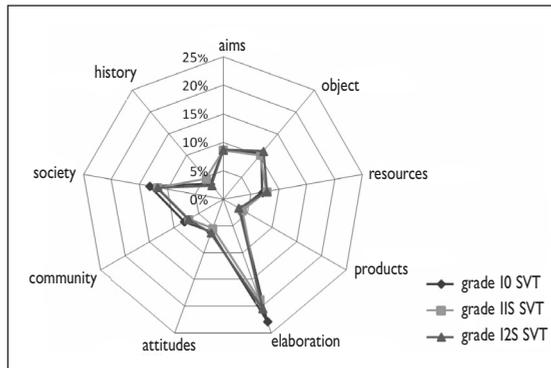
On the figure 9, which concerns the justification parts of the syllabuses of the grade II for different majors and school disciplines, some differences can be noticed. Three dimensions are more represented in the science syllabus of the economic-literary major than in the PC and SVT syllabuses of the scientific major: “society”, “community” and “attitudes”. In the scientific major, the dimension emphasized is again “elaboration”.

FIGURE 7



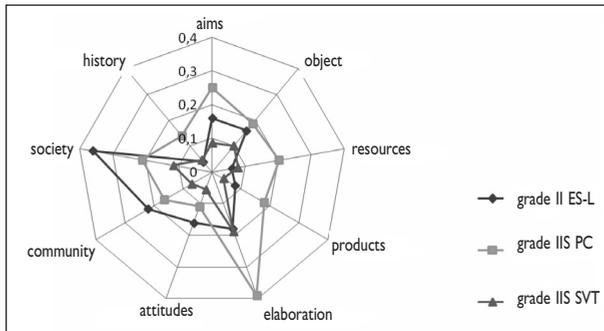
Justification parts of PC syllabuses for grades 10-11-12

FIGURE 8



Justification parts of SVT syllabuses for grades 10-11-12

FIGURE 9



Justification parts of grade 11 syllabuses for different majors (scientific, economic-literary) and school disciplines (PC, SVT, science)

Some results on the qualitative analysis

The analysis of the units extracted from the syllabuses leads us to identify different sub-dimensions and categories within a same dimension. The comparison reveals that if some categories are common to both syllabuses, others are specific to one syllabus.

We illustrate this point in taking the example of the grade 10 syllabuses and the dimension “aims and general characteristics”. The table 4 shows that four categories are in common (in white) to the SVT and PC syllabuses and five are specific to the PC syllabus (in grey). The two syllabuses shared categories which report of the fact that sciences allow to understand the world and to provide explanations, that these explanations are consistent and that they provide a global and consistent representation of the world. The common categories also report of the ideas of progress, of a relationship between the different experimental sciences and also of a specificity of the

scientific knowledge compared to other types of knowledge. Concerning the categories present in the PC syllabus only, they report of the idea that the aim of sciences is not only to provide explanations but also to describe, to predict and to act. They also report of the idea that laws and science are universal, that sciences possess cognitive and aesthetic values.

TABLE 4 *The categories evoked by the grade 10 syllabuses in the dimension “aims and general characteristics”*

Matrix I	Matrix 2			
NOS dimensions	Subdimensions	Categories	PC	SVT
Aims and general characteristics	Types of aims	Descriptive aim	X	
		Explanatory aim	X	X
		Predictive aim	X	
		"act on" aim	X	
	General sciences features	Sciences look for/ search/ aspire for universality	X	
		Sciences aspire for products / field consistency	X	X
		Sciences join a positive evolution	X	X
		Sciences have aesthetic and cognitive dimensions	X	
		Scientific practices are specific (relationship between scientific disciplines, demarcation)	X	X

It is also important to notice that differences which correspond to different focuses inside the common sub-dimensions or categories can exist. Thus, in the sub-dimension “activities” of the dimension “elaboration”, the SVT syllabus mentions only the rational thinking whereas the PC syllabus highlights also imagination and creativity. Similarly, in the sub-dimension “ways of elaboration of the scientific knowledge” of the dimension “history”, we note that the PC syllabus highlights some internal and external social aspects of science and underlines the fact that assumptions can reveal themselves wrong whereas the SVT syllabus focuses on conceptual aspects (table 5).

TABLE 5

Sentences of the grade 10 syllabuses classified in the sub-dimension “ways of elaboration of the scientific knowledge” of the dimension “history”

PC grade 10 syllabus	SVT grade 10 syllabus
<p>Science is a way of thinking that seeks to understand and describe the real world with ever more universal and effective laws, by back and forth, inductive and deductive, movements between theoretical modeling and experimental verification.</p> <p>[...] science is [...] made of questions, inquiries, and responses that evolve and grow richer with time.</p> <p>By challenging the world’s conceptions and the man’s place, the sciences’ progress often faced conservatism, traditions, arguments of authority, and obscurantisms of all kind.</p> <p>Science is also a school for humility and for patience in so far as this story is associated with an impressive amount of false assumptions and passionate controversies.</p>	<p>The history of the scientific knowledge elaboration, of its modification through time is useful means to understand the nature of the scientific knowledge and its ways of construction with their advances and their regressions.</p> <p>The historical approach must not be reduced to the evocation of successive events and thus give a wrong idea of the scientific demonstration: if some arguments have major historical importance, it is rare that only one of them is sufficient to result in decisive changes in scientific knowledge; similarly, it would be pointless to claim that students could “reinvent”, in one or two sessions, which required the work of several generations of researchers.</p>

The representations of science conveyed by the syllabuses

Concerning the grade 10⁵, the syllabuses of the two school subjects refer to science as a reduced social practice since a limited number of dimensions is emphasized. The philosophical aspects (what are the characteristics of scientific knowledge? how is it produced?) are the most evoked. In both cases, sociology and psychology are less considered. Some differences can be noticed:

- concerning psychology, the SVT syllabus emphasizes more rational aspects than the PC syllabus, which also considers emotional aspects and creativity;
- concerning sociology, the SVT syllabus focuses on the impact of science on society whereas the PC syllabus takes also into account the role of the community, and the impact of society on science and scientists;
- concerning history, the SVT syllabus refers to a conceptual history whereas the PC syllabus refers more to cultural aspects.

These differences reflect different points of views about NoS between school subjects. The SVT syllabus conveys a more rationalist and internalist vision of science whereas the PC syllabus gives more importance to the human and social dimensions of science.

5 For a first comparison, with English-spoken curricula, see Maurines (2013), Maurines et al. (2013).

Moreover, the PC syllabus mentions some values of the scientific enterprise. Even if the idea of demarcation is present in the two syllabuses, it seems that the PC syllabus explicitly promotes science.

The comparison of the PC and SVT syllabuses of the grades II and I2 scientific major, even if not completely done at a qualitative fine grain, seems to reveal the same differences between school subjects. However it has to be noticed that in the SVT syllabus of the grade II scientific major, the only one of the SVT syllabuses to specify a topic to study on the basis of a historical approach (see below), some internal social aspects of science are evoked.

Besides, regarding the grade II, a more rationalist and internalist vision of science is conveyed in the PC syllabus of the scientific major than in the PC-SVT syllabus of the economic-literary major. As to the PC syllabuses of the scientific major, the representation of science is reduced to a more internalist vision in grade I2 than in grade I0.

The place of the NoS teaching, the strategies suggested by the syllabuses and the role of the history of science

Whereas the explicit discourse on science is more represented in the PC syllabuses than in the SVT syllabuses, NoS remains an implicit goal of education in the PC syllabuses. In grade I0, only the acquisition of a scientific literacy for citizenship is emphasized but this latter is not defined. In grades II and I2, the issues are also to motivate students for scientific studies and to prepare them for such studies.

NoS is an explicit goal of education in all the SVT syllabuses. In the justification part of the scientific major (grades I0 to I2), we read: *“If the amount of scientific knowledge to remember is reasonable, it is to enable teachers to devote time to help students to understand what scientific knowledge is, its construction and its evolution in the history of science”*. The focus is on philosophical and historical aspects.

In the PC-SVT syllabus of the grade II economic-literary major, the education purpose is the acquisition of a scientific literacy for citizenship. The question for students is *“to understand in a simple manner the approaches that led to the current notions and concepts”* and *“to grasp scientific issues related to societal questions (sustainable development and health)”*. Advantages, but also limits⁶, of the scientific and technological advances have to be discussed.

All the syllabuses (PC and SVT) of the scientific major recommend implementing inquiry teaching based on experimental activities if possible. The PC-SVT syllabus of the grade II economic-literary major emphasizes oral and written argumentation activities based on documentary research.

6 This is the only syllabus which mentions the points students need to examine in debates on societal issues and which explicitly evoke limits for the scientific and technological advances.

In the PC justification part of the syllabuses, history of science is presented as a mean to build scientific knowledge in grade 10 and to put science into context and culture in grades 11 and 12. Some scientific subjects are elicited for such purpose; no justification is given for the choice made and nearly nothing is said about what needs to be highlighted (table 7 in annex 1). The points emphasized concern the relation between theory and observation/experiment, the importance of the technical aspects in the advancement of science and some values such as universality.

In the justification part common to the SVT syllabuses, history of science is presented as a mean to build original inquiry teaching but also to understand the nature of scientific knowledge and its construction. The risk to convey a false idea of the scientific demonstration by presenting a succession of events is emphasized. It is pointed that if some arguments have major historical importance, it is rare that only one of them is sufficient to result in decisive changes in scientific knowledge. Only one scientific topic is suggested for an historical approach in the SVT syllabus of the grade 11 scientific major: the plate tectonics model. This example is presented as an opportunity to help students to understand the concept of scientific model and how it is produced. *Inter alia*, the syllabus emphasizes the process of enrichment of the model through a hypothetical deductive approach, the exchanges in the scientific community and the technical progress: *“This is a hypothetical and tentative intellectual construction. Over time, the scientific community refines and clarifies it by constantly confronting it with reality. It has a predictive value and this is often one of these predictions that led to the search of a new fact which, according as it is discovered or not, leads to support or modify the model. The strength of the model is gradually acquired by accumulating observations agreement with him. Technical advances accompany the development of the model as well as the debates and controversies”*.

In the justification part of the syllabus of the economic-literary major, history of science is presented as a mean to understand the ways of elaboration of scientific knowledge. Some topics are suggested in the content part of the syllabus for an historical approach. Three are quoted without further indication: vision, colors and arts, food processing and preservation. For the last one, the methods of birth control, the question is to locate the chronology of their emergence in time and society.

All this suggests that doing science through inquiry activities based on experiment or/and documentary activities in school would be sufficient for students to build an adequate image of NoS.

Curriculum implications

These results raise questions about teachers and lead us to promote some curricular suggestions about the NoS teaching. Indeed, as the NoS remains an implicit purpose of science teaching and as this general objective is not declined into specific goals in the

content part, we can ask whether teachers choose NoS as a teaching purpose and if yes how they do in practice. Indeed, different studies conducted in France and abroad show that teachers are unaware of the epistemological issue of science learning. Even those for whom this is a significant dimension tend simply to privilege the acquisition of knowledge and scientific competency (Robardet, 1995; Roletto, 1998; Hipkins, Barker & Bolstad, 2005; Lederman, 2007; Pélissier, Venturini & Calmettes, 2007; Pélissier, 2011). Therefore, let us suggest that the NoS should be presented as an explicit purpose of science education in the justification parts of all science syllabuses and that this general objective should be elicited in the content parts into specific teaching goals consistent with the educational issues. Let also suggest that contents to be taught and ways to implement them should be proposed to teachers.

Similar questions arise about the role given by teachers to the history of science in their teaching, in particular in the case of the PC teachers. Indeed, some studies reveal that physics textbooks present very few elements of HS, and that they convey a reductive and false image of science, either through the approaches and the vocabulary used, or the choice of historical elements (Johsua, 1989; Dupin, 2006; Guedj, Laubé & Savaton, 2007; Beaufils & Maurines, 2008, 2013). These elements refer to only one person who is most often well known. Discoveries seem to happen immediately and are linked to a specific date; they appear to be animated by a superhuman mind possessed with intuitive genius, arising from an unequivocal idea or a decisive experiment. By focusing on the discovery of the laws of science, these historical elements obfuscate the importance of scientific technique and the social and cultural dimensions of science. They overlook the diversity of issues at stake (theoretical, experimental, technical, epistemological) that scientists pursue, along with the theoretical, epistemological, and metaphysical assumptions that guide their work, and the problematic of discerning what aspects characterize science in relation to other cultural fields (the specific nature of scientific inquiry, proofs, and methods). At the same time, the anachronism consisting in the juxtaposition of modern practices and of the evocation of historical figures can be strongly criticized because it may suggest that the scientists' concerns and approaches have always been the same. This is consistent with the results of studies conducted abroad about chemistry and biology textbooks (Mathy, 1997; Abd-El-Khalick, Waters & Le, 2008)

The gap between what is implicitly expected by the teaching programs about HS, the textbooks' content, and the practices we supposed teachers have caught our attention. We look to examine the possibility to convey a richer and more complex representation of science consistent with the educational issue of scientific literacy for citizenship. The area of specialization of the team members who worked on that subject led us to explore this problem in the case of physics. The results can be generalized to the case of SVT.

CONVEYING A RICHER AND MORE COMPLEX REPRESENTATION OF SCIENCES WITH THE HISTORY OF SCIENCE

Our position concerning the introduction of the history of science is similar to the one shared for example by Adúriz-Bravo (2004) and Höttecke, Henke and Riess (2010). When we started to work on the introduction of the history of physics in science teaching ten years ago, we adopted a position unique in France. Indeed, in most of the studies conducted at this period, the epistemological educational purpose remains implicit so that there was no effective epistemological learning. In fact, no meta-analysis of what can be learned about NoS from the historical elements introduced in teaching was proposed to students; these historical elements were only means to teach scientific concepts which are known to be difficult.

NoS features chosen as learning-teaching goals

The idea that NoS teaching is a discourse on science that needs to be produced in the context of concrete scientific episodes, in particular historical, in order not to be blind or void, led us to an epistemological analysis of the history of physics. This analysis allowed us to discern different characteristics which can be considered as key points of an authentic image of physics upon which didactic goals may be based *a priori*. In our project, HS is not considered per se but as a means to introduce students to twentieth century philosophical ideas on science in order to help them to acquire a cultural and citizen scientific literacy, and also to motivate them for scientific studies. This is a richer understanding of how science works mainly today, and not in the past, that we expect. Consequently, we sought to identify through the analysis of the history of physics what aspects of physics can be considered as temporal invariables.

The first column of the table 6 presents some of the key points we former identified as characteristics of the scientific activity and that can be chosen as NoS teaching goals. They are set in perspective with the multidimensional NoS matrix designed for the analysis of the syllabuses.

It has to be noticed that since these teaching goals focus on epistemological aspects, they are independent of conceptual or procedural learning objectives, which therefore can be only secondary, if not completely absent.

Teaching situations based on historical investigations whose objectives deal with NoS misconceptions

The next step was to create and design didactic resources and activities that were both appropriate to a given level of instruction and fulfilled a specific epistemological objective.

As our primary topic of focus, we pinpointed the field of optics. This choice was the

TABLE 6

Some features of the scientific activity characterized using the multi-dimensional matrix (It has to be noticed that, here, we characterize the science feature “Scientists’ ideas are not born in a void” with NoS dimensions that are not explicit. It is the same for the following feature dealing with technical aspects. It shows the importance to state clearly and in detail the NoS features chosen as teaching goal)

Some characteristics of the scientific activity (Maurines and Beaufile, 2011, 2012a, 2012b SVT grade 10 syllabus	Matrix I (Maurines et al., 2012, 2013)								
	Matrix	Objects	Resources	Products	Elaboration	Attitudes	Community	Society	History
A scientist does not work in isolation but within a community							x		
Scientists are concerned with numerous issues and take a variety of approaches to their work	x				x				
Scientific activity is a nexus of controversy							x	x	
Scientists’ ideas are not born in a void							x	x	x
There is a strong relationship between technical questions and the evolution of ideas			x	x					x
Scientists test their explanations against facts that result from observation and experiments					x				
Scientists follows criteria of internal coherence, simplicity, and strength	x				x				
Scientific knowledge has evolved over time (through continuity and ruptures)									x
Scientific activity are based on beliefs (about the world, the individual and what it can know, and the ways to produce knowledge)	x				x				
Scientific activity and the societal, political, economical and cultural context are in interaction								x	

result in part of the area of specialization of our team members and the identification of several “historical situations” (the interpretation of refraction in the 18th century, the invention and development of astronomical telescopes, the discovery and interpretation of black rays in the solar spectrum, etc.) that could be integrated into physics curricula from grade 7 (age 12) to grade 1.

Several didactic choices determined the direction of our pedagogical research.

Following an approach similar to the one proposed by Martinand (1989) in the case of scientific content, we decided to focus the design of our first innovative units on goals related with well-known misconceptions about NoS and connected to the edu-

cational issues we privileged. It seems to us the most relevant way to choose between the numerous NoS learning goals that can be extrapolated from an epistemological and historical analysis of physics. Beyond simply providing documentary resources for teachers, we decided to design not only sets of documents selected in relation to a specific NoS goal and scientific issue that unifies the material but also activities for students.

The following work was based on two main choices: the selection of historical material and the type of activity.

The paper documents present information in different forms -texts, diagrams, drawings, etc- which is usually taken from texts written by historians or scientists keen on history but also from primary sources or which we can have written. Indeed our primary objective is to propose students with texts easily to read. The information extracted from the historical resources we used is of two types. Some is scientific elements (e.g. facts, hypothesis, knowledge, experiment) at a given historical period. Other can be associated to other characteristics of the nature of science presented above. So to say, the historical scientific elements constitute the skeleton, the others the coating of the richer image of the science we want to convey.

In our first study (Maurines & Mayrargue, 2005, 2007), the reading of historical texts was coupled with doing an experiment described or inspired by the texts, thereby following the hypothesis that some teachers prefer situations that link texts with experiments, since they might not want to deviate from their preferred conceptual or procedural learning goals. This approach becomes most meaningful when the targeted goal stresses the process of validating a model by confronting its prediction with facts derived from observation and experimentation; the choice seems artificial, however, and therefore inappropriate in relation to a goal like studying 'interactions between scientists'.

But the choice of basing conceptual learning teaching on a historical foundation is questionable: not only does the problematization of knowledge in school not require an historical reference, but on the contrary, the historical reference that is introduced to convey a synoptic idea of scientific practice in a particular historical period requires that students put themselves into the conditions and circumstances of scientific and technical knowledge applicable to the historical period in question. This strategy raises questions on the possibility of asking students to comprehend what was actually at stake then—for instance, the ingenuity of a particular approach or the revolutionary nature of an idea in its time and the nature of the historical elements that are introduced.

In this type of experimental historical investigative situation, the risk of drifting off course toward an emphasis on knowledge and methods is especially high. It is fundamentally important that the stage of establishing knowledge is related not only to the notions developed and the approaches used in class but also to the historical process

of developing knowledge and to what it teaches us about the nature of science and scientific practice. Höttecke, Henke and Riess (2010) whose approach is close to ours propose to arrange furniture in the classroom in order to create an 'epistemological corner', that is to say a place dedicated to the reflection on the nature of science.

In our second study (Maurines & Beaufiles, 2011, 2012a; Maurines et al., 2012; Beaufiles & Maurines, 2013) and in those conducted by Slaïmia & Maurines (2011) and Slaïmia (2014) in our laboratory, the learning situations that are developed are exclusively focused on a goal related to the image of scientific activity in reference to the characteristics that we have previously mentioned. We describe as 'historical documentary investigations' this type of learning situations based only on the study of documents.

The paper kits are usually composed of about ten interrelated documents (usually one page length). Contrary to the stories proposed by Clough (2010), each document of the kit gives only some information since we decided to integrate the resource kits with inquiry-based learning situations including a phase of collective synthesis. The reading assignment of the kit is divided among all members of the class and students are guided by instructions that specify the type of information to be culled from the text: who, what, how, why, etc. (in relation to the documents and the question). The collective synthesis is made under the teacher's 'guidance'. Thus, enough information can be provided to students in order to convey a more realistic image of NoS without discouraging poor readers and requiring too much time. As far as we know, this strategy has never been proposed by science educators. The wiki-atlas project seems the closest one (Piliouras, Siakas & Seroglou, 2011). Insert I shows a way of structuring the work done in class.

INSERT 1

Appropriating or/and constructing a problem:

- integrate the topic into the teacher's learning sequence for the class; highlight questions of a historical nature: *how do we know that...?*
- specify a specific problematic that sets the goal to be achieved

Resolving the problem:

Documentary work (as homework or in class, individual or in small groups)

- present documentary resources.
- distribute the documents among the members of the class
- read documents and prepare the lesson in which the synthesis will be done, guided by instructions that specify the type of information to be culled from the text; who, what, how, why, etc. (in relation to the documents and the question).

Reaching a synthesis (students will do this collectively based on each class member's contribution)

Establishing knowledge:

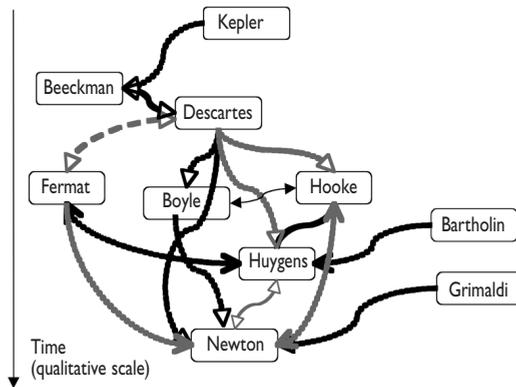
- the teacher generalizes the results that were found by students and shows the connection between how science worked in the past and the present situation.

A possible structural outline of an investigative situation based on historical texts

A collective synthesis leading to a synoptic view provided by a synthesis tool

The collective synthesis that is made in class under the teacher's 'guidance' is supposed to produce a specific type of result. It can be a time line, a map, a table, a diagram that provides a synoptic visualization of the information that has been gathered and illustrates the targeted goal. The synoptic view is crucial to an understanding of the nature of science since details are not essential. It is important to note that this synthesis tool depends on the epistemological goal on which the learning situation is focused. Insert 2 presents an example of such tool for the epistemological goal "interactions between scientists" and the topic "law of refraction".

INSERT 2



Example of diagram on the epistemological goal 'interactions between scientists' and the topic 'laws of refraction'

One difficulty that our project has had to overcome is the relationship between historical considerations and current science. The above NoS features have been identified as a-time, meaning that they appear in the work of scientists of past centuries, but they apply to current scientific activity. This leads us to propose to the teacher to conclude the lesson by the generalization of these characteristics, while pointing to some significant developments that have taken place: for instance, the interaction between scientists today is obviously out of proportion to that of the eighteenth century.

First feedback on our proposals

In this way, we were able to create kits of material on various topics, including documents for students and guidelines for teachers describing the objectives of the activity and how it is to be conducted; each kit also introduces historical information correlated to the chosen episode of scientific inquiry as well as various other supportive ancillary documents.

The first feed-back obtained from approximately twenty teachers about our first two kits confirms that they consider the epistemological issue less important than the acquisition of scientific content, even if they judge it interesting, useful, and even necessary. Resistance also emerged on the type of synthesis tool we propose (for more details see Maurines & Beaufils, 2011, 2012b).

The experimentation of the innovative unit based on the history of the law of the refraction of light elaborated by Slaïmia (2014) shows encouraging results about the possibility to change the image of the scientific practices of grade 10 students in relation to the epistemological objectives chosen as teaching goals: the diversity of issues and approaches followed by scientists.

CONCLUSION

The analysis of the high school science syllabuses reveals that they refer to science as a reduced social practice since a limited number of dimensions is emphasized. However some variations have been pointed out between school subjects, levels and high school diploma fields. Concerning the scientific major, the SVT syllabuses convey a more rationalist and internalist vision of science than the PC syllabuses, which give more importance to the human and social dimensions of science. However, the representation of science is reduced to a more internalist vision in the scientific major and in grade 12 than in the economic-literary major and in grade 10.

Nos is emphasized as a teaching goal only in the SVT syllabuses of the scientific major and in the syllabus of the grade 11 economic-literary major. The history of science is presented as a means to achieve such goal but no indication on the way to implement it is given to teachers. In the PC syllabuses, NoS remains an implicit teaching goal and the history of science is presented as a way to construct scientific knowledge in grade 10 and to set science in cultural context in grades 11 and 12.

The discussion presented above about the introduction of the history of science in classes shows that it is possible to construct historical teaching units giving access to another representation of science. The first feedback from teachers about the first units we elaborated reveals some resistance and their lack of training on NoS aspects and NoS teaching. The first experimentation of an innovative unit under controlled conditions with pre and post-tests and a trained teacher suggests that the units can be implemented successfully. However, only further experimentation can validate our choice.

REFERENCES

- Abd-El-Khalick, F. (2012a). Examining the sources for our understandings about Science: Enduring confluences and critical issues in research of nature of science in science education. *International Journal of Science Education*, 34(3), 353-374.
- Abd-El-Khalick, F. (2012b). Teaching *with* and *about* nature of science, and science teacher domains. *Science & Education*, 22(9), 2087-2107.
- Abd-El-Khalick, F., Waters, M., & Le, A. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, 45(7), 835-855.
- Adúriz-Bravo, A. (2004). Methodology and politics: a proposal to teach the structural ideas of Philosophy of Science through the pendulum. *Science & Education*, 13, 717-731.
- Allchin, D. (2011). Evaluating knowledge of the Nature of (whole) science. *Science Education*, 95, 918-942.
- Allchin, D., Andersen, H.-M., & Nielsen, K. (2014). Complementary approaches to teaching nature of science: integrating student inquiry, historical cases, and contemporary cases in classroom practice. *Science Education*, 98(3), 461-486.
- Beaufils, D., & Maurines, L. (2008). « La loi des sinus » : quelques considérations épistémologiques et didactiques. *BUP*, 909, 1345-1351.
- Beaufils, D., & Maurines, L. (2013). L'image de la physique au travers de l'enseignement de la spectroscopie : propositions didactiques. *BUP*, 107(956), 657-679.
- ByBee, R. W., & Ben-Zvi, N. (2003). Science curriculum: Transforming goals to practice. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 487-498). Dordrecht: Kluwer Academic Publishers.
- Chalmers, A. F. (1991). *La fabrication de la science*. Paris: La Découverte.
- Clough, M. P. (2010). The story behind the science: Bringing science and scientists to life in post-secondary science education. *Science & Education*, 20(7), 701-717.
- Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Bristol: Open University Press.
- Dupin, J. J. (2006). L'enseignement de l'histoire des sciences et des techniques devrait-il avoir sa place à l'école ? *Tréma*, 26, 29-33.
- Duschl, R. A. (2008). Science education in 3 part harmony: Balancing conceptual, epistemic and social goals. *Review of Research in Education*, 32, 268 – 291.
- Duschl, R. A., & Grandy, R. (2012). Two views about explicitly teaching nature of science. *Science & Education*, 22(9), 2109-2139.
- Erduran, S., & Dagher, Z.-R. (2014). *Reconceptualizing the Nature of Science for Science Education. Scientific knowledge, practices and other family categories*. The Netherlands: Springer.
- Guedj, M., Laubi, S., & Savaton, P. (2007). Démarche d'investigation et EHST. Un constat et des pistes de réflexion. In *Actes des Troisièmes Journées ReForEHST*, (pp. 6-10, second cahier), Caen.

- Hipkins R., Barker, M., & Bolstad R. (2005). Teaching the “nature of science”: modest adaptation or radical reconception? *International Journal of Science Education*, 27(2), 243-254.
- Höttecke, D., Henke, A., & Riess, F. (2010). Implementing history and philosophy in science teaching: strategies, methods, results and experiences from the European HIPST project. *Science & Education* 21, 1233-1261.
- Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science for science education, *Science & Education*, 20(7-8), 591-607.
- Irzik, G., & Nola, R. (2014). New directions for nature of science research. In M. Matthews (Ed.) *International Handbook of research in history, philosophy and science teaching* (pp. 999-1021). Dordrecht: Springer.
- Johsua, S. (1989). Le rapport á l'expérimental dans la physique de l'enseignement secondaire. *Aster*, 8, 29–54.
- Lederman, N. G. (2007). Nature of Science: past, present and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-879). London: Lawrence Erlbaum associates.
- Martinand, J.-L. (1986). *Connâître et transformer la matiére*. Berne : Peter Lang.
- Martinand, J.-L. (1989). Des objectifs-capacités aux objectifs-obstacles: Deux études de cas. In N. Bednaz & C. Garnier (Eds.), *Construction des savoirs. Obstacles et conflits* (pp. 217–227). Ottawa: CIRADE & Agence d'AEC inc.
- Mathy, P. (1997). *Donner du sens aux cours de sciences*. Paris: De Foeck.
- Matthews, M. R. (2012). Changing the focus: from Nature of Science (NOS) to features to Science (FOS). In M. S. Khine (Ed.), *Advances in Nature of Science Research* (pp. 3-26). Dordrecht: Springer.
- Maurines, L. (2013). Les programmes de sciences du lycée en France et la nature des sciences : rapport á la vérité, aux croyances et á la culture. In *Actes du colloque international de l'AREF*. Retrieved from <http://www.aref2013.univ-montp2.fr/cod6/?q=content/2851-les-programmes-de-sciences-de-seconde-en-france-et-la-nature-des-sciences-rapport-%C3%A0-la>.
- Maurines, L., & Mayrargue, A. (2005). How the investigations of the students' reasoning on waves and the history of physics can help us to develop research-based innovative units for secondary students on the velocity of light? In *Proceedings of the eight IHPST conference*, Leeds. Retrieved from <https://halshs.archives-ouvertes.fr/REHSEIS/hal-00385723v1>.
- Maurines, L., & Mayrargue, A. (2007). Utiliser l'histoire de l'optique dans l'enseignement: pourquoi? Comment? In *Actes des Journées de l'Union des Professeurs de Physique et Chimie « Paris de sciences »*. Retrieved from www.udppc.asso.fr/paris2007/docactes/2007/185_21032008123615.doc.
- Maurines, L., & Beaufile, D. (2011). Un enjeu de l'histoire des sciences dans l'enseignement : l'image de la nature des sciences et de l'activité scientifique. *Revue de Didactique des Sciences et des Technologies*, 3, 271-304.
- Maurines, L., & Beaufile, D. (2012a). An aim for science education in France: the image of the nature of science. How to introduce the history of science in science classes in order to

- reach it? In A. Roca-Rosell (Ed.), *Proceedings of the 4th International Conference of the European Society of History of Science* (pp. 148-154). Barcelona: SCHCT-IEC.
- Maurines, L., & Beaufils, D. (2012b). Teaching the Nature of Science in Physics courses: the contribution of classroom historical inquiries. *Science & Education*, 22(6), 1443-1465.
- Maurines, L., Fuchs-Gallezot, M., Beaufils, D., & Ramage, M.-J. (2012). A proposal to analyze the representation of the Nature of Science conveyed by science teaching and to elaborate new pedagogical proposals. In G. Katsiampoura (Ed.), *Proceedings of the 5th International Conference of the European Society of History of Science* (pp. 222-233). Athens: National Hellenic Research Foundation / Institute of Historical Research.
- Maurines, L., Fuchs-Gallezot, M., Ramage, D., & Beaufils, D. (2013). La nature des sciences dans les programmes de seconde de physique-chimie et de sciences de la vie et de la Terre. *Revue en Didactique des Sciences et des Technologies*, 7, 19-52.
- Maurines, L., Fuchs-Gallezot, M., & Ramage M.-J. (2014). Conduire des études sur la nature des sciences et de l'activité scientifique dans l'enseignement des sciences : une discussion sur les références fondée sur une analyse des programmes de sciences du lycée et sur une exploration des représentations des étudiants en France. Colloque international de l'AAE « Les sciences sociales européennes face à la globalisation de l'éducation et de la formation : vers un nouveau cadre réflexif et critique ? » Amiens, Novembre 2014.
- Mc Comas, W. (1998). *The nature of science in science education. Rationales and strategies*. Dordrecht: Kluwer Academic Publishers.
- Mc Comas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In W. Mc Comas (Ed.), *The nature of science in science education. Rationales and strategies* (pp. 53-70). Dordrecht: Kluwer Academic Publishers.
- Pélessier, L., Venturini, P., & Calmettes, B. (2007). L'épistémologie souhaitable et l'épistémologie implicite dans l'enseignement de la physique. De l'étude sur l'enseignement de la seconde à la démarche d'investigation au collège. In *Actes des Troisièmes Journées ReForEHST*, (pp. 8-13, premier cahier), Caen.
- Pélessier, L. (2011). *Études des pratiques d'enseignement des savoirs de l'Épistémologie de la physique en classe de lycée général*. Doctoral Thesis. France, Université de Toulouse.
- Pestre, D. (2006). *Introduction aux Sciences Studies*. Paris: La Découverte.
- Piliouras, P., Siakas, S., & Seroglou, F. (2011). Pupils produce their own narratives inspired by the history of science: Animation movies concerning the geocentric–heliocentric debate. *Science & Education*, 20(7-8), 761-795.
- Robardet, G. (1995). *Didactique des sciences physiques et formation des maîtres : contribution à l'analyse d'un objet naissant*. Thèse, France, LIDSE, Université Grenoble I-Joseph Fourier.
- Roletto, E. (1998). La science et les connaissances scientifiques : point de vue de futurs enseignants. *Aster*, 26, 11-30.
- Sandoval, W. (2014). Science Education's need for a theory of epistemological development. *Science Education*, 98(3), 371-548.

- Slaïmia, M., & Maurines, L. (2012). L'image des sciences au travers de l'histoire de la dioptrique dans l'enseignement secondaire tunisien : conceptions d'élèves de seconde après une séance innovante. In *Actes des septièmes rencontres de l'ARDiST* (pp. 413–424). Bordeaux: ARDiST.
- Slaïmia, M. (2014). *L'image de l'activité scientifique au travers de l'histoire de la dioptrique : élaboration et expérimentation d'une séquence d'enseignement pour la classe de seconde ; rapport des enseignants tunisiens à l'enseignement des sciences et à l'innovation*. Doctoral thesis, France, Université Paris-Sud.

APPENDIX

TABLE 7

The units extracted from the PC syllabuses referring to the history of science

Grade	Scientific domain	Units of the syllabuses referring to the history of science	Place in the syllabus
I0	Chemical species, pure substances and mixtures	The approach used by Mendeleev to establish its classification	Content table
	Extraction, separation and identification of chemical species	Historical aspect and experimental techniques	Content table
	Universe	The Man has always observed the stars to be in the Universe	Content table
II and I2 Scientific major	Universe	It should be recalled in this respect the role of measurement accuracy in scientific progress. The history of science provides many illustrations: the degree of precision of the observations of Mars made by Tycho Brahe allowed Kepler to establish its laws. The greatest revolution in the history of thought, the Copernican hypothesis, has not been advanced for reasons related to the observations of time, which found a seemingly natural explanation in the Aristotelian cosmology. Validation came only over two hundred years later, with the discovery of the small parallax movement of stars thanks to technical progress in observational instruments	Common justification part
II Scientific major	Fields and Forces	Understanding how the notion of field has historically emerged from experimental observations	Content table
I2 Scientific major	Chirality	Historical approach	Content table
	Time, movement, evolution Time and its measurement	The history of this measure [of time], which can be traced back to ancestral processes (sundial), provides the material for a documentary study of the research of progress subtended by ever greater concern for precision, stability and universality. [...] The teacher's freedom is to make a choice, especially between a historical approach, which could immediately announce the postulate [c independent of the referential] and follow with experimental tests, and a more "pedagogical" approach which starts with the experimental results to make then more natural Einstein's hypothesis .	Specific justification part